Independent Review of the Coordinated Long-Term Operation of the Central Valley Project and State Water Project

Prepared for:
National Marine Fisheries Service
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By:
Ronald T. Kneib, Ph.D.
10 Taza Trail
Hillsboro, NM 88042

Executive Summary

The upper San Francisco Bay Estuary, including the Sacramento-San Joaquin River Delta, is the only known habitat of wild Delta Smelt. Over the past century there have been substantial anthropogenic alterations of the system, including a highly engineered system designed to store and distribute freshwater resources for human uses. In recent decades substantial declines in the abundance of native fishes have been observed and underlying causes remain a matter of scientific debate. Once abundant in the estuary, Delta Smelt is now among the species listed under the Endangered Species Act as being at risk of extinction.

The U.S. Fish and Wildlife Service Biological Opinion (BiOp) effects analysis of the Proposed Action associated with the Reinitiation of Consultation on the Coordinated Long-Term Operation of the Central Valley Project and State Water Project is intended to evaluate potential impacts on Delta Smelt and their critical habitat for a mixture of standard site-specific and programmatic action elements The analyses are based largely on information derived from research and modeling efforts conducted primarily by cohorts of creative and talented individuals at universities, state and federal agencies and private institutions with a keen interest in the San Francisco Bay Estuary and associated watersheds.

The effects analyses that are the subject of this review rely on four interrelated components: (1) Status of the species, (2) the Environmental Baseline, (3) Effects of the Action and (4) Cumulative Effects. The key to understanding the effects analyses presented in this BiOp is in the definition and interpretation of these components.

The status of Delta Smelt is not an issue. The species is listed as threatened under the Endangered Species Act and is routinely nominated as a candidate for being listed as endangered. However, endangered status has been precluded by consideration of species given higher priority, even though there is a scientific consensus that Delta Smelt are on an accelerating path toward extinction in the wild.

The definition of Environmental Baseline is perhaps the most important key to understanding how risk to the survival of Delta Smelt and their critical habitat is evaluated. The Environmental Baseline includes "all the past and present impacts of all Federal, State and private actions and other human activities in the Action Area". The purpose is to describe the condition of the listed species and its critical habitat in the absence of the Proposed Action subject to a current consultation. In essence, this means that the Environmental Baseline is reset prior to each consultation.

Effects of a Proposed Action are then considered largely in isolation from all known and unknown effects that may have occurred prior to the Action. Researchers have produced a diversity of perspectives, ideas and hypotheses regarding the underlying causes of the decline of native species,

including Delta Smelt. However, experimental studies to test these ideas, in a rigorous manner and with minimal assumptions, are often expensive and time-consuming. So a variety of conceptual and numerical models have been developed to guide future research and to make predictions based on suites of assumptions that may ultimately be flawed. Nonetheless, predictions from these models are used in the effects analyses to make determinations about the risk of jeopardy to Delta Smelt and their critical habitat. It is often acknowledged that a high degree of uncertainty is associated with such findings but they are presented in the BiOp as the best available information. Also, there continue to be substantial gaps in key pieces of information related to the critical habitat of Delta Smelt (e.g., spawning substrates). How can one assess risk to an unknown critical habitat?

Cumulative effects are confused with additive effects in the BiOp analyses. This seems to flow directly from the definition of Environmental Baseline. In the BiOp analyses, cumulative effects are considered to be all of the current potential risks to the survival, growth and reproduction of Delta Smelt and its critical habitat. However, real cumulative effects require a temporal component. That is, repeated exposure to the same, or a series of different stressors. This does not seem to have a role in the current effects analyses.

A lack of consideration for the effects of ecological thresholds, sometimes referred to as tipping points, is a potentially serious omission in the BiOp's effects analyses. Small changes in environmental conditions, particularly in connection with true cumulative effects, can produce abrupt and unexpected changes in ecosystems and/or their components. This review strongly recommends a consideration of ecological thresholds in future analyses of potential effects of actions on Delta Smelt and their critical habitat.

The successful hatchery-rearing of Delta Smelt for use in research and possible supplementation of the wild population has provided research opportunities that have yet to be fully exploited for the purpose of filling important knowledge gaps that would aid in future effects analyses. One such area involves testing hypotheses about preferred spawning habitat and behavior.

Finally, there is an apparent shift in focus away from water operations as a direct or indirect risk of jeopardy to Delta Smelt and toward a growing number of "non-operational" potential risk factors or stressors. Dealing with an increasing number of moving parts increases the risk of management decisions having negative effects on listed species in the Delta. One of the overarching new risk factors considered in the BiOp is climate change. Associated increases in temperature and sea level rise are expected to substantially reduce suitable habitat for Delta Smelt in the Sacramento-San Joaquin Delta ecosystem. If these predictions are true, radical measures may be required to restore this species in the wild. Perhaps it is time to seek a new estuarine habitat for Delta Smelt.

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1 Introduction

1.1 Background

Water flowing through California's Central Valley and into the San Francisco Bay Estuary is directed spatially and temporally through a highly engineered system developed over the past 85 years or more by federal and state agencies. The complex system was designed to regulate the temporal and spatial distribution of water resources for a variety of human uses including agriculture, flood control, municipal water supplies, power generation, etc. The allocation of water in the system is based on an entangled legal structure of water rights that attempts to accommodate a diverse set of user needs. The development of this complex engineered and legal structure did not originally account for the support of natural aquatic resources, including native fishes such as anadromous salmon, sturgeon and Delta Smelt *Hypomesus transpacificus*, which is the subject of this review.

There is little scientific dispute regarding the cumulative effects of anthropogenic alterations in the watersheds of the San Francisco Bay Estuary on native aquatic organisms over the past century. Aquatic habitat suitable for the growth, survival and reproduction of many species, particularly Delta Smelt, has been compressed in spatial extent and quality to the point that a clear path to extinction has become evident.

The passage of the Endangered Species Act (ESA) by the U.S. Congress in 1973 formally recognized the need to protect and recover imperiled species and the ecosystems on which they depend.

Section 7(a)(2) of the ESA requires that any action taken, funded or authorized by Federal agencies is not likely to jeopardize the continued existence of a listed species. This includes anything that would appreciably reduce the likelihood of the survival or recovery of a listed species in the wild by reducing the reproduction, numbers or distribution of that species.

Section 7(a)(2) also requires that Federal agencies are not involved in anything that directly or indirectly diminishes the value of critical habitat for protected species.

In April 2019, the U.S. Fish & Wildlife Service (USFWS) requested an independent peer review of their draft Delta Smelt effects analysis in connection with a Reinitiation of Consultation regarding Proposed Actions involving the Coordinated Long-Term Operation of the Central Valley Project and State Water Project.

Delta Smelt is currently listed as threatened under the ESA. This means it is likely to become endangered in the foreseeable future. The USFWS has repeatedly submitted Delta Smelt as a candidate for endangered status but it has been precluded by listings of other species with higher priority. Under the ESA, endangered means "a species is in danger of extinction throughout all or a significant portion of its range." The range of Delta Smelt is limited to lower salinity portions of the

San Francisco Bay Estuary, with the population centered in the Sacramento-San Joaquin delta in the Central Valley of California. Delta Smelt occupy a limited niche at the southernmost range of inland smelt species and are unlikely capable of establishing a viable population south of their current location along the U.S. Pacific Coast. Furthermore, if current climate change predictions are correct, it seems likely that environmental conditions will become suitable to support the extant wild population of Delta Smelt in the foreseeable future.

1.2 General Observations

The Biological Assessment submitted by Reclamation to the USFWS in January 2019 seems to emphasize opportunities to maximize water supply delivery and power generation by minimizing constrains on operations and emphasizing actions other than long-term water operations (LTO) of the CVP and SWP as a way of avoiding significant adverse effects on Delta Smelt.

The October 19, 2018 Presidential Memorandum on promoting the reliable supply and delivery of water in the West directing the Secretaries of the Interior and Commerce to streamline regulatory processes involving western water infrastructure cited in the BiOp's Consultation History section, seems to suggest the existence of federal political pressure favoring water operations over the preservation of endangered species. Within this context, it appears that USFWS historically has been very accommodating to requests from Reclamation to relax restrictions on water operations intended to avoid negative effects on Delta Smelt.

The USFWS understands that current information demonstrates "the increasingly imperiled state of Delta Smelt and its designated critical habitat". Furthermore, "emerging science shows the importance of outflows to all life stages of Delta Smelt and to maintaining the primary constituent elements of designated critical habitat". Nonetheless, the Proposed Actions seem to be attempts to shift responsibility for adverse effects on Delta Smelt away from water operations and place the focus on "nonoperational factors". This seems to propagate the public impression that environmental regulations on water operations have been unnecessarily limiting water diversions, particularly for apparently ineffective protections of threatened and endangered species such as Delta Smelt. However, while constraints on water operations to protect Delta Smelt have been relatively modest during Water Years 2011-2018 (see Table 6 in Reis et al. 2019) outflows to San Francisco Bay during the critical winter-spring period has been declining over the past several decades to the point where the estuary may be experiencing drought conditions in most years (Reis et al. 2009).

Food limitation has emerged as a focus of interest in constraining the growth and survival of Delta Smelt in most life stages but, even if true, the underlying cause(s) of limited food supply are not disconnected from water operations. A recent analysis of temporal changes in chlorophyll a and zooplankton in the San Francisco Estuary during the period 1969-2014 showed that nearly all of the

observed declines in pelagic primary productivity could be related to invasion of the clam *Potamocorbula amurensis* and water exports from the state and federal pumping facilities. While there appears to be a current general scientific consensus that limited pelagic food resources and/or temporal shifts in normal seasonal patterns of food availability (e.g., Merz et al. 2016) may be jeopardizing the survival and recovery of Delta Smelt, the role of water exports have not been eliminated as an underlying driver in the process.

The USFWS effects analysis relies on four interrelated components: (1) Status of the species, (2) the Environmental Baseline, which is the current condition and factors responsible for that condition, (3) the Effects of the Action, and (4) Cumulative Effects, which evaluates the effects of FUTURE NON-FEDERAL activities in the action area. These same categories are applied in the consideration of effects on both Delta Smelt and its critical habitat. This seems a bit redundant because effects on critical habitat are also effects on Delta Smelt. If there were a fishery for Delta Smelt, perhaps it would be appropriate to consider fishing effects on the population dynamics to be separate from effects on critical habitat but it is difficult to distinguish any effects on Delta Smelt that are independent of the suitability of their critical habitat.

A key to understanding how USFWS evaluates the risk of jeopardy to Delta Smelt is found in the functional definition of Environmental Baseline which includes "all the past and present impacts of all Federal, State and private actions and other human activities in the Action Area". The purpose is to describe the condition of the listed species and its critical habitat in the absence of the Proposed Action subject to a current consultation. In essence, this means that the Environmental Baseline is reset prior to each consultation. The fact that previous actions are known to have likely caused negative effects to a species or its critical habitat is discounted and any evidence that could be generated to show continued or additional effects of a Proposed Action would be unavailable until sometime after the action was undertaken, at which point the effect becomes incorporated into the next Environmental Baseline. This has implications for how "cumulative effects" are defined and analyzed. Cumulative effects require a time component (i.e., the history of effects) such as sequential exposure to a stressor.

For example, an action that results in the loss of 10% of a population may not have a long-term negative effect as an isolated event as long as reproduction can result in the recovery of those losses within a certain time frame. However, a series of impacts from the same action with each occurrence resulting in the loss of 10% of the population before the population has sufficient time to rebound is a cumulative effect.

The treatment of any real cumulative effects on Delta Smelt seems to be effectively ignored, or at least obfuscated, in the BiOp by virtue of the definition of Environmental Baseline, which does not allow any past or future actions to be considered in the analysis. How can the cumulative effects of only current actions be evaluated? There is no temporal element involved. The BiOp seems to

consider a suite of stressors operating concurrently to be cumulative effects, but these are better described as "additive effects". Cumulative effects are actions or suites of actions repeated over time. The definition of Environmental Baseline essentially eliminates a consideration of cumulative effects in this analysis.

1.3 Review Activities

- April 12, 2019 – Download seven parts of the draft BiOp + 2 appendices as well as supplemental materials on Suisun Salinity Control Gate and X2 proposal from Anchor QEA; begin reviewing the draft BiOp
- April 13-17, 2019 – Continue reading and reviewing draft BiOp, including appendices.
- April 18, 2019 – Develop and submit questions for consideration by USFWS prior to web conference on April 19th; continue reviewing draft BiOp.
- April 19, 2019 – Web conference with Michelle Havey (Anchor QEA), BiOp reviewers (J. Merz, E. Peebles, R. Kneib) to discuss issues in the BiOp materials that may need clarification. Following a brief break, the web conference resumes with the addition of Kaylee Allen, Jana Affonso and Matt Nobriga of USFWS to discuss questions previously submitted. The discussion ranged across topics regarding the definition of terms in the charge to reviewers, the identity of federal agencies providing data and input to the BiOp, the general process involved in listing species under the Endangered Species Act, the process by which effects analyses were conducted, and specific questions about non-programmatic actions as well as any known current and planned future research that might be pertinent to issues presented in the BiOp.
- April 19, 2019 – Received link to a potentially pertinent publication from J. Merz and received from Michelle Havey copies of Figs 17 and 18 that had been omitted from the original supplemental materials on the X2 proposal.
- April 19-23, 2019 – Continued reviewing draft BiOp and located/read a subset of the literature cited in the BiOp as well as additional recent publications on a number of topics related to issues arising from the BiOp effects analyses that were not cited, including relationships between different sources of nitrogen and plankton community structure, the role of turbidity in trophic interactions involving Delta Smelt, role of flows in the Delta, captive-reared Delta Smelt for research and recovery, ecological thresholds and tipping points, current literature on assessing extinction risk.
- April 22, 2019 – Received a revised template for the BiOp review from Michelle Havey.
- April 23, 2019 – Received corrected Table 2 in Part 4 of draft BiOp from Michelle Havey.
- April 24-26, 2019 – Began drafting review of the draft BiOp.
- April 26, 2019 – Requested and received an additional 1.5 days to complete review of the draft BiOp.
- April 28, 2019 – Submitted review of draft BiOp to Michelle Havey.

2 Responses to Questions

2.1 How well do the draft sections of the biological opinion for delta smelt use best available scientific and commercial information?

This question solicits a qualitative answer that involves consideration of not only the volume of available information but the quality of the information being relied upon, the original purpose for which it was assembled, and how it was used in the effects analyses. In conducting any study or summary of information, it is common for authors to make observations not directly related to the central focus of the research, particularly if there is a possible connection to some issue of perceived importance. Usually these observations and associated opinions are expressed as hypotheses for future consideration and testing. However, sometimes these ideas, which were not tested in the original study, can improperly be used as evidence in support of a given position.

The San Francisco Bay Estuary area is fortunate to have an abundance of talented and creative scientists working in universities as well as government and private agencies and institutions, most with a keen interest in understanding how this ecosystem functions. This wealth of talent has produced a diversity of perspectives, ideas and hypotheses. Experimental studies to test these ideas, in a rigorous manner and minimal assumptions, are often expensive and time-consuming. So it is not surprising that a variety of conceptual and numerical models also have been developed to guide future research and to make predictions based on suites of assumptions that may ultimately be flawed; measures of uncertainty associated with such findings are essential to consider when applying such predictions.

The BiOp includes much of the pertinent and current information regarding factors that are likely to affect the survival, growth and reproduction of Delta Smelt so, from this perspective, the draft BiOp does a good job of capturing the available information. Important basic information on the habitat requirements (e.g. spawning habitat) of Delta Smelt seems to continue to allude researchers, which makes it difficult to conduct a complete effects analysis on critical habitat.

Although time constraints on the production of this report precluded a thorough analysis of the applicability of available information used in the effects analyses, there were examples (discussed in subsequent sections) where the available information seemed inappropriately applied or applied beyond the scope of a study from which it was derived in order to support conclusions that effects on Delta Smelt or their critical habitat were minor.

2.1.1 Do the analyses in the status of the species and critical habitat, and environmental baseline sections reflect the best available scientific and commercial information?

Not always, and for a number of reasons, sometimes involving the way that the definition of Environmental Baseline is used in the analyses. The concept of ecological thresholds and rapid transitions in state resulting from apparently minor shifts in conditions (e.g., see Clements and Ozgul, 2018 and references therein) do not appear to be considered in the analyses of species status, critical habitat, environmental baseline or effects of the proposed action. The following narrative provides some examples.

Reclamation presented a "without action scenario" as part of the Environmental Baseline which excludes CVP and SWP operations.

The USFWS claims to be unaware of any available scientific evidence that can distinguish among four hypotheses presented to explain why there has been no discernible relationship between freshwater flows and Delta Smelt population dynamics:

(1) A relationship never existed.
(2) Any historical relationship that may have existed was extinguished by decades of landscape and flow regime changes prior to initiation of monitoring programs.
(3) Changes in community structure and food web functioning masked any historical relationship not detected prior to initiation of monitoring programs.
(4) Some combination of (2) and (3) above.

The assertion that there is no scientific evidence for a relationship between freshwater flows and Delta Smelt population dynamics may not be defensible. Although time constraints prevented a more thorough review of the literature, this reviewer found at least two recent publications that seem to support either a direct or indirect association between freshwater exports and decline of the Delta Smelt population.

Reis et al. (2019) found, as a result of exports, that the percentage of Central Valley runoff reaching San Francisco Bay during the winter-spring period, which is critical to the propagation of Delta Smelt, has declined over the past several decades such that the estuary essentially experiences drought conditions in most years. This pattern also is shown in Figure 6 of Part 3 of the BiOp as bars labeled "Super Critical". The use of a line showing an apparent decline in exports relative to unimpaired flows is misleading because exports become constrained by deteriorating water quality at some absolute threshold level of exports. This distracts from the apparent fact that exports since 1980 have resulted in many more "super critical" years than prior to 1980 (i.e., artificial drought conditions).

Hammock et al. (2019) found a relationship between declining chlorophyll a concentration, which supports a pelagic food web essential to Delta Smelt, and the combined effects of filtering by the invasive overbite clam and freshwater exports; together these two factors could account for 97% of the decline in chlorophyll a, and exports alone could account for 74%.

Figure 4 in Part 3 of the BiOp shows a time series of biomass of six pelagic fishes, including Delta Smelt, from 1967 to 2017 and is presented as evidence that biomass of Delta Smelt was already lower than the other species by the time water exports from the pumping facilities were initiated in 1968. If this is meant to provide evidence that water exports have not been responsible for the general decline of Delta Smelt biomass over the time period depicted in the figure, it fails to do so. First, the dataset does not provide any actual "baseline" information on Delta Smelt biomass in most of the years prior to the initiation of exports. Second, it provides evidence for a drastic decline in the biomass of all species, but especially Delta Smelt, in the 37 years after 1980. The effects of freshwater exports, particularly if they operated indirectly to impact food supply or available critical habitat, would likely develop over time in such a large system as a Cumulative Effect. However, because of the definition of Environmental Baseline used in the BiOp, all effects prior to the current consultation are incorporated in a new baseline and so are discounted.

It is difficult to evaluate the analysis of Delta Smelt population trends for a number of reasons. First, it seems to be based largely on methods described in a publication (Polansky et al., 2019, in press or in revision) that was not available to this reviewer. However, there was an Appendix that provided additional details. A stage-structured model of population dynamics used data from several gear types. Second, each gear likely has a different catch effectiveness and all are almost certainly size-selective as has been shown by several recent studies (e.g., Peterson and Barajas 2018, Mitchell et al., 2017, 2019). It is difficult to account for all of the biases associated with combining data collected from different gear types and the combined effects on the results of models to capture historical dynamics of the Delta Smelt population, much less to predict future population dynamics from such models. Third, while all models predicted a continued decline in Delta Smelt abundance, it was also clearly noted that prediction uncertainty was "extreme".

Concerns about the accuracy and precision of Delta Smelt population estimates are partially balanced by the fact that there have been recent and significant incremental improvements in Delta Smelt monitoring. Consequently, it is likely safe to conclude that there is a scientific consensus that the population has past yet another threshold in decline that appears to be leading to extinction in the wild (e.g. Moyle et al. 2016, Baumsteiger and Moyle 2017, Hobbs et al. 2017).

Information on the reproductive requirements, especially in terms of critical spawning habitat, is woefully scarce and uncertain. For example, spawning behavior is only known from captive populations and preferred spawning substrates remain unknown. This makes it very difficult to identify specific critical spawning habitat. Eggs of Delta Smelt are demersal and adhesive so could be

attached to any number of substrates including coarse sand, gravel, crevices in stones, submerged logs or even algal mats or the lower portions of emergent vegetation in shallow subtidal or wet intertidal habitats. It is difficult to protect critical spawning habitat without knowing what it is, much less to analyze the potential effect of any action on critical habitat.

Climate change was recently added to a growing list of threats to Delta Smelt. While the list of threats grows, progress toward maintaining and recovering Delta Smelt in the wild continues to fail. At best, it might be said that extinction could have occurred already had it not been for protective actions previous taken, but there is no substantial scientific support for this.

The role of turbidity in critical habitat of Delta Smelt is based largely on positive associations between turbidity and catches of Delta Smelt in trawls and in salvage at the pumping stations. The USFWS seems to dismiss the suggestion that turbidity simply covaries with undetermined underlying causal factors such as sampling gear effectiveness in clear versus turbid water or flow rates. Turbidity *per se* is a very coarse variable that may need to be qualified in order to be useful. For example, there may be no functional equivalency between any given turbidity value due to the sediment suspension versus robust growth of phytoplankton in response to nutrient levels. In the first case, there may be little or no connection between turbidity and useful food resources for Delta Smelt. In the second case, different source nutrients (e.g., ammonium vs nitrate) at certain concentrations can lead to very different size classes of primary producer communities (e.g., Glibert et al. 2016) that support zooplankton communities of different food value to Delta Smelt. Measures of turbidity alone are of no value in making these functional distinctions.

In an apparent search of some mechanistic advantage of turbidity, the BiOp (Part 3, p. 36) argues that turbidity produces a dark background against which larval Delta Smelt can better see their translucent prey citing Hasenbein et al. 2013, 2016 to support the suggestion that feeding success and survival of larvae are higher at 12-80 NTU than at lower or higher turbidities and that juvenile Delta Smelt are less reliant on turbidity to see their prey. However, an examination of the data in these references shows that the only statistically significant differences in larval survival were between 25 NTU, which was associated with higher survival than at either 5, 120 and 250 NTU; there was no difference in survival at any other level of turbidity (see Fig. 1 in Hasenbein et al. 2016). Similarly, not only was there little difference in feeding rates of juvenile Delta Smelt across a wide range of turbidity but some evidence that feeding rates were greatest at 0 NTU and declined with increasing turbidity (see Fig. 1 in Hasenbein et al. 2013). Furthermore, it is also suggested that juvenile Delta Smelt rely on turbid waters to avoid predation. The two positions suggesting that a dark background aids Delta Smelt in locating their prey but at the same time hides them from their predators seems inconsistent. Delta Smelt are largely translucent and not darkly colored, so why would they not be more visible to their predators in turbid waters?

The association of turbidity fronts with the location of X2 and concentrations of food for Delta Smelt is perhaps the most convincing connection between turbidity and Delta Smelt abundance but this only occurs in relatively small regions of the habitat. Environmental variables other than turbidity (e.g. temperature and salinity) have a demonstrable physiological effect on all species, including all life stages of Delta Smelt (e.g., Hammock et al. 2017) but the importance of turbidity remains an open question. Consider that Delta Smelt are now being successfully reared in captivity. Is turbidity from sediment suspension an essential element for successful growth and survival in hatchery stocks in the same way that temperature and salinity ranges are crucial?

The BiOp argues that turbidity persists at and near X2 while Delta Smelt catches have continued to decline, which disproves the hypothesis that turbidity affects gear effectiveness (Part 3, p. 36). This argument is difficult to understand. No one seems to be questioning the decline in Delta Smelt abundance but trawl gears can be less effective in clear water. There are other issues related to tidal stage and distribution of Delta Smelt that could affect gear effectiveness (e.g., if fish move toward shallows on ebbing tides but gear is used in deeper water, catch will be reduced); effects of sampling gear issues on estimates of abundance should not be discounted.

On p. 44, Part 3 of the BiOp it states that since the RPA in the 2008 BiOp was implemented, there has been a much lower likelihood of water operations that are highly detrimental to Delta Smelt spawners or larval transport. However, how is this determined? Delta Smelt population size has declined substantially since implementation of the RPA, so how is effectiveness measured?

2.1.2 Are assumptions in the effects analysis clearly stated and reasonable based on current scientific thinking?

Assumptions were sometimes made to justify the finding that some element of an action would have no further impact on Delta Smelt. For example, because all Delta Smelt entrained at the pumping facilities are assumed to be lost, the salvage operation is judged to have no additional effect on the population. This could be viewed as a very conservative approach but at some level suffers from a lack of logic. For example, if live Delta Smelt are present in salvage, the assumption is proven false. It also calls into question the use of salvage as a means of determining take at the pumping facilities.

Another issue with assumptions is that even when they are clearly stated they are sometimes inconsistent with the Proposed Action as, for example, Table 2 in Part 4 of the BiOp, there is no decision to favor the protection of Delta Smelt. Instead, the decision will be made in real time by management groups identified in the Proposed Action. Essentially, the analysis defaults to others and any effects, either positive or negative, become part of the next Environmental Baseline.

In other cases, assumptions were not readily apparent. The narrative in Appendix 2 (GLM relating an index of proportional entrainment loss to turbidity and OMR flow) is an example.

The Polansky et al. 2019 referenced relied on heavily in this appendix was unavailable at the time of this review of the BiOP. The approach is based on a number of assumptions and does not distinguish natural mortality from entrainment mortality. Also the method described uses an OMR Index which the LOBO 2017 panel strongly discouraged because of its failure to capture true variations from gage data due to tidal flows, especially through the critical range of -2500 to -5000 OMR flows. The LOBO panel proposed a method that could improve predictions of the USGS tidally filtered OMR flow estimates (see LOBO 2018, Appendix 2) but it is unclear if the OMR Index used was the same, or an adjusted version in response to prior concerns.

Adult DS abundance estimates were based on Spring Mid-water Trawls from 1993-2000 and on Spring Kodiak Trawls from 2001-2015. I presume the "Spring Mid-water Trawl" referred to in this Appendix is the survey that the more effective surface Kodiak Trawl replaced for the collection of DS. Mid-water trawls are not as effective as surface trawls for DS and a number of gear efficiency issues can lead to implausible patterns in catch densities when using different gears and sampling approaches under different environmental conditions (e.g. turbidity) and fish abundance levels (e.g., Peterson and Barajas 2018; Mitchell et al. 2017, Mitchell et al. 2019).

2.2 Do the draft sections of the biological opinion adequately analyze effects of the proposed action on delta smelt and critical habitat?

As mentioned previously in this report, there seems to be very little difference between the analyses of effects on Delta Smelt and effects on their critical habitat. One issue that could be considered further involves any action to improve the amount or quality of habitat for Delta Smelt at stationary locations (e.g., marsh restoration or food web enhancements in the Cache Sough complex). These should be analyzed in light of actions (e.g., shifts in X2) or anticipated events (e.g., climate change) that are likely to change environmental conditions for Delta Smelt.

Much of the effects "analysis" is based on models that are being applied for purposes they may never have been intended. For example, the complex CalSim II model is perhaps the most relied upon water management model but when used inappropriately could very well lead to analytical controversies and misunderstandings. Such issues were addressed in Ferreira et al. 2005, which was not referenced in the BiOp.

This holds as well for Delta Smelt population models which have high degrees of uncertainty largely due to the current small population size and associated issues with sampling and incomplete understanding of how critical habitat is being defined and affected.

2.2.1 Did the Service adequately analyze effects for both standard/site-specific (described at a site-specific level with no future consultation required) and programmatic (which require future consultation before they can be implemented) components of the proposed action?

As acknowledge in the BiOp, the Proposed Action by Reclamation is considered a mixed programmatic action with many elements subject to reinitiation of consultation, in essence deferring analysis until additional information is available. Many of the action elements are associated with a high degree of uncertainty with respect to effects on Delta Smelt and their critical habitat. The following narrative highlights some issues that stood out in this review of the BiOp with respect to uncertainty associated with the effects analysis of critical habitat and cumulative effects.

The BiOp considers that turbidity associated with sediment load is important to mediate effects of predation on Delta Smelt and facilitate feeding of larvae, but the effects of the Proposed Actions on suspended sediment are not estimated. Despite the lack of information regarding sediment load, the current BiOp assumes the Proposed Actions will have only minor effects on critical habitat in the winter compared with the Environmental Baseline.

The BiOp does not expect food resources to change as a result of Delta outflow and cites several actions including habitat restoration, water management and food web subsidy studies, most of which are considered part of the Environmental Baseline but will not be completed until later. It is assumed that these actions may provide data to inform adaptive management of food webs. As with much of the analysis on critical habitat, there are many hypotheses but relatively few substantial scientific facts or tests available. For example, tidal habitat restoration is expected to improve the availability of food for all life stages of Delta Smelt but "at unknown locations and to an unknown degree". This is not a very compelling endorsement.

The operation of the Suisun Marsh Salinity Control Gate to direct more freshwater into Suisun Marsh in summer and fall under certain constraints was presented in the context of improving habitat for Delta Smelt but the action may be primarily intended to benefit waterfowl. The results of a pilot study suggested that Delta Smelt may see some modest benefit from the action but this remains to be seen.

Other actions are also guided by the hypothesis that food resources can be redistributed to benefit Delta Smelt but other species, perhaps superior competitors, may benefit as well and there is a risk of redistributing contaminants from agricultural and areas affected by ship traffic (e.g. hydraulic reconnection of the Sacramento Ship Channel with the mainstem of the river). Delta Smelt are already exposed to contaminants in the Liberty Island/Cache Slough complex (e.g., Hammock et al. 2015), which is being targeted for the redistribution of potential food resources from the ship channel.

Similarly, what appears to be a cooperative effort among the DWR, Reclamation and water users to flush nutrient-rich water from the Colusa Basin Drain into the Yolo Bypass and north Delta, may also contribute additional agricultural contaminants to the target area.

The BiOp states that the net direction and magnitude of the effect of these actions to stimulate the food web is currently unknown. This also means that the risk of jeopardy is also unknown and by the time it is known the effects will be incorporated into the next Environmental Baseline.

Table 2 in Part 5 of the BiOp summarizes Proposed Actions for the summer-fall habitat by water year type. In wet years, it appears that the trade-off being made for the Suisun Marsh Salinity Control Gate action is to reduce outflow such that X2 is located at 80 km in September and October closer to a critical threshold for maintaining acceptable salinity levels near the center of the juvenile and subadult Delta Smelt population in the vicinity of Suisun Bay. Threshold levels at which critical conditions change abruptly from acceptable to unacceptable are usually only considered in the context of operating as close to those thresholds as possible. While this may maximize exports, it increases the risk of jeopardy to Delta Smelt, particularly in areas where the populations are most abundant. However, the BiOp states that the management actions "will likely provide better salinity conditions for rearing Delta Smelt than those modeled in CalSim II, but the magnitude of the effect is uncertain". How can anything be considered "likely" if the effect is "uncertain". Could this be one of those issues that CalSim II was not designed to address (Ferreira et al. 2005)? The argument appears to be that significant landward shifts in X2 would have occurred in September and October. However, when considering substantial shifts in X2, it would be appropriate to consider that restoration areas remain stationary and under the current Environmental Baseline, how will water quality in the restored habitats be affected by shifts in X2?

Figure 10 in Part 5 of the BiOp shows how frequently X2 is expected to be located at or above 85 km, which results in no overlap of the low-salinity zone with Suisun Bay under the proposed actions relative to current operations according to 82 simulation runs of the CalSim II model. During September to December. X2 is predicted to be located at or above 85 km much more frequently than under current conditions. This shows that conditions will be less favorable more often in the primary center of the Delta Smelt population. It is difficult to imagine how these predicted conditions could be considered an acceptable risk to the critical habitat of a listed species.

In regard to river flow (p. 19, Part 5 of BiOp), USFWS asserts that "new scientific understanding of factors affecting entrainment risk suggest that turbidity in addition to river flow plays an important role in attracting migrating adults to spawning habitat." Sommer et al. (2011) is cited to support the notion that freshwater flows in combination with turbidity cue adult Delta Smelt to disperse to spawning habitat in December through March. However, Sommer et al. (2011) concludes that the spawning migration pattern is variable. First flush flow events in winter are identified as the primary trigger for upstream spawning migration and turbidity may be associated, but is not presented as a

trigger; turbidity may be associated, but is not presented as a trigger. Also mentioned in this paper is a strong association between the center of Delta Smelt abundance and X2 in the fall. Proposed actions would drive X2 farther upriver in the fall, degrading critical habitat at the core of remaining Delta Smelt population. Turbidity seems to receive ubiquitous mention in much of the literature as a factor that affects key processes (e.g., feeding, survival, migration, etc) affecting all life stages of Delta Smelt but the linkages are rarely clear.

The treatment of any real cumulative effects on Delta Smelt seems to be effectively ignored, or at least obfuscated, by virtue of the definition of Environmental Baseline, which does not allow any past or future actions to be considered in the analysis. How can the cumulative effects of only current actions be evaluated? As described in this section, the effects of multiple risk factors are better described as "additive effects" not cumulative effects, which are repeated over time. The definition of Environmental Baseline essentially eliminates a consideration of cumulative effects in this analysis.

Furthermore, as in other sections of the BiOp, there seems to be a selective use of the findings in cited literature. One example is the use of Nobriga et al. (2004) to support the assertion that Delta Smelt seem to have a low vulnerability to entrainment associated with unscreened water diversions used in the irrigation of agricultural fields. The study was limited to measurements of entrainment at two agricultural irrigation diversions, one screened and the other unscreened. Sampling occurred during periods of approximately 40 hrs over two days in July over each of two years (2000 and 2001). No Delta Smelt were collected from the screened diversions and a total of 42 Delta Smelt were collected at the unscreened diversions. In general, these numbers were lower than those of other species collected from the unscreened diversion but the interannual variation in numbers of fish entrained was very high. For example, 59 Threadfin Shad were collected in 2000 but 7,824 were collected in 2001. The authors acknowledged several uncertainties in their results including the fact that they did not know how many Delta Smelt (or other species) were impinged on the screen diversion and that the findings may not have been representative of entrainment at other diversions. They believed that the low number of Delta Smelt entrained by the diversion reflected an offshore rather than nearshore distribution of fish (i.e., Delta Smelt were not susceptible to entrainment). Placed in the context of cumulative effects on a listed species, the number of Delta Smelt entrained in this study would have to be expanded by the number of agricultural diversions in operation and the total number of hours or volume pumped in areas occupied by Delta Smelt. This study did not attempt to do this, yet the limited temporal and spatial coverage of the results seems to be applied to support the conclusion that small water diversions for agricultural (regardless of their number or location) pose only a minor risk to survival of Delta Smelt. This single limited study (Nobriga et al. 2004) is used in a summary of cumulative effects to suggest that the Delta Smelt is at low risk as a result of agricultural diversions. However, this seems rather thin evidence to discount a "death by a thousand cuts" type of risk.

The potential effects of contaminant and nutrients in the analysis of cumulative effects seems to be largely descriptive and, like other sections of the BiOp, replete with unknowns and uncertainties. Given that some of the Proposed Actions involve the redistribution of nutrients (and likely contaminants) in an effort to enhance food resources for Delta Smelt, the many uncertainties with respect to potential impacts on survival, growth and reproduction of Delta Smelt become an issue in the cumulative effects analysis.

While it is possible that changes in key environmental factors (e.g., temperature, salinity, etc) that are known to effect the survival, growth and reproduction of Delta Smelt will likely lead to the extinction of the species in the San Francisco Bay Estuary, climate change is not part of the cumulative effects that have led to the current status of Delta Smelt.

2.2.2 Are the methods utilized appropriate to determine if the proposed action is likely to jeopardize delta smelt or adversely modify its critical habitat?

The short answer is no. See the answers to previous questions. There is an apparent lack of consideration of ecological (environmental) thresholds with respect to effects on Delta Smelt and their critical habitat, apparent confusion over additive and cumulative effects, an often high degree of uncertainty in methods applied in the analyses, and a definition of environmental baseline that seems to preclude a consideration of real cumulative effects.

3 Additional Thoughts, Concerns, and Suggestions for Improvements to the Analyses

A set of minor comments on consistent form, missing references and typos detected while reviewing the draft BiOp are provided in Appendix A – Some Minor Comments for Consideration.

Following are some recommendations/suggestions for future effects analyses, research and potential relocation of Delta Smelt in the wild:

(1) A consideration of ecological thresholds in future effects analyses is strongly recommended. See Clements and Ozgul (2018) and references therein for a recent review and synthesis of concepts and applications. At or near threshold levels, small changes in conditions can lead to rapid and dramatic changes in Delta Smelt populations and the quality of their critical habitat.

(2) Now that Delta Smelt are available for experimentation from hatchery stock, it is possible to test hypotheses about preferred spawning substrate, spawning water depth, spawning periodicity and synchrony (e.g. tidal, lunar, diurnal/nocturnal, light level) – all key issues for defining critical spawning habitat. Mesocosm experiments could be conducted to provide choices of possible spawning substrates (e.g., coarse sand, gravel, algal mats, submerged aquatic vegetation, tule shoots, etc.) at different relative water depths could certainly help to provide basic information on critical spawning habitat.

(3) If climate change is now a serious concern, how will this affect plans to reintroduce or supplement Delta Smelt when the wild population is considered functionally extinct? Because Delta Smelt is already at the southern end of its potential range, and the species does not migrate to the ocean, there is little possibility that natural northerly dispersal of the population with changing temperatures can occur. Although this will be perceived as a radical idea, perhaps it is time to consider a new home for Delta Smelt in the wild; it may not be able to survive in the Sacramento/San Joaquin Delta in the future even if supplemented with hatchery fish. Also, once hatchery fish are released into the wild, and if hatchery support is required for successful reproduction, the required introduction of wild popn genes into the hatchery fish may no longer be possible.

Undoubtedly, there would be resistance and legal hurdles to overcome in transplanting Delta Smelt between watersheds or states, it may be time to search for a new wild home for this species in estuaries north of San Francisco Bay. It is becoming clear that the choice between restoring Delta Smelt populations in the San Francisco Bay Estuary and providing a reliable source of water for human uses has already been made. It may be time to remove the Delta Smelt-child from its current guardian and place it in a foster home. Are there any suitable

estuaries north of San Francisco Bay that could sustain populations of Delta Smelt? If so, there is a certain irony in the fact that Delta Smelt, if relocated, would likely be considered a non-native species.

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Appendix A
Minor Comments for Consideration

(1) Recommend consistency in referring to Delta Smelt in the BiOp. "Delta Smelt", "Delta smelt" and "delta smelt" are all used. Although it was never my personal preference, the American Fisheries Society 7th edition of the Common and Scientific Names of Fishes (2013) recommended capitalizing common names (i.e., Delta Smelt). My current understanding is that the USFWS adopted this convention for fishes.

(2) The X-axis of Fig 16 in Part 3 of the BiOp is improperly labeled as "Julian Day"; the axis actual shows the number of days since the beginning of the calendar year; Julian Date is the number of days since the beginning of the Julian Period, January 1, 4713 BC.

(3) In the time allotted to produce this review (10 days), I was unable to check all of the references in the Literature Cited to determine if there were missing citations or the cited literature was actually referenced in the text of the BiOp, but I did happen across the following errors:

   a. DWR 2009a and DWR 2011 were cited in the BiOp text (p. 7, Part 6) but do not appear in the Lit Cited section.
   b. EPA 1999 was cited in the BiOp text on p. 5 of Part 6 but did not appear in the Lit Cited section.
   c. Glibert (2011) cited on p. 5 of Part 6 should be Glibert et al. 2011 according to the Lit. Cited.
   d. On p. 6 of Part 6 there is a reference to Dugdale et al. 2013 that is not included in the Lit. Cited; could this be Dugdale et al. 2012?
   e. Also on p. 6 of Part 6, Delta Protection Commission 1997 is cited but is not in the Lit. Cited; could this be Delta Protection Commission 2012 instead of 1997?

f. Publication year of Huber and Knutti is cited in the text (p. 7, Part 6) as 2011 but listed in the Lit Cited as 2012. I believe the text should be corrected to 2012, even though the paper was first published on line in December 2011.
g. Solomon et al 20092009 is cited on p. 7 of Part 6; one of the "2009" should be deleted.
h. Inkley et al. 2004 is cited in the BiOp text but does not appear in the Lit Cited.
i. Moyle et al. 2016 appears to be listed twice in the Lit Cited. The first reference appears to be incomplete and the second omits an author (Hobbs, J.A.).
j. Murphy and Hamilton 2013 in the Lit Cited should be moved to appear following Moyle et al 2010.
k. California Department of Boating and Waterways (2003) cited on p. 6 of Part 6 does not appear in the Literature Cited.

Independent Review of the Coordinated Long-Term Operation of the Central Valley Project and State Water Project

Prepared for:
National Marine Fisheries Service
U.S. Fish and Wildlife Service

By:
Joseph E. Merz, Ph.D.
Cramer Fish Sciences
3300 Industrial Blvd #100
West Sacramento, CA 95691

Executive Summary

I was asked to provide input, as an independent scientist, on whether the biological opinion is scientifically sound and the conclusions are based on the best available scientific information as it pertains to Delta smelt; scientifically defensible. Relevant background materials and sections of the biological opinion to be reviewed were provided.

In short, I believe that the BiOP provides enough information to demonstrate that the status of delta smelt critical habitat under the PA will most likely be degraded by cumulative effects under the early long-term. However, I think this is more due to the lack of information demonstration by Reclamation than analyses in the BiOP. In particular, it is almost impossible to identify what the overall PA effects would be in measureable terms other than estimated percent change to outflow.

Information provided in each section is disorganized and not enough information is provide in background. For instance, why 1850-1967? Why is Figure 4 Biomass of six "pelagic" species placed in the 1850-1967 period?

BiOP should be more fully developed into the life cycle of delta smelt. What is the timing of each life stage? What are the key physical requirements for each life stage? Then clearly articulate the timing and effects of each component of the PA as it relates to delta smelt. Delta smelt life stages are not well defined and in many cases, have conflicting or ambiguous descriptions of the fish.

Estuary seasonality is not well described in the environmental setting. For instance, "wet and dry season" are alluded to in document but the seasonality of habitat flood-up and subsequent water quality and foodweb activity are not well established. There is significant information available on the trophic interactions of the estuary, including seasonality as it related to the life cycle of delta smelt. How would the PA influence this?

What are the implications for not re-classifying delta smelt? The argument made that "there are bigger fish to fry" is not well supported and if the conclusion of this BiOP is that the PA will make things worse for delta smelt and that the numbers are continuing to decrease, coupled with a conservation hatchery expected to go on line at the date delta smelt are expected to blink out of the environment, doesn't that suggest great peril for the species?

Tables and Figures do not adequately explain what information is being described (see specific comments below). In short, they should be "stand alone". Acronyms and initials should be clearly spelled out in captions. This includes explanation of color differences in best-fit lines and what appears to be confidence intervals etc.

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1 Introduction

1.1 Background

I was asked to provide input, as an independent scientist, on whether the biological opinion (BiOP) is scientifically sound and the conclusions are based on the best available scientific information as it pertains to Delta smelt; scientifically defensible. Relevant background materials and sections of the BiOP to be reviewed were provided. I also participated in a single conference call with the other reviewers and USFWS representatives for discussing key topics prior to submitting the individual review report.

Under section 7 consultation, the USFWS has been given the daunting task of evaluating the ROC PA effects on listed species and designated critical habitat of several species, including delta smelt. An analysis and conclusion of whether the entire ROC action as described in the PA is likely to jeopardize the continued existence of listed species or result in the destruction or adverse modification of their critical habitat are meant to be provided within the BiOP.

This report on review of the draft BiOp section on delta smelt was submitted using the format provided, addresses questions posed by USFWS and was delivered electronically to the Anchor QEA representative, Michelle Havey, for consolidation with other review reports. Due to the overwhelming amount of information provided and the relatively short window for review (this is in the middle of my field season), I requested a 48-hr extension.

1.2 General Observations

Two main points I take away from reading this: (1) delta smelt numbers are so low, it is difficult to track habitat use and life stages. Therefore, why aren't they listed? (2) Even though numbers are too low to track, PA suggests increased water deliveries at all times.

Information provided in each section is disorganized. Build a document strawman with headings and subheading put in order and an explanation of each. For instance, why 1850-1967? Why is Figure 4 Biomass of six "pelagic" species placed in the 1850-1967 period? Once this is done, populate with text, figures etc.

Who is responsible for describing each action and the best science available for delta smelt? Shouldn't USFWS hold Reclamation responsible for "doing their homework" first? Otherwise, doesn't USFWS become responsible for making sure information is correct?

BiOP section on delta smelt should be more fully developed into the life cycle of the fish. What is the timing of each life stage? What are the key physical requirements for each life stage? Then clearly articulate the timing and effects of each component of the PA as it relates to delta smelt (see recommendations below).

Delta smelt life stages are not well defined and in many cases, have conflicting or ambiguous descriptions of the fish. "Primarily pelagic or primarily occupies open water", semi-anadromous, migration vs dispersal (what is the difference?).

Estuary seasonality is not well described in the environmental setting. For instance, "wet and dry season" are alluded to in document but the seasonality of habitat flood-up and subsequent water quality and foodweb activity are not well established. Winder and Schindler (2004) provide an excellent example of depicting seasonality of the Lake Washington trophic interactions and how climate change is altering/decoupling these relationships. See example figures from Merz et al. (2016) manuscript.

What are the implications for not re-classifying delta smelt? The argument made that "there are bigger fish to fry" is not well supported and if the conclusion of this BiOP is that the PA provided will make things worse for delta smelt and that the numbers are continuing to decrease, coupled with a conservation hatchery expected to go on line at the date delta smelt are expected to blink out of the environment, doesn't that suggest great peril for the species?

Tables and Figures do not adequately explain what information is being described (see specific comments below). In short, they should be "stand alone". Acronyms and initials should be clearly spelled out in captions. This includes explanation of color differences in best-fit lines and what appears to be confidence intervals etc.

2 Responses to Questions

2.1 How well do the draft sections of the biological opinion for delta smelt use best available scientific and commercial information?

The draft sections use reasonable science, including modeling, to predict entrainment effects and generally where X2 is, and delta out flow etc. However, there is much related to trophic interactions, seasonal water quality etc that has not been well described or used. Please see specific comments below.

2.1.1 Do the analyses in the status of the species and critical habitat, and environmental baseline sections reflect the best available scientific and commercial information?

Please see comments below.

2.1.2 Are assumptions in the effects analysis clearly stated and reasonable based on current scientific thinking?

In general, yes. However, there is conflicting and ambiguous language related to seasonal movement of delta smelt, the life stages and associated habitat needs of the fish. See comments below.

2.2 Do the draft sections of the biological opinion adequately analyze effects of the proposed action on delta smelt and critical habitat?

In short, the BiOP demonstrates that the PA generally will reduce delta outflow with relatively little evidence from Reclamation that this will not negatively alter delta smelt from its present trajectory. Please see comments below.

2.2.1 Did the Service adequately analyze effects for both standard/site-specific (described at a site-specific level with no future consultation required) and programmatic (which require future consultation before they can be implemented) components of the proposed action?

Not sure this is relevant.

2.2.2 Are the methods utilized appropriate to determine if the proposed action is likely to jeopardize delta smelt or adversely modify its critical habitat?

In general, I believe that the methods provide the minimum requirements to determine jeopardy of delta smelt critical habitat by the proposed action. However, please see my comments below.

3 Additional Thoughts, Concerns, and Suggestions for Improvements to the Analyses

For the information, including the analyses provided, it is imperative that each section of the BiOP provide key information as to what it is meant to be accomplished. For instance, the background section, while this seems self-explanatory, does not offer the reader what information it is meant to provide. In contrast, the Environmental Baseline section does provide an explanation as to what the authors are meant to convey. This should be standardized and will help readers follow the immense amount of information, including analyses, provided.

The reasons why Reclamation requested re-initiation of consultation are:

1. New information related to drought
2. low smelt populations (this is confusing; conserved one population in the wild)
3. New expected information from "ongoing collaborative work"

However, these statements are ambiguous at best and there appears to be little relationship between these data and what actions are being proposed. From the background reviewed, the PA appears primarily driven by increasing reliability of water delivery. Should that be clearly stated in the Background?

The BiOP purpose is also a bit confusing. For instance, Table 1 (Consultation Approach for Programmatic Components of the Proposed Action) identifies 11 actions but does not clearly articulate what species each is meant to benefit. It is also confusing as to why studies are considered "actions". Furthermore, there are significant actions related to water deliveries and flow changes that are not provided in the table. Finally, if Tidal Habitat Restoration was already initiated in 2008, how can the entire 8,000 acres be included in PA?

3.1 Description of Proposed Action

Shouldn't power generation be included?

Table 2 (pg 6) – needs full description for each project component. Describe NLAA and LAA in caption. Why delta smelt, yb cuckoo, valley elderberry long horn beetle, giant garter snake etc and not other species? Why call out delta smelt critical habitat in some locations and not others? Finally, most of the document focuses on delta smelt so why are other species brought up here?

Under Analytical Framework for the Jeopardy Determination (pg 18) clearly articulate how each action might impact delta smelt.

3.2 Environmental Baseline

Page 3- "delta smelt primarily occupies open-water habitats…" This is un-substantiated and existing information supports the contrary. This is also an example where the BiOP over-simplifies by lumping delta smelt life stages. For instance, Aasen (1999) found that juvenile delta smelt densities were significantly greater in shallow water habitat of Honker Bay and Sherman Lake than in adjacent channels, indicating they use shallow bay areas and flooded islands as nursery habitats. There also appeared to be differences in smelt size related to habitat. Chotkowski (1999) reviewed historical Bay-Delta shallow water surveys and found that delta smelt were common in beach seine surveys (1976-1999). A draft manuscript using beach seine and Kodiak trawl data (Merz et al. in prep) demonstrates relatively higher CPUE in beach seine than Kodiak Trawl (Figure 1) and that as Delta inflow increased, adult delta smelt move toward shore areas susceptible to beach seine (Figure 2). These data suggest that 8,000 acres of seasonal wetlands may benefit offset some of the negative impacts related to increased diversions under the PA. However, neither Reclamation or USFWS provide how this habitat will work and how they might influence the identified drivers (e.g., salinity, turbidity, food, temperature, critical habitat etc) of where delta smelt are and how susceptible they are to entrainement etc.

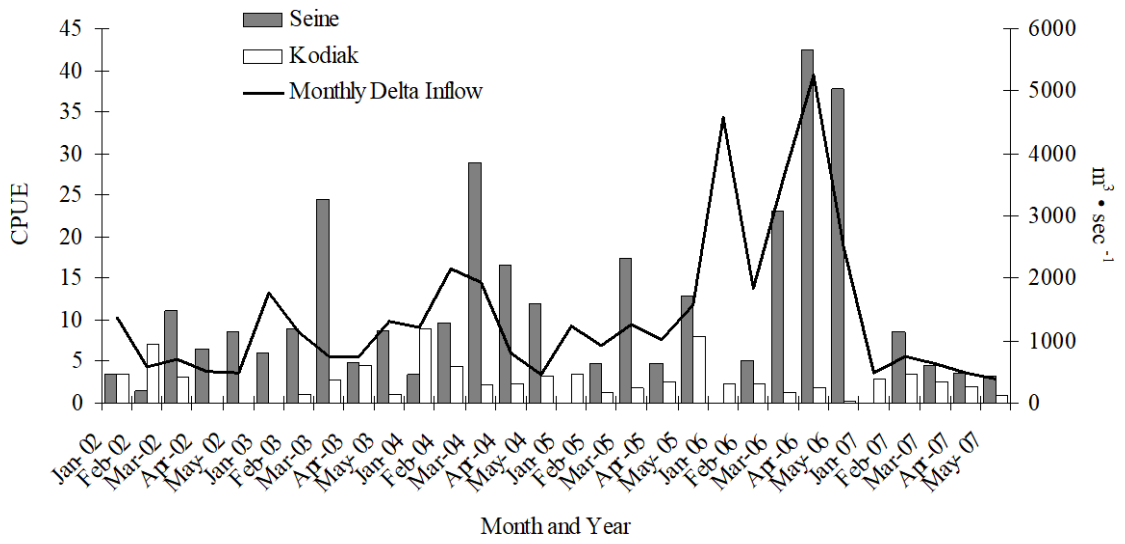

Figure 1. Catch per unit effort of delta smelt by beach seine and Kodiak trawl within the Sacramento San Joaquin Delta, January through May 2002 to 2007. No Kodiak samples were collected April 2002 through January 2003.

Page 4 – The description of delta smelt relationship to flow has not been well defined. When describing flow relationships, what are some of the classical environmental relationships to a hydrograph? In short, why would flow affect delta smelt? Is it just moving the fish or alter where X2

is? Flow, volume, timing, duration, frequency and magnitude all have demonstrated effects on migratory fish and their habitat. From sediment mobilization to triggering food web dynamics, to migrations. In a paper by Zeug et al (2014), flow management from CVPIA projects not only alters native migratory fish size and survival but life history strategy.

Figure 1 (pg 5) – A map is provided to depict tidal wetland and open water available circa 1950. Why not provide an estimate of acreage? Why not provide all rivers associated with CVPIA? Why only river inflow icons on some river? What is the purpose?

Page 6- confusing section to follow. It is not a part of the environmental setting- more an explanation as to why X2 is used today. Figure 2, what is yellow line? What is blue and green?

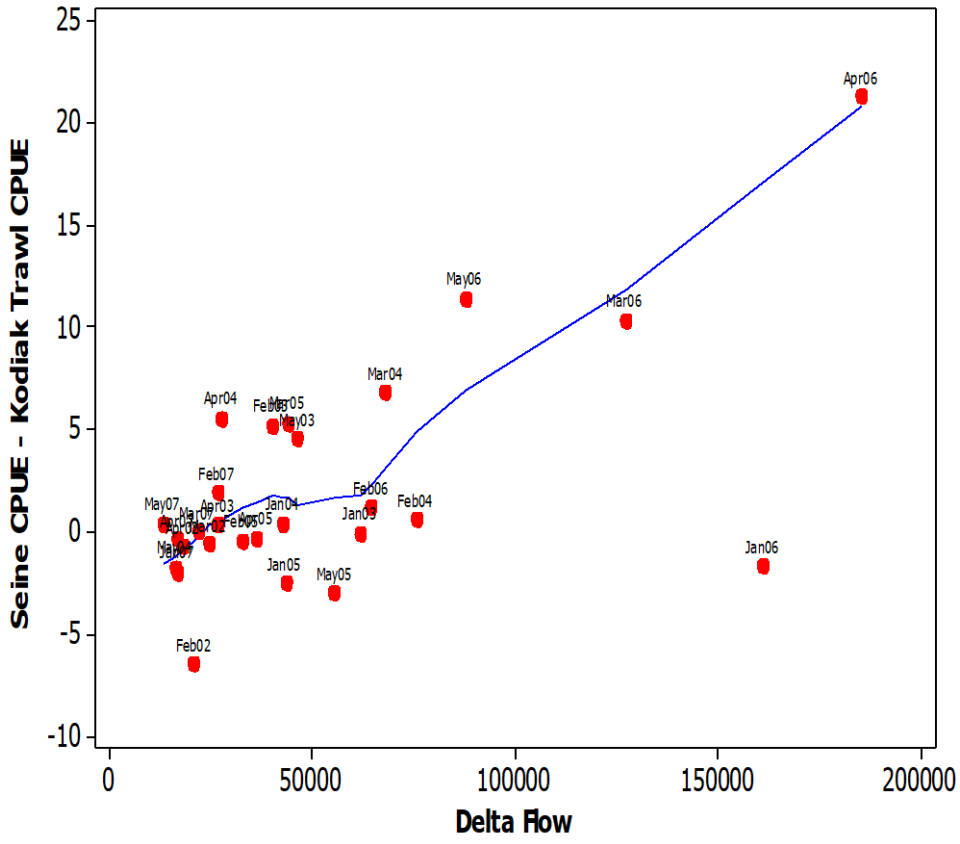

Figure 2. Pearson correlation between mean monthly Delta inflow and monthly beach seine minus Spring Kodiak Trawl CPUE. Pearson correlation = 0.641 (p <0.00001).

I would suggest that a life cycle model be provided, including the timing, fish size and general characteristics, and general habitat needs for each life stage. This is critical in evaluating historical impacts (see page 7 discussion where X2 is by season) and PA impacts.

3.2.1 Environmental Setting (1850-1967)

This section does not clearly articulate environmental setting. For instance, why does it begin with flow relationships? First, clarify why 1850 – 1967 was chosen. Then, clarify from large-scale- California Mediterranean climate – cold-wet to warm-dry seasonality. Flooding and desiccation driving foodweb and productivity. Then the physical and biological changes, from largescale mining, water management, introduced species etc. that changed during this time.

Bay-Delta Estuary- Since PA includes 8000 acres of habitat restoration; shouldn't historic wetland and tidal habitat estimates be cited to put that into context of what occurred historically? What about sediment and nutrient inputs? Historic flooding? (Quantify figure 1 page 5) Jumping into flow-salinity relationship – why? How does salinity fit into the life cycle of delta smelt? Don't they disperse/migrate along a salinity gradient?

Page 7 "By 1920, most of the Delta tidal wetlands had been reclaimed". Not only is this a poor characterization of habitat conversion/destruction/removal, but it provides no measureable terms to put actions into context.

What is the context of striped bass and American shad establishment? What are the ramifications of this? CDFW and others have provided historic list of introductions (Light et al 2005).

Shipping Channel dredging has caused hydrodynamic changes and facilitated species introduction via shipping traffic but what about hydro-chemical effects?

Page 9. Why is Figure 4 put under 1850-1967 heading?

Page 10. How would future development of major storage stop conflict? If average annual water exports have leveled off, then why haven't we seen rebound in major fish species of interest? This suggests that a graph of annual exports alone isn't enough. What about annual flow variability?

Page 12. Figure 6. When did Fed and State projects start and how did they affect that pre-project % unimpaired? See first paragraph on page 10. That suggests that a fitted line, long-term is misleading. 1990 => present appears almost flat.

Page 14. Clearly explain language about abundance indices in Figure 8.

Page 16 Figure 8. Years are tiny in figures. Provide year ranges in caption.

Page 18. The discussion of temperature effects and spawning success could benefit from graphics demonstrating life stage timing and environmental conditions conducive to success.

This can then be used to depict how various aspects of the PA might change this. Language suggests spawning may occur from January through June depending on water temperatures.

So are you saying that a female, with appropriate water quality and sufficient food, could produce up to 5 clutches from January through June?

Page 20. The term "disperse" is ambiguous and confusing. Just because delta smelt aren't migrating specifically up the Sacramento or San Joaquin, doesn't mean they aren't migrating to ward environmental conditions conducive to reproductive success. Delta smelt is a seasonal reproductive migrant (diadromous). Variability in migration behavior, not just winter (Sommer et al. 2011). Some DS remain year-round in fresh water, primarily in north Delta (Erkkila et al. 1951; Merz et al. 2011; Sommer et al. 2011; Sommer and Mejia 2013).
For instance, they clearly move toward freshwater, appropriate temperature and turbidity, and if hypotheses about substrate size are correct, they must seek this as well. The concept of "spreading out" suggests they are simply reducing competition or are primarily driven by density dependent behavior. Low salinity is a key driver of movement- this has been a reason for their past description as a semi-anadromous fish. Note that in Table 2 (page 31), the term "adult migration" is used when defining critical habitat.

As mentioned previously, I would suggest a generalized life cycle figure that can be referenced throughout the BiOP. I would further suggest a calendar Gantt chart that depicts the life stages of delta smelt. PA items, including timing could then be laid over this chart to offer a clearer depiction of proposed actions as they relate to specific life cycle and environmental needs.

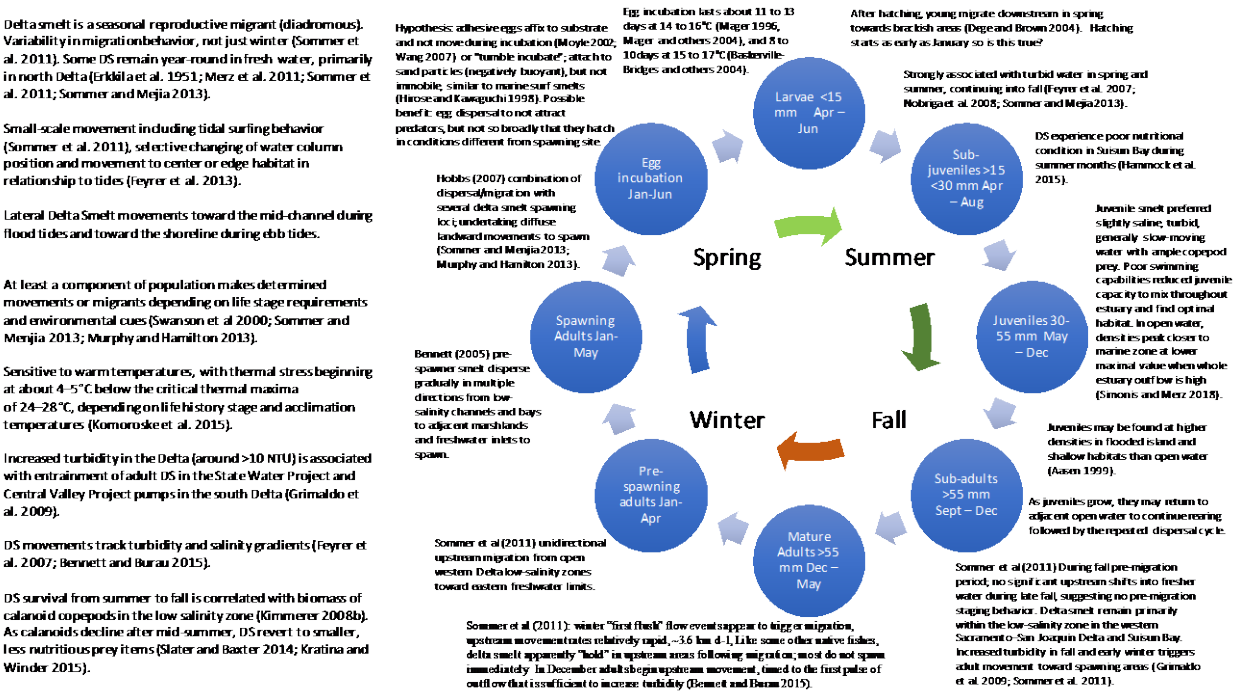

Figure 3. Conceptual delta smelt life cycle including what is known about general timing, water quality, movement, and size by life stage.

3.2.1.1 Food

Food page 22. This section is disorganized. It should be put into the seasonality of the system and the life cycle of delta smelt.

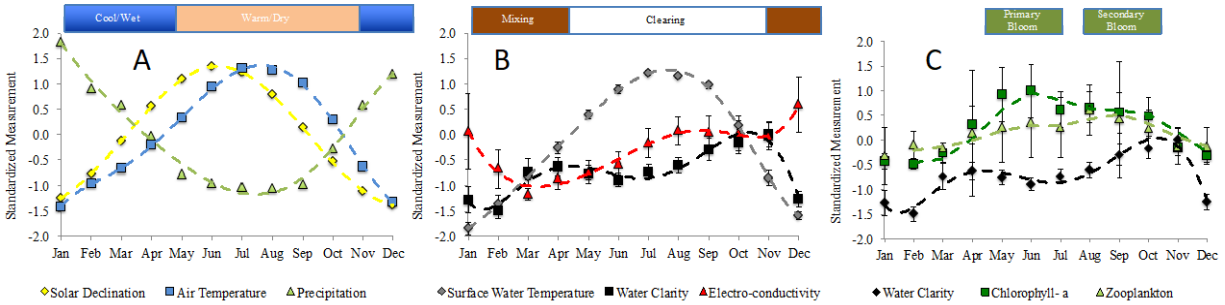

Figure 4. Relationships between the (A) primary drivers solar declination and precipitation and mean monthly air temperature for Port Chicago Naval Depot, and (B) electro-conductivity (EC), water clarity, surface water temperature, and (C) primary productivity and zooplankton biomass for the 15 zooplankton stations monitored during the pre-clam invasion period (1978 – 1985). Lines represent Locally Weighted Scatterplot Smoother (Lowess), which is the locally weighted fit of the simple curve at sampled points in the domain (Cleveland 1979). Means are standardized for comparisons and presented as Z-scores. Figure from Merz et al. (2016).

In Figure 4(C), note relatively high turbidity in cool wet period most likely associated with fine sediment dispersal due to flow and storm disturbance. Once, clearing phase occurs, phytoplankton increases and zooplankton follows closely after. The second turbidity pulse is most likely a response to primary productivity. There is then a second clearing phase (most likely invertebrate consumption of primary productivity) with a second, smaller pulse in the late summer. In short, before suspension-feeding overbite clam invasion in the mid-1980s, the estuary demonstrated monomictic thermal mixing in which winter turbidity and cool temperatures contributed to seasonally low productivity, followed by a late-spring-summer clearing phase with warm water and peak phytoplankton blooms that continued into early winter.

Overall, Merz et al. (2016) demonstrates abiotic factors and species introductions have trophic interactions including altered food web timing, disrupted life cycles, and changed life history expressions and the temporal scale of population dynamics in zooplankton communities. Following clam invasion (Figure 5), a shift in peak phytoplankton bloom timing occurred, with peak productivity now occurring in May compared to June prior to invasion. Peak abundance of several zooplankton taxa (Eurytemora affinis, Pseudodiaptomus, other calanoids, and non-copepods) also shifted to earlier in season. This suggests a timing shift of peak abundance for zooplankton species that are key

prey items of delta smelt. These timing shifts may have exacerbated well-documented food limitations of delta smelt due to declines in primary productivity since the invasion of overbite clam. This suggests that future management actions should consider measures designed to restore the timing and magnitude of pre-invasion phytoplankton blooms. How might the PA flow schedule influence this?

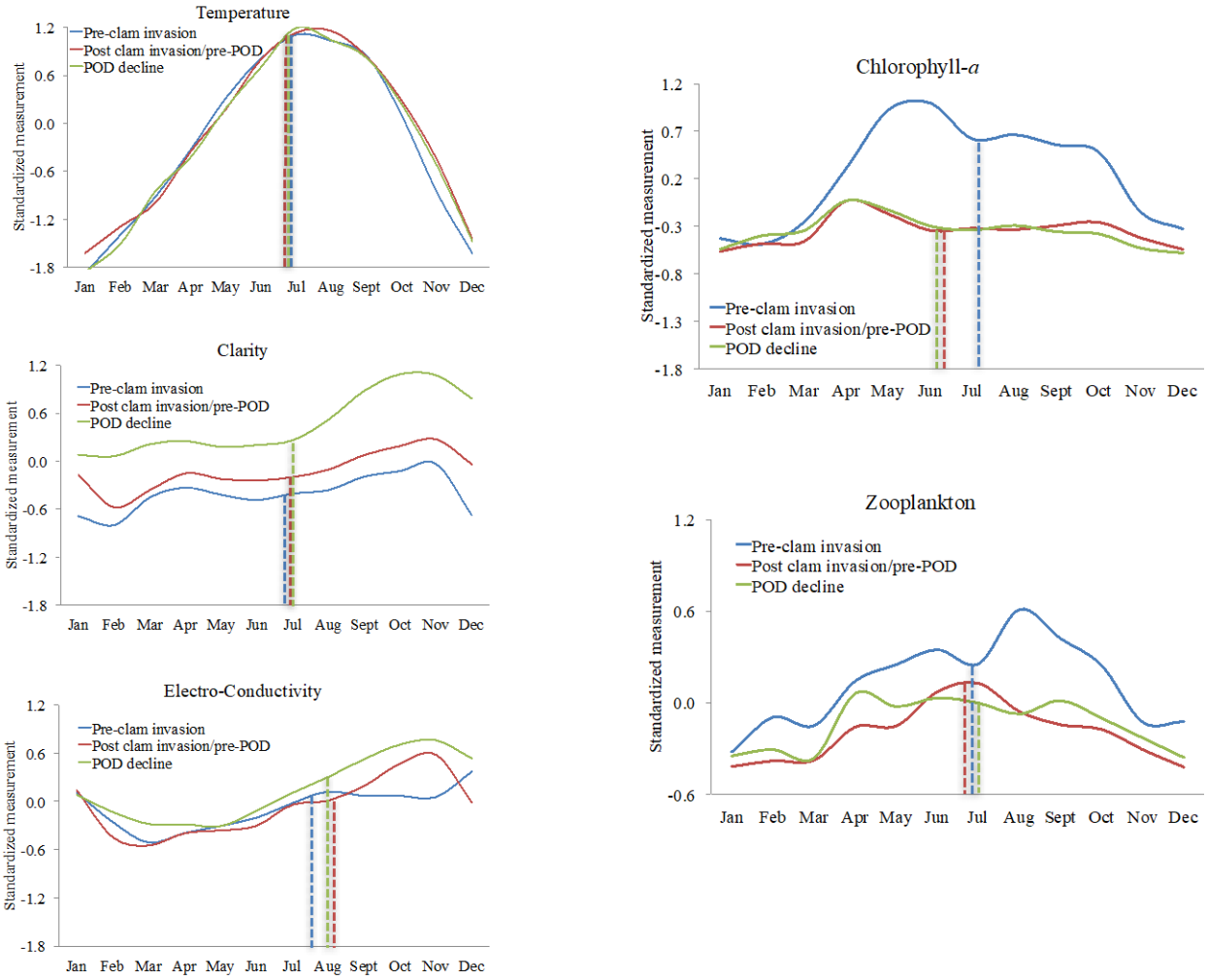

Figure 5. Patterns of water quality variables and Chlorophyll-a and zooplankton within the Estuary associated with the three time periods. Lines of corresponding color represent the Locally Weighted Scatterplot Smoother (Lowess), which is the locally weighted fit of the simple curve at sampled points in the domain for mean monthly measurements (Cleveland 1979). Means were standardized for comparisons. Broken lines indicate the weighted mean month for each measurement for each period.

More background should be given to key environmental parameters, such as food, as they relate to delta smelt life cycle. For instance, USFWS (2004) noted change in food web structure could

decrease growth efficiency: "When food ingestion rates are low, gross growth efficiency is low. At low gross growth efficiencies, larval fish take much longer to metamorphose to juveniles. Long larval stage durations increase the likelihood that density dependent mechanisms (e.g. predators, overgrazing of food resources, etc) and density independent mechanisms (e.g. adverse salinities, temperature, absence of zooplankton, water diversion entrainment and impingement mortality, etc) would develop to adversely affect survival and recruitment."

The Interagency Ecological Program focused on the mismatch between delta smelt larvae and food (Armor et al 2005, Figure 9 & pp. 29-30) whereby a spatial or temporal separation of larvae and food may lead to increased mortality or decreased growth. The concern was specific to larval smelt as the problem was believed to diminish as the swimming ability of delta smelt improved. They observed unusually poor growth rates and condition in fish from Suisun Bay that they did not attribute to contaminants, and therefore deduced the problem was due to food limitations (Armor et al 2005, p. 38; Baxter et al 2008 p. 22). Such food limitations during juvenile development, they suggested, could lead to greater predation, higher disease incidence and lower abundance.

3.2.1.2 Climate Change

Winder and Schindler (2004) provided an excellent example of how climate change is decoupling the food web of the Lake Washington. The Merz et al (2016) manuscript suggests the SFE foodweb behaves similarly to this large lake. I suggest you give more background on seasonality of the SFE and how climate and proposed PA might affect this seasonality.

Fewer "good" turbidity days- what does this mean?

Figure 12 (page 27) – caption should clarify what all acronyms stand for.

3.2.1.2.1 Recovery and Management

The subject of variable hydrograph is only touched upon with primary focus on the fall. Spring is also a period of productivity and movement yet not mentioned.

3.2.1.3 Conservation Role of Delta Smelt Critical Habitat

This is the first time that "successful completion of the life cycle" is mentioned. It is also the first time I can find where specific life stages are identified. Per Rosenfeld and Hatfield (2006), for species with multiple life history stages, sufficient individuals need to recruit to each life history stage to meet the adult recovery target. When life history stages are dependent on different habitats, separate habitat–abundance relationships, stage-specific population targets, and critical habitat areas need to be defined to meet the adult population recovery target. So, Table 2 should be a critical component of the document and life stage timing and descriptions should be consistent with language through the rest of the document. If science has changed from 1994 to 2016, it seems appropriate to provide the science that supports that change. For instance, "Adults are never fully ripe and ready to spawn

before February…." First, this sentence is confusing and can be simplified. "Delta Smelt mature and can successfully spawn after January". Where is this information from? Suggest a citation column added to support these changes.

3.2.1.4 Primary Constituent Elements

Why are only spawning and adult habitat associations described in "Physical Habitat"?

Again, pelagic and open water as terms to describe the general location of delta smelt are inappropriate.

Turbidity- Turbidity is the measure of relative clarity of a liquid. It is an optical characteristic of water and is a measurement of the amount of light scattered by material in the water when a light is shined through the water sample. The higher the intensity of scattered light, the higher the turbidity. Material that causes water to be turbid include clay, silt, very tiny inorganic and organic matter, algae, dissolved colored organic compounds, and plankton and other microscopic organisms. Turbidity should be viewed as a measurement of what causes it. Again, the Lake Washington story provides an example of how complex this subject is. Within the BiOP (and many discussions of delta smelt), turbidity seems to be considered a habitat parameter, more so than the parameters that create turbidity or other conditions that tend to correlate with turbidity. For instance, lake turnover is typically a period of low water clarity and often corresponds with re-suspension of nutrients vital to the food web. Is it possible that relatively low turbidity may be an indication of reduced seasonal disturbance of the estuary that supports seasonal productivity? How might climate change affect this? Again, how might the PA influence this?

Page 38 – What do delta smelt eat by life stage?

Page 39 – River flow and smelt movement- are the mechanisms all the same? Delta smelt don't have well-formed swim bladders or fins until after ~15 mm TL. This suggest less controlled swimming abilities. See conceptual life cycle provided above.

Page 42 – What was the historic shape of the hydrograph (flow entry and exit) during each of the periods? What causes the turbidity? What was the seasonality of the estuary? How did the environmental conditions known to influence each delta smelt life stage respond to those conditions? How have these changed?

Figure 17 page 43. Entrainment proportional to what? Why the 42 and 66 cm Secchi?

Page 44. What is the value of explaining the delta smelt can survive at relatively high salinities if forced to? It appears that delta smelt move along a gradient and like other fish that utilize freshwater estuaries, especially anadromous fish, while they can tolerate a range of salinities at most life stages, there tends to be preferred levels for each life stage.

3.2.2 Summary of Status of Delta Smelt Critical Habitat

It seems appropriate that tis summary should be formatted following the life cycle of the delta smelt. This should be reflected in Table 3 as well. "seasonally" should also be defined by period for each life stage.

3.2.3 Effects of Delta Smelt from Operations of the CVP/SWP

Flow and subsequent environmental responses

Page 4 – what is "meaningful numbers"?

Terms such as "migration", "dispersal", and "transport" are vague.

Dispersal is the lengthening of the mean distance between neighboring individuals. Migration is a continued movement in a more or less definite direction, in which both movement and direction are under the control of the animal concerned (Schneider 1962). In many ecological studies, juveniles often disperse from high concentrations due to both controlled and uncontrolled movement. In contrast, migration is often considered intrapopulational, round-trip movements toward and away from breeding sites. If numerous breeding sites are available, this might give the impression of dispersing but, in fact, adults are moving to appropriate spawning grounds. Furthermore, if a portion of delta smelt move from fresh to saline to fresh water to complete the life cycle, wouldn't that constitute anadromy?

Page 6 Figure 2. The three regimes displayed in Figure 2 are not discussed anywhere else in the BiOP. If used, it is important to explain in background what they are and why they are meaningful. Why the term "muddy" for secchi =42cm? Is it assumed that substrate disturbance in causing turbidity? What are the red lines?

Table 2- What is difference between OMR Flow vs Index? The term 50% loss threshold is not defined in document.

Page 12 – The swimming ability of delta smelt changes with age/size. We can assume that delta smelt larvae are more susceptible to flow than juveniles and adults. Simonis and Merz (2018) found that juvenile delta smelt density was highly spatiotemporally autocorrelated and strongly tracked prey availability yet was also constrained by local hydrological factors (salinity, turbidity, velocity). They assumed this was partially explained by relatively poor swimming ability. Therefore, how well does particle tracking inform entrainment susceptibility for larvae compared to more developed lifestages?

Figure 7. Why not fit a line to the dots to demonstrate relationship between flow and particle entrainment?

3.2.3.1 Larval and Early Juvenile Entrainment

The modeling predicts (does not show) that conditions in June will be similar between PA and COS. From April through June, OMR flow shall be no more negative than 5,000cfs. What does "similar" mean? DO the models predict more, less or no difference in entrainment for each life stage?

3.2.3.2 Future Increases in Entrainment

Clarify what is meant by "supplementing a wild population that is more resilient to withstanding the effects of entrainment ".

The language surrounding hatchery completion and population supplementation is vague and suggests the schedule is later than the expected loss of population in wild. For instance, production increase goal date is 2025 but hatchery completion is 2030.

Don't understand "This interim measure will increase the likelihood that the population will be sustained in the wild…" How will hatchery do this?

3.2.3.3 Clifton Court Forebay Aquatic Weed Program

What is the purpose of weed control?

3.2.3.4 Delta Operations

Why are you not clearly laying present and PA flow conditions over delta smelt life cycle?

The water transfer information is written more as a professional opinion. What do the models say? Recognize, all monitoring in the delta now requires an estimate of take. Why does that not occur here?

3.2.3.5 Delta Smelt Summer-Fall Habitat

3.2.3.5.1 SMSCG Operation

It seems inappropriate that diversions are to be increased yet the gates will be operated 'experimentally". How do they propose they will work? Why is this proposed as adaptively operated? If the gate operation doesn't work, then outflow increased etc.

Pages 24-25 has 2 Figure 12's.

3.2.3.5.2 Non-Operational Actions

Hatchery – Language is somewhat ambiguous and suggests hatchery doesn't come on line until high extinction is predicted. States that no effect of FCCL is expected to delta smelt- what about gene pool? Also, why not build a delta smelt food hatchery? Supplement macroinverterbrate population?

3.2.3.5.3 Tidal Habitat Restoration

Reclamation is proposing to build the rest of the habitat. However, how is the habitat already built working? Is it providing food? Are delta smelt using it?

Predation Hotspot Removal

Agreed that predator hotspot removal effects on delta smelt is unknown. However, stating that "it is believed that" predation on smelt is driven by macroscopic drivers and therefore not likely to affect predation greatly follows the same logic. Neither is strongly supported.

4 References

4.1 Materials Provided Prior to the Review

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Bennett, W.A. 2005. Critical Assessment of the Delta smelt Population in the San Francisco Estuary, California. San Francisco Estuary and Watershed Science, 3(2). jmie_sfews_10969. Retrieved from: http://escholarship.org/uc/item/0725n5vk. Last accessed on 9 September 2015

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Zeug, S.C., Sellheim, K., Watry, C., Wikert, J.D. and Merz, J., 2014. Response of juvenile Chinook salmon to managed flow: lessons learned from a population at the southern extent of their range in North America. Fisheries management and ecology, 21(2), pp.155-168.

Independent Review of the Coordinated Long-Term Operation of the Central Valley Project and State Water Project

Prepared for:
National Marine Fisheries Service
U.S. Fish and Wildlife Service

By:
Ernst Peebles, Ph.D.
3017 Seventh Avenue North, St. Petersburg, FL 33713

Executive Summary

It is my opinion that the best available information was generally used in preparing the US Fish and Wildlife Services Biological Opinion (BiOp) on Delta Smelt, with certain exceptions. The BiOp is generally based on good information, although some specifics were missing.

The success of the PA appears promising, but will depend on presently unavailable information, notably (1) lack of more specific information on Delta Smelt spawning habitat, (2) knowing whether or not operational aspects of the PA, including food enhancement actions and SMSCG operations, will improve Delta Smelt critical habitat in a manner that is understood in a process-based manner, and (3) knowing whether efforts at future stock enhancement will work.

In many cases, the interpretation of critical habitat is commendably process-based rather than being simply correlative. In other cases, the Service sensibly refrained from assuming too much about future operational effects of the PA, as studies of these have only recently begun (Delta Smelt food enhancement actions) or have not begun (stock enhancement via hatchery-raised fish). In the BiOp's effects analyses, Delta Smelt salvage was presented as being numerically inconsequential (i.e., no real potential for improving Delta Smelt abundance).

In this review, I suggest that information presented by ICF (2017, Figures 52-94), rather than by the BiOp, may have influenced interpretation of the effectiveness of the Fall X2 action within the BiOp. These figures are based on prey-organism density (i.e., the number of individual prey organisms per unit volume or unit area) rather than total abundance of such organisms within the LSZ; the latter would be more informative.

Additional research attention needs to be directed toward processes that support Delta Smelt success in different habitat settings, particularly as these relate to prey access under the PA. Some of this can be approached using experiments with hatchery-reared Delta Smelt.

It is commendable that researchers have been engaging approaches suggested by Reed et al. (2012), developing hypotheses/predictions based on the conceptual model for Delta Smelt (MAST 2015) that can be applied to adaptive management and can contribute to new PAs, and also that vital rates and condition indicators are being used as performance measures.

At a time when Delta Smelt numbers are perilously low, ceasing supportive actions such as the Fall X2 adaptive management action may not be prudent, even if the conclusions presented by ICF (2017) seem to make a case that X2 has a questionable relationship with Delta Smelt stock-recruitment.

A number of recommendations are made in this review, including requests for more comprehensive information on the data types and analyses used in preparing the BiOp and clarification of the types

of data that will be considered by the Delta Coordination Team while evaluating the management of the SMSCG.

When investigating the pelagic organism decline, I also suggest that all energy pathways should be considered, not just plankton-based ones. Specifically, different forms of benthically based primary production should be evaluated in regard to Delta Smelt production.

TABLE OF CONTENTS

1 Introduction

1.1 Background

The Delta Smelt appears to be at a critically important crossroads regarding both its status and the development of scientific knowledge that affects its management as a federally listed, threatened species. Recent years have yielded an abundance of new insights into how the Delta Smelt uses habitat. As a result, the new Proposed Action (PA) for Delta Smelt management has become more adaptive and better informed.

1.2 General Observations

Many aspects of the PA, such as entrainment modeling, have evolved into more-or-less established routines over the years, whereas other aspects of the PA are based on the evaluation of ecosystem processes that are, in turn, based on newer information and insights. In general, I have found the quality of science that contributes to Delta Smelt management to be very high.

1.3 Review Activities

The review approach used here was to first read materials that influenced the US Fish and Wildlife Service's ("Service") most recent Biological Opinion (BiOp) on the US Bureau of Reclamation's ("Reclamation") revised PA for Delta Smelt, including Reclamation's Biological Assessment and the materials listed at the end of this document under "Materials Provided Prior to the Review." These readings were followed by reading the BiOp itself, including the two appendices listed under "Supplemental Materials Review." At the request of Anchor QEA, questions were developed from these readings that would later be asked of Service personnel during a conference call on April 19, 2019. The list of questions was submitted to Anchor QEA one day prior to the conference call for submission to Service personnel. The first part of the conference call involved introductions among the three reviewers (Ernst Peebles, Ronald Kneib, Joseph Merz) followed by a general discussion of the state of knowledge of Delta Smelt and some known processes that might affect its status. The most notable concern that I raised during the call involved the lack of knowledge about how benthic processes might affect Delta Smelt. The other two reviewers concurred with my concern, and I have elaborated on this topic within this review document. There were no substantive disagreements among the three reviewers during the conference call. The second part of the conference call entailed asking Service personnel our pre-prepared questions. I found their answers to be satisfactory and informative. After the conference call, we were given one week, as determined previously, to prepare our respective reports.

2 Responses to Questions

2.1 How well do the draft sections of the biological opinion for delta smelt use best available scientific and commercial information?

The general answer to this question is yes, the best available information was used, given exceptions that are discussed in Sections 2.1.1 and 2.1.2. Some important types of information are not available at present, including (1) lack of more specific information on Delta Smelt spawning habitat, (2) whether or not operational aspects of the PA, including food enhancement actions and SMSCG operations, will improve critical habitat in a manner that is understood in a process-based manner, and (3) whether efforts at future stock enhancements using hatchery-raised Delta Smelt will work.

2.1.1 Do the analyses in the status of the species and critical habitat, and environmental baseline sections reflect the best available scientific and commercial information?

There is considerable information available on the status of the Delta Smelt, its critical habitat, and the environmental baseline, and the BiOp makes good use of this information. The BiOp cannot make use of unavailable, yet important, information, notably the lack of more specific information on Delta Smelt spawning habitat (i.e., spawning-habitat characteristics and geographic locations). Likewise, the BiOp statement "*The degree to which movement of delta smelt around the LSZ is constrained by opening and closing the SMSCG is unknown*" identifies another important piece of information on critical habitat that is unavailable (p. 25, Draft Delta Smelt Effects Analysis). This latter type of information is important because the success of the PA, in part, hinges on beneficial aspects of SMSCG operations, yet these beneficial processes are not explicitly known. The BiOp is based on good information, but the success of the PA depends on important, yet unavailable, information.

In some cases, a single gear type, data type, or analysis is used to characterize information for which there are multiple gear types, data types, or analyses available (e.g., Figure 4, Draft Delta Smelt Status and Critical Habitat). It would be helpful if these other types of information could be acknowledged in the document as having been considered during BiOp development. Otherwise, the reader cannot determine the extent of the information considered.

The 2016 changes to the Delta Smelt critical habitat definition (Table 2, Draft Delta Smelt Status and Critical Habitat) were particularly useful for orientation purposes, and are appreciated. The evolution of guidelines within this table is evidence of clear progress.

The interpretation of critical habitat is commendably process-based rather than being simply correlative. Reduced prey availability is acknowledged as a likely cause of Delta Smelt decline, and it is also acknowledged that the Delta Smelt declines did not coincide with the overbite clam invasion

(one major Delta Smelt decline preceded the clam invasion and a second occurred 15 yrs after the invasion). The recognition that refuges from strong tidal flows are part of the Delta Smelt habitat definition is also important in a process-based sense, as strong tidal flows would tend to disperse the Delta Smelt's zooplankton prey. Likewise, process-based support for turbidity as a critical habitat element was offered in the suggestion that darkfield (caused by turbidity) is a better visual environment for Delta Smelt detection of transparent organisms (planktonic prey) than brightfield; this could be explored experimentally using hatchery-reared Delta Smelt. The Service already plans to use cultured fish enclosures to investigate the possibility that Delta Smelt use turbidity to hide from predators or to minimize competition. Turbidity in the LSZ is not simply characterized as a water-quality parameter, but is instead described as turbidity fronts that move with X2, where vertical haloclines exist in the water column. Regarding salinity, the critical habitat description observed "*This contrast between where most wild delta smelt are found and what laboratory research indicates they can easily tolerate suggests one of two things. Either there is a persistent laboratory artifact, or it may be evidence that delta smelt's distribution along the estuary salinity gradient is due to a factor or factors other than salinity per se.*" Given the history of habitat analysis in estuaries, the latter part of this suggestion is particularly progressive.

2.1.2 Are assumptions in the effects analysis clearly stated and reasonable based on current scientific thinking?

The entrainment portion of the effects analysis appears to be based on well-established methods, models, and associated assumptions. It is recognized that larger Delta Smelt can modulate their positions within the Delta rather than being incorrectly assumed to act as passive particles. Other aspects of the effects analysis, notably larval entrainment into the CVP and SWP canals and the absence of information on predation studies in the vicinity of Clifton Court Forebay, prevented assessment of any assumptions that would be associated with these analyses. Salvage was presented as being numerically inconsequential (i.e., no real potential for improving Delta Smelt abundance in the LSZ area), and was thus not examined closely. The Service sensibly refrained from assuming too much about future operational effects of the SMSCG and the food enhancement actions, as studies of these have only recently begun. The idea of stock enhancement via hatchery-raised fish has not been implemented, and so no assumptions were made about its effects, either. These approaches appear reasonable, given that the present lack of information will be addressed using an adaptive management approach, as suggested by Reed et al. (2012).

2.2 Do the draft sections of the biological opinion adequately analyze effects of the proposed action on delta smelt and critical habitat?

As mentioned in Section 2.1.2, some effects were not analyzed (i.e., certain types of entrainment and predation abatement), and several other aspects of the PA are either too new to be analyzed (i.e., food enhancement actions) or have not been tested at all (i.e., stock enhancement).

2.2.1 Did the Service adequately analyze effects for both standard/site-specific (described at a site-specific level with no future consultation required) and programmatic (which require future consultation before they can be implemented) components of the proposed action?

I am not an expert on the types of models that were used to estimate entrainment, and therefore will not evaluate those. I did appreciate that it was recognized that the larger stages of Delta Smelt are capable of modulating their upstream-downstream positions via selective tidal stream transport ("tidal surfing") and by taking advantage of winter storms during their dispersal period (i.e., they are not passive particles).

Lack of information on larval entrainment into the CVP and SWP canals appears to be a primary shortcoming of the effects analysis. Likewise, the absence of information on predation analyses in the vicinity of Clifton Court Forebay also prevented assessment (p. 16).

The significance of the salvage analysis was greatly diminished by the statement "*The salvage of delta smelt does not return meaningful numbers of delta smelt back into the Delta and current TFCF and Skinner Fish Facility protocols dictate that delta smelt that are subsampled for fish counts are euthanized and retained in order to determine gender and sexual maturation of each individual*" (p. 18).

All of the relevant Delta operations appear to have been carefully treated, yet from the perspective of Delta Smelt, the PA has particular emphasis on SMSCG operation. However, the fundamental processes that influence Delta Smelt interaction with Suisun Marsh (such as movement, feeding, predator avoidance) are poorly understood at present, and thus a realistic effects assessment of this part of the PA cannot be made (this problem is discussed in more detail at the end of Section 2.2.2). Given this lack of information, it appears that management of the SMSCG will be monitored, and possibly modified, on an annual basis by a Delta Coordination Team. Additional detail on this adaptive management process, including the types of data that will be considered by the team, is needed.

There is a similar lack of information of the various food enhancement actions (Suisun Marsh, Ship Channel, Colusa Basin) that prevents assessment of the associated effects, and this is acknowledged in the document (p. 26). It is not clear how these will be adaptively managed.

In regard to introduction of cultured Delta Smelt into the Delta, the assessment takes a progressive approach in its ambition to preserve the existing genetic diversity of Delta Smelt. Field tests of the predation competence of released fish are also both planned and warranted.

2.2.2 Are the methods utilized appropriate to determine if the proposed action is likely to jeopardize delta smelt or adversely modify its critical habitat?

Under most considerations, the answer to this question is yes. An exception is data presented by ICF (2017, Figures 52-94) rather than by the BiOp, which may have influenced interpretation of the effectiveness of the Fall X2 action within the BiOp. Those figures generally show little or no responsiveness between X2 and the densities of several Delta Smelt prey types (copepods, mysids, and amphipods). The problem is density (i.e., the number of individual organisms per unit volume or unit area) does not completely represent the abundance of prey within the LSZ. Prey abundance within the LSZ would be better portrayed as the product of density and the size of the LSZ, with the size of the LSZ represented as volume (copepods, mysids) or possibly area (amphipods). Because the size of the LSZ increases dramatically as X2 moves downstream, the effect of Fall X2 (and other X2-based actions) on prey abundance in Delta Smelt critical habitat is likely to be much larger than what is suggested by these figures.

The above consideration is analogous to the concept of nitrogen loading in estuaries, as chemical concentrations and organism densities are analogous units of measure. In its simplest form, nitrogen loading is the product of nitrogen concentration and freshwater-inflow volume. This simple calculation can expose counterintuitive results, such as cases where large volumes of low-concentration nitrogen result in larger loadings than small volumes of high-concentration nitrogen. Likewise, large volumes of low-density copepods may contain more total copepod prey than small volumes of high-density copepods.

Mysids and amphipods are recognized as being prey types used by Delta Smelt (Slater and Baxter 2014, Hammock et al. 2017), yet both mysids and amphipods are benthically associated (i.e., bottom-associated). The role of water management on different forms of benthic primary production appears to have been largely overlooked by studies of the general ecology of the LSZ. Some forms of benthic primary production are imported to estuarine sediments or to the sediment-water interface, rather than being produced there. These include phytodetritus (i.e., phytoplankton cells that have sunk to the bottom and are decomposing there), vascular wetland detritus (i.e., decomposing marsh-grass litter), and allochthonous (imported) vascular plant detritus from the watershed (i.e., decomposing agricultural and riparian plant litter). Other forms of benthic primary production are more truly benthic in origin, such as benthic diatoms, benthic macroalgae, and rooted aquatic vegetation, inclusive of exotics. The idea that benthic diatoms are limited to the intertidal zone needs to be abandoned, particularly as decreasing turbidity in the LSZ (Figure 14, lower left panel, Draft Delta Smelt Status and Critical Habitat) has improved the light environment for benthic primary producers. Benthic diatoms can be the dominant

primary producers in shallow waters, or even in waters >100 m depth on the continental shelf (Cahoon et al. 1990). Any or all of the above forms of benthic primary production can be important within the energy pathways that support individual species at higher trophic positions such as Delta Smelt, although typically one or a few are more important than others.

The significance of benthic production is that even classically pelagic species such as Delta Smelt can be dependent on benthic energy pathways at least part of the time (Rooney at al. 2006), which is reflected in the occasional presence of mysids and amphipods in the Delta Smelt's diet (Slater and Baxter 2014, Hammock et al. 2017), with amphipods, in particular, being strongly associated with benthic primary productivity of one form or another. Although the routine energy pathways that support pelagic species such as Delta Smelt may be primarily plankton-based, plankton production is closely linked to freshwater inflow patterns and is thus sporadic and unreliable over time. During times when plankton production is low, pelagic fishes such as Delta Smelt may be supported by benthic energy pathways (Slater and Baxter 2014), and this possibility makes such pathways potentially critical to their survival (Vander Zanden and Vadeboncoeur 2002, Rooney et al. 2006, Higgins and Vander Zanden 2010). Benthic prey such as mysids and amphipods are typically physically larger than planktonic prey species such as copepods, and both this larger body size and the more stable nature of their own benthic primary-producer food base (i.e., their basal resource) tend to allow their abundances to be more stable over time, making them more available as a food resource at times when plankton-based prey are less available (Rooney et al. 2006).

An organism's dependence on benthic prey can be somewhat cryptic, wherein trophic intermediates mask the benthic dependence. For example, individual Blackfin Tuna (another classically pelagic species) may have isotopic signatures that suggest substantial dependence on benthic energy pathways, yet this species is known to primarily feed in the water column rather than at the bottom. Diet analyses have revealed that squids are an important diet item for Blackfin Tuna, and squids prey heavily on benthic shrimps and crabs, therein establishing the connection between Blackfin Tuna and benthic energy pathways. The Delta Smelt, on the other hand, has direct evidence of occasional dependence on benthic energy pathways in the form of direct consumption of benthically associated mysids and amphipods (Hammock et al. 2015). When investigating the pelagic organism decline (e.g., Figure 4, Draft Delta Smelt Status and Critical Habitat), all energy pathways should be considered, not just plankton-based ones.

Another observation that supports investigation of periodic benthic dependence by Delta Smelt is the fact that the calanoid copepod genus *Pseudodiaptomus* is generally considered to be demersal (i.e., bottom oriented). *Psuedodiaptomus forbesi* is an exotic calanoid copepod from Asia that has replaced a large part of the biomass of the native calanoid copepod *Eurytemora affinis* within the LSZ (Draft Delta Smelt Status and Critical Habitat). Thus, the Delta Smelt has had one of its more important planktonic prey items replaced by a more bottom-oriented one. What effect has this change had on Delta Smelt feeding?

While most species of fish appear to be dependent on a combination of plankton-based and benthos-based energy pathways (Higgins and Vander Zanden 2010, Zeug et al. 2017), there is

variability among individual species regarding their capacity for adaptive trophic behaviors that help them cope with changing energy pathways and available prey types (Valdovinos et al. 2010; see also Figure 2, Vander Zanden and Vadeboncoeur 2002). Higgins and Vander Zanden (2010) stated *"…the inability of some fish species (e.g., obligate planktivores or deepwater benthic fish) to fully utilize benthic–littoral energy pathways may result in declines in individual body condition, reproduction, and recruitment …"*. In this statement, "benthic-littoral energy pathways" acknowledges the tendency for shoreline (littoral) prey communities, particularly along shorelines that are made structurally complex by emergent, submerged, or floating shoreline vegetation, to resemble benthic prey communities.

In the PA, attention is being directed to prey production in the North Delta Habitat Arc (Cache Slough Complex through Suisun Marsh) where Delta Smelt have been most persistently observed. The 2016 floodplain fish food augmentation effort (ICF 2017) appears to have successfully increased fish food availability in the Sacramento River, notably as the result of rice farmers retaining and releasing water and by flushing other quiescent areas such as the Ship Channel into Delta Smelt habitat.

It is commendable that researchers have been engaging approaches suggested by Reed et al. (2012), developing hypotheses/predictions based on the conceptual model for Delta Smelt (MAST 2015) that can be applied to adaptive management and can contribute to new PAs, and also that vital rates and condition indicators are being used as performance measures (p. 25, Draft Delta Smelt Effects Analysis, Hammock et al. 2015, Sommer and Conrad 2018, Sommer et al. 2019). For example, Hammock et al. (2015) found Delta Smelt within Suisun Marsh to have relatively high stomach fullness and relatively low incidence of histopathological lesions than Delta Smelt from other areas associated with the LSZ. This is interesting because Suisun Marsh has a large ratio of shoreline length to open water area, and this physiographic condition tends to favor benthic-littoral energy pathways, as discussed above (see Figure 2, Vander Zanden and Vadeboncoeur 2002).

Ultimately, however, the "*degree to which movement of delta smelt around the LSZ is constrained by opening and closing the SMSCG is unknown*" (p. 25, Draft Delta Smelt Effects Analysis), as is whether the Delta Smelt is capable of exploiting benthic-littoral energy pathways, as suggested by Slater and Baxter (2014), in a manner that improves vital rates or body condition. The latter issue could be addressed using experiments with hatchery-reared Delta Smelt. In general, additional research attention needs to be directed toward processes that support Delta Smelt success in different habitat settings, particularly as these relate to prey access under the PA. For example, was the Delta Smelt response in Suisun Marsh (Sommer and Conrad 2018, Sommer et al. 2019) due to active habitat selection (i.e., for lower salinity, higher turbidity, suitable temperatures, quiescent waters) via swimming, advection of Delta Smelt into a larger area of habitat, better in situ survival due to increased productivity (higher chlorophyll a concentrations in Suisun Marsh) and associated prey availability, or a combination of these processes?

At a time when Delta Smelt numbers are perilously low, ceasing supportive actions such as the Fall X2 adaptive management action may not be prudent, even if the conclusions presented by ICF (2017) seem to make a case that X2 has a questionable relationship with Delta Smelt stock-recruitment (however, see the first paragraph of this section as it relates to ICF's third conclusion). X2 does appear to interact with turbidity at some locations (ICF 2017). In regard to the high river flows of 2011, implementation of the Fall X2 action was coincident with successful Delta Smelt recruitment, leading to the highest Delta Smelt abundances observed in many years.

3 Additional Thoughts, Concerns, and Suggestions for Improvements to the Analyses

The introduction of slow-moving water from the Ship Channel and flooded rice fields has the potential to introduce copepods as well as phytoplankton into the LSZ. Achieving this objective (i.e., introducing copepods instead of just phytoplankton) would depend on the length of time that the fields remained flooded relative to the subitaneous generation times of the copepods; copepod generation times are temperature dependent.

Hatchery-raised Delta Smelt could be used to compare the condition of fish fed copepods vs. those fed mysids or amphipods. Because mysids and amphipods are larger than copepods, younger Delta Smelt are likely to be gape-limited and older ones may experience long handling times while consuming such prey. Feeding experiments could determine the extent of these potential restrictions. It is likely that these larger prey types will only be relevant to Delta Smelt during times of year when the fish are larger.

4 Conclusions and Recommendations

In some cases, a single gear type, data type, or analysis is used to characterize information for which there are multiple gear types, data types, or analyses available (e.g., Figure 4, Draft Delta Smelt Status and Critical Habitat). It would be helpful if these other types of information could be acknowledged in the BiOp as having been considered during its development. Otherwise, the reader cannot determine the extent of the information considered.

It appears that management of the SMSCG will be monitored, and possibly modified, on an annual basis by a Delta Coordination Team. Additional detail on this process, including the types of data that will be considered by the team, needs to be presented. A similar request can be made for the food enhancement actions in Cache Slough, the Ship Channel, and the Colusa area.

Prey abundance within the LSZ, as characterized by ICF (2017), rather than the BiOp, would be better portrayed as the product of density and the size of the LSZ, with the size of the LSZ represented as volume (copepods, mysids) or possibly area (amphipods).

When investigating the pelagic organism decline (e.g., Figure 4, Draft Delta Smelt Status and Critical Habitat), all energy pathways should be considered, not just plankton-based ones. Specifically, different forms of benthically based primary production should be evaluated in regard to Delta Smelt production.

It is commendable that researchers have been engaging approaches suggested by Reed et al. (2012), developing hypotheses/predictions based on the conceptual model for Delta Smelt (MAST 2015) that can be applied to adaptive management and can contribute to new PAs, and also that vital rates and condition indicators are being used as performance measures.

At a time when Delta Smelt numbers are perilously low, ceasing supportive actions such as the Fall X2 adaptive management action may not be prudent, even if the conclusions presented by ICF (2017) seem to make a case that X2 has a questionable relationship with Delta Smelt stock-recruitment.

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Independent Review of the Coordinated Long-Term Operation of the Central Valley Project and State Water Project

Prepared for:
National Marine Fisheries Service
U.S. Fish and Wildlife Service

By:
Michael A. Chotkowski, Ph.D.
U.S. Geological Survey, Southwest Region
6000 J Street, Placer Hall
Sacramento, CA 95819

Executive Summary

This report summarizes my review of the Delta Smelt portion of the draft Biological Opinion (BiOp) for the Reinitiation of Consultation on the Coordinated Operations of the Central Valley Project and State Water Project.

In my opinion, the US Fish and Wildlife Service generally gathered together and reasonably analyzed the best available information regarding Delta Smelt and the likely effects of this project on the species and its critical habitat. I focused exclusively on big-picture issues in this review. I have a few comments and concerns. In short:

(1) Despite years of study, Delta Smelt remain imperfectly understood and even more imperfectly monitored, so the available information does not lend itself to clear answers in some cases, leaving conclusions regarding the effects of the proposed action a matter of professional judgment.

(2) The definition of critical habitat for this species remains confusing and unhelpful. That said, the BiOp's treatment of habitat provided a work-around that was generally clear and well-motivated.

(3) The Summer-Fall Habitat action in the Proposed Action is not very well explained, and because the action is small and the implementation approach appears ad hoc, I suspect that even if it reliably produces a beneficial response, the response will not be measurable during the term the consultation is intended to cover.

(4) Reduction of the uncertainties associated with flow and habitat management for this species will require rigor and resources; the proposed approach may need to be refined to achieve this.

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1 Introduction

1.1 Background

This review addresses the Delta Smelt portion of a draft Biological Opinion being prepared by the U.S. Fish and Wildlife Service to cover the Coordinated Long-Term Operation of the Central Valley Project and State Water Project in the State of California. The U.S. Bureau of Reclamation, which operates the Central Valley Project, has proposed that the term of this consultation extend to 2030, meaning that the consultation is intended to cover CVP/SWP water operations for about a decade.

I was provided an excerpt of the draft BiOp that includes the basic elements of the Opinion and sections specific to Delta Smelt. As well, the three questions posed in the template this report was written into are Delta Smelt questions. As such, the review pertains only to Delta Smelt and the general science challenges posed by the consultation.

This review was written in the context of a second round of review. As the materials provided to me make clear, the first round of review occurred in April of 2019. I did not participate in that review. As I understand it, both the draft BiOp and Proposed Action have been modified since April in response to the first review and other developments. I have been provided copies of the first-round reviews, but all of my comments pertain to the presumably updated versions of the BiOp and supplemental materials that I was provided on July 31st.

Because of the amount of material and limited amount of time available for this review (approx. July 31st to August 12th, 2019), I have focused on looking for big issues in the use of scientific information that should, in my opinion, be given further attention before the analysis is relied upon to make the determinations (at least with respect to Delta Smelt) and other decisions that are needed to finalize the consultation.

1.2 General Observations

1. The PA appears to be an incremental update of CVP/SWP operations that have been highly optimized over many years, as well as some voluntary actions intended to achieve conservation benefits to Delta Smelt. Apart from some new modeling elements, the analytical approaches the Service has used are generally not new.

2. Delta Smelt is an Osmerid endemic to the Sacramento-San Joaquin Estuary. It has been fairly intensively studied in the decades since its listing (as Threatened) under the Endangered Species Act in 1993, because of its potential to disrupt export operations at the Jones (CVP) and Banks (SWP) facilities in the South Delta. Despite the attention, aspects of Delta Smelt natural history and ecology are still not well-known. The fish are hard to observe in the field, and probably were even before

their post-1980 decline in abundance drew widespread attention. They generally occur in the water column and prefer turbid water. As far as I know, there has never been a direct observation of Delta Smelt spawning in the wild. Where, specifically, they spawn in any given year is known only indirectly and often after the fact. As well, other details as basic as the chronic upper temperature tolerance of the species, which has been known from laboratory studies for quite a while, have been revisited within the last decade based on data obtained during routine monitoring in the field. The long-term monitoring programs that have been used to track and study Delta Smelt present problems of their own that hamper penetrating analysis.

The consequence of all this is that despite years of study it is hard to pin down to a high degree of confidence how various factors affect the abundance of Delta Smelt, and hard to predict or measure the effects of management actions. As we see in this BiOp, the result is that a good deal of the analysis necessarily concludes with judgment calls.

4. The PA includes a variety of actions that entail collection and application of scientific information, including various real-time management actions in the Delta, seasonal through-Delta flow and/or X2 actions, and some forward-looking actions intended at least in part to address learning objectives (Table 2-1 summarizes). To effectively implement the adaptive management approach and facilitate identifying actions that do not work as expected will require real commitment by both the project and regulatory agencies.

1.3 Review Activities

1. I received a package of documents on approx.. July 31, 2019 that included the draft BiOp, related materials, the earlier reviews, and a report template.

2. I requested and received a copy of the following in-press article mentioned in the draft BiOp:

Polansky, L., L. Mitchell, and K. B. Newman. 2019. In press. Using multistage design-based methods to construct abundance indices and uncertainty measures for Delta Smelt. Trans-actions of the American Fisheries Society.

3. There was a conference call, arranged by the review facilitators, on August 7th 2019. It was attended by the facilitators, the four reviewers, and a number of Fish and Wildlife, Reclamation, and Department of the Interior parties. The call gave the reviewers an opportunity to ask questions pertaining to the review and documents. I asked the following three questions (lightly edited quote from an email):

"(1) The three state-space models introduced on pp 75 ff. The multiple life stage model does not incorporate a change point in the time series, but one of the two annual step models does. It's

2009. A bit more explanation why '09 was chosen would help me to understand this section better, as would an explanation why the ca. 2002 change point hypothesized in the POD investigation wasn't tried.

(2) Effects of ACOE maintenance dredging in the legal Delta aren't mentioned in the X2 analysis in the baseline that I could find, though such dredging is included in the baseline. Have there been analyses that quantify an X2 effect (or dismiss it) with respect to maintenance dredging in the western Delta?

(3) Summer-Fall habitat actions in the PA. I read the relevant sections in effects on habitat and effects on recovery pretty carefully, but I did not glean a clear idea of how the potential effects of these actions were assessed, or how the X2 milestones in the PA were sized. I'd like to know more about what the Service has drawn from the (substantial) conflicting literature on this subject. Pointers to the text would be fine; I may have missed something important..."

2 Responses to Questions

2.1 Question 1: How well does the BiOp use best available scientific and commercial information? Specifically:

Generally reasonably well. I struggled a bit with the way the the critical habitat analyses were framed. As noted below, I think some important questions, particularly with respect to the effects of habitat enhancement by flow or X2 management, and likely food enhancement as well, are probably unanswerable with the information that is available at present. Notes below.

2.1.1 Do the analyses in the status of the species and critical habitat, and environmental baseline sections reflect the best available scientific and commercial information?

The environmental baseline covers the relevant literature and seems solid. The baseline benefits greatly from new publications that were unavailable in 2008, including Whipple et al. (2012), which describes the early drain-and-dike era (1850 through mid-20th century) very well, and updated life history conceptual models, including Moyle et al. (2016). The critical habitat analysis seems reasonable and is easy to understand when considered independently of the Service's 1994 critical habitat designation. The latter is confusing, particularly in its description of important habitat qualities, which the Service terms "primary constituent elements." This draft provides a reasonable work-around to the 1994 rule and a useful table (Table 5-1) to compare the 1994 primary constituent elements to habitat features that appear relevant based on work done since 1994.

2.1.2 Are assumptions in the effects analysis clearly stated and reasonable based on current scientific thinking?

Generally, yes. The Service seems to have used the available information to frame its assumptions reasonably. That said, I strongly recommend that the effects portions of the document be policed for careless or imprecise language. I found a number of instances of muddy writing that obscure what appear to be reasonable analyses. For example, the entrainment analysis in Section 5.2.1 discusses the evolving role of measured salvage. The last paragraph on p. 118 describes the declining value of measured salvage as a gauge of entrainment, but uses the word "indicator" in a couple of sentences where "gauge" or or "index" would have been more appropriate. Clearly, if Delta Smelt are salvaged, it indicates that some level of entrainment is occurring; the point that is being developed is that declining abundances make salvage less useful as an index of entrainment. I think the bottom-line here is reasonable, but it is important to be clear how measures of salvage were previously used to gauge entrainment. There are other, similar examples of imprecise language elsewhere that should also be addressed.

2.1.3 Are there alternative interpretations of the best available scientific information with respect to species status, critical habitat, and effects of the proposed action that are equally well supported by the data (i.e., scientific information, analyses) that were not presented in the biological opinion that merit consideration.

Generally, I think the analyses presented cover the most reasonable interpretations of the available data. I think the summer/fall habitat actions analysis should more strongly underline the uncertainty of these actions, as the evidence bearing on their effectiveness is mixed. See comments below.

2.2 Question 2: Does the BiOp adequately analyze effects of the proposed action on delta smelt and critical habitat?

Generally, they seem adequate. Unfortunately, though extensive, present knowledge does not provide clear answers to some of the questions being addressed.

2.2.1 Did the Service adequately analyze effects for both standard/site-specific (described at a site-specific level with no future consultation required) and programmatic (which require future consultation before they can be implemented) components of the proposed action?

The analysis of effects of the "core" elements of the PA that affect Delta Smelt and are being consulted on at the project level generally seems adequate. Ignoring the 3406(b)(13) actions and other programmatic salmonid actions, I think the present analysis adequately documents the historical food web and habitat changes to lay a foundation for project level consultations associated with the various food studies and the Delta Smelt habitat restoration element of the PA that will come later.

2.2.2 Are the methods utilized appropriate to determine if the proposed action is likely to jeopardize delta smelt or adversely modify its critical habitat?

I believe the draft BiOp has drawn together the relevant information and has reasonably analyzed it to prepare for these decisions with respect to Delta Smelt. That said, the decisions will still be challenging judgment calls. The effects of the PA are being evaluated on top of an ongoing long-term decline that water operations, other physical habitat changes, exotic species invasions, food web changes, and possibly other factors have all contributed to. There is little basis, at present, to quantitatively forecast differences in outcome (for Delta Smelt) between existing CVP/SWP operations and those in the PA, and the effects analysis here appropriately does not attempt it. Developing reliable quantitative forecasts should, however, be a focus of attention going forward.

2.3 Question 3: How well does the BiOp incorporate new actions added to the Proposed Action by Reclamation, particularly the Delta Smelt Summer-Fall Habitat action?

The Summer-Fall habitat action is a bit perplexing. While it probably won't do any harm and might do some good, the operating criteria for this action (Table 2-1, p. 45) look like small tweaks to recent historical summer-fall operations. Even assuming benefits reliably accrue as desired, the action seems too small to produce a measurable response, especially one large enough to be detected during the limited term of this consultation (i.e. by 2030). The effects analysis does not really break down why this action is framed as it is, or why a measurable response might be expected.

If the parties to this consultation conclude that they would like to resolve the question whether flow/X2 actions are effective, and, if effective, how the action parameters affect the response, they should consider a more rigorous approach than the annual collaborative planning process described in the PA. I recommend Denise Reed's "Science Plan to Assess the Effects of Ambient Environmental Conditions and Flow-Related Management Actions on Delta Smelt", which appears to have been prepared at the invitation of the Collaborative Science and Adaptive Management Program (Reed 2019; file sent with this report). The overall approach is based on an explicit

predict →detect→understand

paradigm, with the predict phase based on individual-based or integrated environmental modeling that is quantitative, spatially explicit, and designed to capture the critical processes. I recommend this plan as a basis to build a program of evaluation that more explicitly targets learning as part of the action, so learning occurs in tandem with habitat measures that are implemented as part of ongoing water operations.

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Independent Review of the Coordinated Long-Term Operation of the Central Valley Project and State Water Project

Prepared for:
National Marine Fisheries Service
U.S. Fish and Wildlife Service

By:
Ronald T. Kneib, Ph.D.
10 Taza Trail, Hillsboro, NM 88042-9536

Executive Summary

The upper San Francisco Bay Estuary, including the Sacramento-San Joaquin River Delta, is the only known habitat of wild Delta Smelt. Over the past century there have been substantial anthropogenic alterations of the system, including a highly engineered system designed to store and distribute freshwater resources for human uses. In recent decades substantial declines in the abundance of native fishes have been observed and underlying causes remain a matter of scientific debate. Once abundant in the estuary, Delta Smelt is among the species listed under the Endangered Species Act as threatened and is routinely nominated as a candidate for endangered status. However, change in status has been precluded by species given higher priority, even though there is a scientific consensus that Delta Smelt is on an accelerating path toward extinction in the wild.

The U.S. Fish and Wildlife Service Biological Opinion (BiOp) effects analysis of the Proposed Action associated with the Reinitiation of Consultation on the Coordinated Long-Term Operation of the Central Valley Project and State Water Project is intended to evaluate potential impacts on Delta Smelt and their critical habitat for a mixture of standard site-specific and programmatic action elements The analyses are based largely on information derived from recent research and modeling efforts conducted primarily by cohorts of creative and talented individuals at universities, state and federal agencies and private institutions with a keen interest in the San Francisco Bay Estuary and associated watersheds. Substantial strides in research have been made in recent years, especially with respect to estimates of abundance, quantifying uncertainty associated with those estimates and modeling population dynamics. For the most part, this is the best available scientific information.

While the BiOp incorporates these new advances, the process by which effects analyses were conducted was not entirely clear, particularly in regard to reaching conclusions, which were deliberately omitted from the draft BiOp provided for review. It appears that the process is largely qualitative with portions based on available data and modeling. It is always possible that different individuals or teams could reach alternative interpretations of the same information depending on the suite of assumptions they accept.

Researchers have produced a diversity of perspectives, ideas and hypotheses regarding the underlying causes of the decline of native species, including Delta Smelt. However, experimental studies to test these ideas, in a rigorous manner and with minimal assumptions, are often expensive and time-consuming. So a variety of conceptual and numerical models have been developed to guide future research and to make predictions based on suites of assumptions that may ultimately be flawed. Nonetheless, predictions from these models are used in the effects analyses to make determinations about the risk of jeopardy to Delta Smelt and their critical habitat. It is often acknowledged that a high degree of uncertainty is associated with such findings but they are presented in the BiOp as the best available information. Also, there continue to be substantial gaps

in key pieces of information related to the critical habitat of Delta Smelt (e.g., spawning substrates), which contributes uncertainty to the effects analyses.

Two observations stand out in the current BiOp: (1) Delta Smelt abundance is the lowest ever observed and is expected to continue to decline, and (2) the Proposed Action includes an annual increase in water exports from the ecosystem. Interestingly, these two points were made by the USFWS 2008 Delta Smelt BiOp, except that Delta Smelt was many times more abundant then than today.

Consideration of avoiding ecological thresholds, sometimes referred to as tipping points, is a potentially serious omission in the BiOp's effects analyses. Small changes in environmental conditions, particularly in connection with cumulative effects, can produce abrupt and unexpected changes in ecosystems and/or their components. This review strongly recommends a consideration of ecological thresholds in future analyses of potential effects of actions on Delta Smelt and their critical habitat.

There seems to be an apparent shift in focus away from effects of water operations as a direct or indirect risk of jeopardy to Delta Smelt and toward a growing number of "non-operational" potential risk factors or stressors. Dealing with an increasing number of moving parts increases the risk of management decisions having negative effects on listed species in the Delta.

The successful hatchery-rearing of Delta Smelt for use in research and possible supplementation of the wild population has provided research opportunities that have yet to be fully exploited for the purpose of filling important knowledge gaps that would aid in future effects analyses. A plan to expand the capacity for hatchery rearing of Delta Smelt is intended to supplement the wild population. However, if the critical habitat of Delta Smelt continues to be degraded, it is difficult to imagine that hatchery-based augmentation efforts could succeed in stemming the species' trajectory toward extinction.

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APPENDICES

1 Introduction

1.1 Background

A highly engineered system for the storage and conveyance of water in the Central Valley of California was developed over the past 85 years or more by federal and state agencies. The complex system was designed to regulate the temporal and spatial distribution of water resources for a variety of human uses including agriculture, flood control, municipal water supplies, power generation, etc. The allocation of water in the system is based on a variety of legal agreements and water rights that attempt to accommodate a diverse set of user needs. The development of this complex engineered and legal structure did not originally account for the support of natural aquatic resources, including native fishes such as anadromous salmon, sturgeon and Delta Smelt *Hypomesus transpacificus*, which is the subject of this review.

There is little scientific dispute regarding the aggregate and cumulative effects of anthropogenic alterations in the watersheds of the San Francisco Bay Estuary on native aquatic organisms over the past century. Aquatic habitat suitable for the growth, survival and reproduction of many species, particularly Delta Smelt, has been compressed in spatial extent and quality to the point that a clear path to extinction has become evident.

The passage of the Endangered Species Act (ESA) by the U.S. Congress in 1973 formally recognized the need to protect and recover imperiled species and the ecosystems on which they depend.

Section 7(a)(2) of the ESA requires that any action taken, funded or authorized by Federal agencies is not likely to jeopardize the continued existence of a listed species. This includes anything that would appreciably reduce the likelihood of the survival or recovery of a listed species in the wild by reducing the reproduction, numbers or distribution of that species.

Section 7(a)(2) also requires that Federal agencies are not involved in anything that directly or indirectly diminishes the value of critical habitat for protected species.

In April 2019, the U.S. Fish & Wildlife Service (USFWS) requested an independent peer review of their draft Delta Smelt effects analysis in connection with a Reinitiation of Consultation (ROC) regarding Proposed Actions (PA) involving the Coordinated Long-Term Operation of the Central Valley Project and State Water Project in the San Francisco Bay-Delta System. The BiOp has since been revised and the current review (August 2019) now considers the revised BiOp. This following report should be considered an overview rather than a detailed comprehensive review of the BiOp or the validity of the underlying information used in the analysis of effects on Delta Smelt or their habitat. The reason for this notation is that less than two weeks were provided to review, consider and comment on over 4,400 pages of information, including the BiOp and supplemental information.

Delta Smelt is currently listed as threatened under the ESA. This means it is likely to become endangered in the foreseeable future. The USFWS has repeatedly submitted Delta Smelt as a candidate for endangered status but it has been precluded by listings of other species with higher priority. Under the ESA, endangered means "a species is in danger of extinction throughout all or a significant portion of its range." The range of Delta Smelt is limited to lower salinity portions of the San Francisco Bay Estuary, with the population centered in the Sacramento-San Joaquin delta in the Central Valley of California. Delta Smelt occupy a limited niche at the southernmost range of inland smelt species and are unlikely capable of establishing a viable population south of their current location along the U.S. Pacific Coast. Furthermore, if current climate change predictions are correct, it seems likely that environmental conditions will become unsuitable to support the extant wild population of Delta Smelt in the foreseeable future.

1.2 General Observations

The Biological Assessment (BA) submitted by Reclamation to the USFWS in January 2019 and revised in July 2019 seems to emphasize opportunities to maximize water supply delivery by minimizing constraints on operations and emphasizing actions other than long-term water operations (LTO) of the CVP and SWP as a way of avoiding significant adverse effects on Delta Smelt.

The October 19, 2018 Presidential Memorandum on promoting the reliable supply and delivery of water in the West directed the Secretaries of the Interior and Commerce to streamline regulatory processes involving western water infrastructure (cited in the BiOp's Consultation History section), seems to suggest the existence of federal political pressure favoring water operations over the preservation of endangered species. Within this context, it appears that USFWS historically has been very accommodating to requests from Reclamation to relax restrictions on water operations intended to avoid negative effects on Delta Smelt.

The USFWS understands that current information demonstrates "the increasingly imperiled state of Delta Smelt and its designated critical habitat". Furthermore, "emerging science shows the importance of outflows to all life stages of Delta Smelt and to maintaining the primary constituent elements of designated critical habitat". Nonetheless, the PA seems to shift responsibility for adverse effects on Delta Smelt away from water operations and places the focus on "nonoperational factors". This seems to propagate the public impression that environmental regulations on water operations have been unnecessarily limiting water diversions, particularly for apparently ineffective protections of threatened and endangered species such as Delta Smelt. However, while constraints on water operations to protect Delta Smelt have been relatively modest during Water Years 2011-2018 (see

Table 6 in Reis et al. 2019) outflows to San Francisco Bay during the critical winter-spring period have been declining over the past several decades to the point where the aquatic inhabitants of the estuary may be experiencing drought conditions in most years (Reis et al. 2009).

Food limitation has emerged as a focus of interest in constraining the growth and survival of Delta Smelt in most life stages but, even if true, the underlying cause(s) of limited food supply are not disconnected from water operations. A recent analysis of temporal changes in chlorophyll a and zooplankton in the San Francisco Estuary during the period 1969-2014 showed that nearly all of the observed declines in pelagic primary productivity could be related to invasion of the clam *Potamocorbula amurensis* and water exports from the state and federal pumping facilities. While there appears to be a current general scientific consensus that limited pelagic food resources and/or temporal shifts in normal seasonal patterns of food availability (e.g., Merz et al. 2016) may be jeopardizing the survival and recovery of Delta Smelt, the role of water exports has not been eliminated as an underlying driver in the process.

The USFWS effects analysis relies on four interrelated components: (1) Status of the species, (2) the Environmental Baseline, which is the current condition and factors responsible for that condition, (3) the Effects of the Action, and (4) Cumulative Effects, which evaluates the effects of FUTURE NON-FEDERAL activities in the action area. These same categories are applied in the consideration of effects on both Delta Smelt and its critical habitat. This sometimes seems redundant because effects on critical habitat are also effects on Delta Smelt.

A key to understanding how USFWS evaluates the risk of jeopardy to Delta Smelt is found in the functional definition of Environmental Baseline which includes "all the past and present impacts of all Federal, State and private actions and other human activities in the Action Area". The purpose is to describe the condition of the listed species and its critical habitat in the absence of the PA subject to a current consultation. In essence, this means that the Environmental Baseline is reset prior to each consultation. It is not entirely clear to this reviewer how previous actions known to have likely caused negative effects to a species or its critical habitat are fully considered in the Environmental Baseline. Any evidence that could be generated to show continued or additional effects of a PA would be unavailable until sometime after the action was undertaken. This has implications for how "cumulative effects" are defined and analyzed.

Cumulative effects usually require a time component (i.e., the history of effects) such as sequential exposure to a stressor. For example, an action that results in the loss of 10% of a population may not have a long-term negative effect as an isolated event as long as reproduction can result in the recovery of those losses within a certain time frame. However, a series of impacts from the same action with each occurrence resulting in the loss of 10% of the population before the population has sufficient time to rebound is a cumulative effect. In the BiOp, cumulative effects appear to be defined as aggregate, additive or multiplicative effects that occur simultaneously and not necessarily

in a sequence. How the Environmental Baseline accounts for these different types of "cumulative effects" seems unclear.

Many elements of the PA (e.g., food enhancements, habitat restoration) have unknown effects but there are two observations that stand out in the current BiOp: (1) Delta Smelt abundance is the lowest ever observed and is expected to continue to decline, and (2) the PA includes a 12.5% annual increase in water exports from the ecosystem. Interestingly, these two points were made by the USFWS 2008 Delta Smelt BiOp, except that Delta Smelt was many times more abundant then than today.

Since the 2008 BiOp on Delta Smelt, there has been a shift in focus from the adverse effects of water operations on Delta Smelt and their critical habitat to an interest in understanding how a wide range of other factors, including food resources, contaminants and climate change impact Delta Smelt abundance.

1.3 Review Activities

- July 31, 2019 – Downloaded review materials, including supplemental materials supplied by the USFW Service from Atkins website; begin reviewing the draft BiOp

- August 1, 2019 -Continue reading and reviewing draft BiOp, including appendices and USFW Service responses to the April 2019 independent reviews of the BiOp.

- August 2, 2019 – Kickoff Skype Meeting with Cheryl Propst (Atkins North America) to discuss procedures, schedules, constraints and questions regarding the BiOp review; continue reviewing draft BiOp.

- August 3, 2019 requested via email that Cheryl Probst request from the USFW Service a copy of the "Conclusions" section which was omitted from the draft BiOp provided for review

- August 5, 2019 – Continued reviewing BiOp; received a copy of Polansky et al. 2019 (In press) reference from Cheryl Propst via e-mail; also learned that the Service intentionally did not provide reviewers with Conclusions or Incidental Take Statements from their BiOp on Delta Smelt.

- August 6, 2019 – Continued to review BiOp and formulated questions for agency representatives in advance of a conference call scheduled for August 7, 2019.

- August 7, 2019 Skype/Conference call with Cheryl Propst (Atkins North America), BiOp reviewers and agency representatives to discuss issues in the BiOp materials that may need clarification. The agencies offered a 3-day time extension to complete the BiOp review; this was gratefully accepted by the reviewers.

- August 8-12, 2019 – Worked on writing review of the draft BiOp from July 2019.

- August 12, 2019 - Submitted review of draft BiOp and a copy of Kneib CV to Cheryl Propst (Atkins North America) via e-mail.

2 Responses to Questions

2.1 Question 1: How well does the BiOp use best available scientific and commercial information? Specifically:

2.1.1 Do the analyses in the status of the species and critical habitat, and environmental baseline sections reflect the best available scientific and commercial information?

This is not a simple question to address. The BiOp demonstrates a comprehensive knowledge of past and current scientific research and modeling results pertinent to hydrodynamics of the Delta system and population trends in Delta Smelt. Knowledge of currently available scientific information gathered on a species and its habitat requirements can provide basic information but may not include key responses to changes in the environment, particularly as related to the aggregate effects of multiple factors. Aggregate and cumulative effects are difficult to predict.

The analyses of the status of Delta Smelt and their critical habitat include a combination of quantitative estimates of abundance and modeling approaches, but at their core, the analyses, perhaps by necessity, are qualitative with respect to the magnitude of effects that the PA may have on Delta Smelt and their critical habitat. Outside reviewers may not have any practical experience with the process by which an Environmental Baseline is determined by the Service. The current BiOp lacked a Conclusions section that might have been helpful in understanding the process.

It does not appear to be possible to parse the effects of CVP/SWP water operations from the effects of other actions that are blended into the Environmental Baseline In terms of the Environmental Baseline, one could argue that CVP/SWP water operations have indirect effects on many, if not most, of the other effects elements by facilitating water availability and use. Water supplied by operating these facilities is used in agriculture and municipal water supplies that return various pollutants to the Bay-Delta system. It is unclear how the BiOp fully accounts for such indirect effects.

The concept of ecological thresholds and rapid transitions in state resulting from apparently minor shifts in conditions (e.g., see Clements and Ozgul, 2018 and references therein) do not appear to be a major consideration in the analyses of species status, critical habitat, environmental baseline or effects of the PA.

The 2008 USFWS BiOp on Delta Smelt concluded that "delta smelt is currently at its lowest level of abundance since monitoring began in 1967." At that time, the Delta Smelt mean abundance estimate was nearly two orders of magnitude greater than it is in 2019 (see Table 5-2 in the current BiOp). There have been recent and significant incremental improvements in Delta Smelt monitoring and modeling of population dynamics. Consequently, it seems safe to conclude that there is a

scientific consensus that the population has passed yet another threshold in decline that appears to be leading to extinction in the wild (e.g. Moyle et al. 2016, Baumsteiger and Moyle 2017, Hobbs et al. 2017). It is unclear how the Environmental Baseline fully accounts for such a precipitous change in the species' state in a way that offers greater protection from any adverse effects of the PA.

In fact, the heading in Table 5-2 of the BiOp suggests that there is statistical evidence the population could actually have stabilized in recent years. The heading states: "If the (95%) confidence intervals of any pair of years overlap, then the populations may not have differed in size between those years." This statement is not false but it is misleading for two reasons. First, even if the confidence intervals do not overlap, there is still some probability – albeit very low (<5%) – that the population sizes are the same. Second, a statistically significant difference in population sizes between any two years could occur even if the confidence intervals overlap to some extent. Perhaps this is not what was intended, but it would be improper to suggest that there may be no significant difference in population abundance between years simply because the 95% confidence intervals overlap at all.

Another component in the relationship of the Environmental Baseline to water operations that is obscure to this reviewer at least, is how unfulfilled assurances from the previous consultation are dealt with. For example, in the 2008 BiOp (RPA Components 4 and 5), DWR was to "create or restore a minimum of 8,000 acres of intertidal and associated subtidal habitat in the Delta and Suisun Marsh." It was required that the restoration commence within a year of signing the BiOp and was to be completed with 10 years. An overall monitoring program was to be established to assess the effectiveness of the restoration in achieving the goal of improving Delta Smelt habitat. Table 5-4 of the current BiOp includes this marsh restoration element (8,000 acres) in the new Environmental Baseline, but what effect does it have if it was not accomplished? Reclamation and DWR are given another 10 years (to 2030) to complete the restoration. So, is the same restoration included in both the current Environmental Baseline and the new PA? If so, how are past and future effects on Delta Smelt and their Critical Habitat parsed?

Information on the reproductive requirements, especially in terms of critical spawning habitat, is woefully scarce and uncertain. For example, spawning behavior is only known from captive populations and preferred spawning substrates remain unknown. The BiOp is left to assume that spawning occurs somewhere in the vicinity that mature adults are collected and that spawning substrates are similar to those used by closely related species. This makes it difficult to develop an Environmental Baseline that includes specific critical spawning habitat. Eggs of Delta Smelt are demersal and adhesive so could be attached to any number of substrates. It is difficult to protect critical spawning habitat without knowing what it is, much less to analyze the potential effect of any action on critical habitat.

Climate change was recently added to a growing list of threats to Delta Smelt. While the list of threats grows, progress toward maintaining and recovering Delta Smelt in the wild continues to fail.

At best, it might be said that extinction could have occurred already had it not been for protective actions previous taken, but there is no substantial scientific support for this.

The role of turbidity in critical habitat of Delta Smelt is based largely on positive associations between turbidity and catches of Delta Smelt in trawls and in salvage at the pumping stations. Turbidity *per se* is a very coarse variable that may need to be qualified in order to be useful. For example, there may be no functional equivalency between any given turbidity value due to the sediment suspension versus robust growth of phytoplankton in response to nutrient levels. In the first case, there may be little or no connection between turbidity and useful food resources for Delta Smelt. In the second case, different source nutrients (e.g., ammonium vs nitrate) at certain concentrations can lead to very different size classes of primary producer communities (e.g., Glibert et al. 2016) that support zooplankton communities of different food value to Delta Smelt. Measures of turbidity alone may be of little value in making these functional distinctions.

The association of turbidity fronts with the location of X2 and concentrations of food for Delta Smelt is perhaps the most convincing connection between turbidity and Delta Smelt abundance but this only occurs in relatively small regions of the habitat.

2.1.2 Are assumptions in the effects analysis clearly stated and reasonable based on current scientific thinking?

Some assumptions are explicitly stated (e.g., the comparison of CalSim II modeling and the PA in Table 5-6, and the population dynamics considered in Appendix 2 of the BiOp). Others are implicitly considered (assumed) to be positive even when there are possibilities of adverse or neutral effects (e.g, action elements intended to enhance food resources and habitat for Delta Smelt}. When populations are in decline, even neutral actions provide no benefit and even small negative direct or indirect effects (e.g. contaminants and the possibility of introduction or stimulation of invasive species in the food resource enhancement efforts) may have greater than expected effects.

2.1.3 Are there alternative interpretations of the best available scientific information with respect to species status, critical habitat, and effects of the proposed action that are equally well supported by the data (i.e., scientific information, analyses) that were not presented in the biological opinion that merit consideration.

Most likely yes, but this will be the case in any opinion that relies heavily on qualitative analyses. The analyses of effects in the BiOp are a mixture of quantitative predictions from hydrodynamic and population modeling and qualitative evaluations by Service staff. Individuals are likely to differ in the way they use and interpret published information.

Although new research has become available since the previous (2008) BiOp on Delta Smelt, it may still be instructive in the context of this question to consider conclusions from the 2008 BiOp on Delta Smelt which included the following:

(1) Diversions of water from the Delta have increased since 1967; past and present CVP/SWP operations have significantly altered the hydrodynamics throughout the Bay-Delta ecosystem and have resulted in numerous direct and indirect adverse effects on Delta Smelt.
(2) Delta Smelt is at its lowest abundance since monitoring began in 1967.
(3) The suite of proposed CVP/SWP operations will reduce Delta outflows and result in chronically lower suitability of Delta Smelt habitat.
(4) Other baseline stressors (e.g. contaminants, invasive species, HABs, etc) will continue to adversely affect Delta Smelt and information regarding the independence of these stressors from CVP/SWP water operations is inconclusive.
(5) In order to survive and recover Delta Smelt need a substantially more abundant population and improved habitat quality, reduction in levels of pollutants, toxic algal blooms, reduced entrainment, and restoration of food web structure in Bay-Delta.
(6) Improved resilience to climate change effects.

Relative to the survival and recovery needs, the 2008 BiOp concluded that effects of the PA were likely to decrease the abundance of Delta Smelt, decrease the quality and quantity of its habitat, maintain or increase high levels of entrainment, contribute to degraded food webs and reduce the population resilience of Delta Smelt.

In 2008, "The Service concludes that the effects of the proposed action, taken together with cumulative effects, are likely to appreciably reduce the likelihood of both the survival and recovery of Delta Smelt in the wild by reducing its reproduction, abundance and distribution." (And this happened.) The same was said about critical habitat.

To determine whether there are alternative interpretations of the best available scientific information, the team that conducted the current (2019) effects analysis could consider the best available scientific information available in 2008 and compare their conclusions with those reported in the 2008 BiOp.

Table 5-8 in the current BiOp provides several examples to illustrate how different individuals might interpret available information differently. Most of the boxes are coded as having neutral effects and two are coded as having mixed effects but it is not clear why. In the mixed effects boxes, there is a statement of some negative effect such as lower outflow reducing the suitability of critical habitat, then there is also a strong statement about how some, as yet, untested action element (Summer-Fall Habitat) will improve conditions, seemingly changing a negative effect into a mixed effect but without any demonstrable positive effect of the future action element. In another River Flow box

affecting dispersing (migrating) adults, there is a clear effect of greater negative OMR flows with only the possibility of OMR management mitigating some of the effects, yet this box is coded as being neutral. Another individual, or team, might code the brown boxes in Table 5-8 red (for negative) by discounting any unproven effect of proposed habitat improvement and code some of the neutral (yellow) boxes brown (mixed effects).

It might be useful to consider the role of ecological thresholds in alternative interpretations of the best available information. These can be difficult to predict, but seem to be apparent as step-declines in the Delta Smelt population over time. There appears to be a tendency to search for inflection points in relationships between pumping rates and effects on either entrainment or the location of X2. The purpose being to identify and operate to some maximum pumping rate just below – or at the threshold of - some adverse effect on Delta Smelt or their critical habitat. With the Delta Smelt population at such a critically low abundance, it may be useful to explore more conservative interpretations of the available information to insure some slight and unanticipated deviation from planned operations does not push conditions past an ecological threshold and trigger another step decline in the abundance of Delta Smelt.

Given the limited time provided for this review, it is unrealistic to expect thoroughly reasoned alternative interpretations on all of the effects considered in the BiOp. However, one simple alternative that specifically considers the role of a declining Delta Smelt population on predicted effects of the PA is provided in Appendix A. It considers the effect of the proposed restriction on entrainment. On its face, it seems that committing to a lower than historical average of entrainment losses should have, at worst a neutral effect on population abundance and at best a positive effect. However, this may not be true as the population declines (e.g., Figure 1 in Appendix A).

2.2 Question 2: Does the BiOp adequately analyze effects of the proposed action on delta smelt and critical habitat?

This is another difficult question to address without greater insight into the specific methodology employed in the qualitative effects analyses. In some cases, there is not sufficient information available to analyze effects. For example, some action components depend on teams of experts to make real-time recommendations for modifying water operations but it is not known whether the modifications will be made and there is no way to predict conditions under which the teams' involvement will be requested. Furthermore, this is not a new approach and it is unknown if it yields any significant protection for Delta Smelt. After all, real-time management has been in place during the time that Delta Smelt abundance has declined to his lowest level ever. The argument could be made that the situation would even be worse without real-time management options, but there is no evidence to support the contention.

2.2.1 Did the Service adequately analyze effects for both standard/site-specific (described at a site-specific level with no future consultation required) and programmatic (which require future consultation before they can be implemented) components of the proposed action?

As acknowledged in the BiOp, the PA by Reclamation is considered a mixed programmatic action with many elements subject to reinitiation of consultation, in essence deferring analysis until additional information is available. Many of the action elements are associated with a high degree of uncertainty with respect to effects on Delta Smelt and their critical habitat. The following narrative highlights some issues that stood out in this review of the BiOp with respect to uncertainty associated with the effects analysis of critical habitat and cumulative effects.

The BiOp does not expect food resources to change as a result of Delta outflow and cites several actions including habitat restoration, water management and food web subsidy studies, most of which are considered part of the Environmental Baseline but will not be completed until later. It is assumed that these actions may provide data to inform adaptive management of food webs. As with much of the analysis on critical habitat, there are many hypotheses but relatively few substantial scientific facts or tests available. For example, tidal habitat restoration is expected to improve the availability of food for all life stages of Delta Smelt but "at unknown locations and to an unknown degree". This is not a very compelling endorsement.

The operation of the Suisun Marsh Salinity Control Gate to direct more freshwater into Suisun Marsh in summer and fall under certain constraints was presented in the context of improving habitat for Delta Smelt but the action may be primarily intended to benefit waterfowl. The results of a pilot study suggested that Delta Smelt may see some modest benefit from the action but this remains to be seen.

Other actions are also guided by the hypothesis that food resources can be redistributed to benefit Delta Smelt but other species, perhaps superior competitors, may benefit as well and there is a risk of redistributing contaminants from agricultural and areas affected by ship traffic (e.g. hydraulic reconnection of the Sacramento Ship Channel with the mainstem of the river). Delta Smelt are already exposed to contaminants in the Liberty Island/Cache Slough complex (e.g., Hammock et al. 2015), which is being targeted for the redistribution of potential food resources from the ship channel.

Similarly, what appears to be a cooperative effort among the DWR, Reclamation and water users to flush nutrient-rich water from the Colusa Basin Drain into the Yolo Bypass and north Delta, may also contribute additional agricultural contaminants to the target area. As long as the net direction and magnitude of the effect of these actions to stimulate the food web remains unknown, so does the benefit or risk to Delta Smelt.

Table 2-1 in the BiOp describes components of the PA, including the summer-fall habitat elements. In wet years, it appears that the trade-off being made for the Suisun Marsh Salinity Control Gate action is to reduce outflow such that X2 is located at 80 km in September and October closer to a critical threshold for maintaining acceptable salinity levels near the center of the juvenile and subadult Delta Smelt population in the vicinity of Suisun Bay. Threshold levels at which critical conditions change abruptly from acceptable to unacceptable are usually only considered in the context of operating as close to those thresholds as possible. While this may maximize exports, it increases the risk of jeopardy to Delta Smelt, particularly in areas where the populations are most abundant. However, the BiOp states that the management actions "will likely provide better salinity conditions for rearing Delta Smelt than those modeled in CalSim II, but the magnitude of the effect is uncertain". Could this be one of those issues that CalSim II was not designed to address (Ferreira et al. 2005)? The argument appears to be that significant landward shifts in X2 would have occurred in September and October. However, when considering substantial shifts in X2, it would be appropriate to consider that restoration areas remain stationary and under the current Environmental Baseline, how will water quality in the restored habitats be affected by shifts in X2?

Figure 5-46 of the BiOp shows how frequently X2 is expected to be located at or above 85 km, which results in no overlap of the low-salinity zone with Suisun Bay under the PA relative to current operations according to 82 simulation runs of the CalSim II model. During September to December. X2 is predicted to be located at or above 85 km much more frequently than under current conditions. This shows that conditions will be less favorable more often in the primary center of the Delta Smelt population. It is difficult to imagine how these predicted conditions could be considered an acceptable risk to the critical habitat of a listed species.

The potential effects of contaminant and nutrients in the analysis of cumulative effects seems to be largely descriptive and, like other sections of the BiOp, replete with unknowns and uncertainties. Given that some of the PA components involve the redistribution of nutrients (and likely contaminants) in an effort to enhance food resources for Delta Smelt, the many uncertainties with respect to potential impacts on survival, growth and reproduction of Delta Smelt become an issue in the cumulative effects analysis.

Voluntary actions and actions requiring "scheduling" and "collaborative planning" may seem appealing but they have been included in previous management requirements. There is no reason to doubt the expertise of the individuals or agencies involved in these Action elements but despite their inclusion in previous "real-time" or adaptive management decisions, the Delta Smelt population has continued to decline sharply. This calls into question the efficacy of this approach. Although it could be argued that Delta Smelt and their critical habitat may have been in worse condition without these voluntary and collaborative planning efforts, there is no objective way to determine this – especially with the qualitative analysis used in the BiOp.

2.2.2 Are the methods utilized appropriate to determine if the proposed action is likely to jeopardize delta smelt or adversely modify its critical habitat?

See the answers to previous questions. There is an apparent lack of consideration of ecological (environmental) thresholds with respect to effects on Delta Smelt and their critical habitat, apparent confounding of additive, aggregate and cumulative effects, a frequently high degree of uncertainty in methods applied in the analyses. A number of PA elements have yet to be approved and it may be difficult to determine a priori if they will meet their intended goal to benefit or further jeopardize Delta Smelt or their critical habitat. Clarity may have come to some of these issues if commitments to restoration efforts and monitoring programs described in the 2008 BiOp had been met rather than being deferred into the next decade.

2.3 Question 3: How well does the BiOp incorporate new actions added to the Proposed Action by Reclamation, particularly the Delta Smelt Summer-Fall Habitat action?

The new actions are incorporated into the BiOp but it is unclear how the effects analyses were impacted by the inclusion of these elements, which are primarily intended to improve food supply and habitat for Delta Smelt. In most cases, it would be premature to give these actions much, if any, weight because the degree to which they are successful in achieving the intended results is unknown. Furthermore, some of the actions may carry unintended risks associated with the redistribution of contaminants, stimulation of harmful algal blooms, further propagation of invasive species, etc. (e.g., Hammock et al. 2015).

The plan to complete the restoration of 8,000 acres of intertidal and subtidal habitat along with a funded monitoring program that was promised as part of the 2008 BiOp is now scheduled to be completed as part of the current PA, with potentially another 10 years to complete the project and collect the data necessary to assess its effectiveness. Even if successful in its goal to improve critical habitat for Delta Smelt, it is currently unclear if the project can be completed before Delta Smelt abundance becomes too low to be viable in the wild. Also, considering that the tidal marsh component of the historical Delta included more than 500,000 acres, this substantial restoration effort represents only a small fraction (about 1.6%) of the marsh area previously lost to the system. It may be difficult to detect the intended positive effects on Delta Smelt.

Some of the Summer-Fall Habitat actions, like the Suisun Marsh Salinity Control Gate,(SMSCG) are associated with some preliminary studies that hint at a limited positive effect. It was unclear whether this action was intended to target Delta Smelt directly or indirectly as an ancillary effect of improving

habitat for waterfowl. The SMSCG is one of the few actions taken in below normal water years as well as above normal and wet years. However, even though positive effects on rearing larvae and juveniles remain to be demonstrated, positive effects of this action seemed to be included as a factor mitigating the negative effects on salinity as a result of the PA effect of locating the Low Salinity Zone upstream of current water operations. It is unclear how much this influenced the effects analysis of the PA on critical habitat as summarized in BiOp Table 5-8. Absent consideration of positive effects of the SMSCG and other proposed components of the Summer-Fall Habitat actions intended to improve salinity conditions, would the mixed effects (brown) boxes in Table 5-8 be coded red? The Table heading does not even include an option for negative effects (coded red) but there is such an option in the Table 5-8 heading shown in the List of Tables (p. 5 of the BiOp).

The Additional Delta Outflow to maintain monthly average X2 at 80 km in above normal and wet years could potentially result in more exports, especially in wet years when the 2008 BiOp required X2 to be at no greater than 74 km. This element of the PA is an example of potentially pushing too close to an ecological threshold for Delta Smelt in order to export more water in wet years. From the perspective of the aquatic organisms in the system, increasing exports enough even during wet years exposes them to environmental conditions that resemble drought years more often (e.g., Reis et al. 2019).

All of the PA elements (e.g., Roaring River Distribution System, Sacramento River Water Diversion, Sacramento Deepwater Ship Channel, North Delta Food Web Subsidies/Colusa Basin Drain Study, Suisun Marsh Food Subsidies) aim to enhance food resources for Delta Smelt but there are risks of elevating levels of contaminants, creating conditions suitable for harmful algal blooms, introducing invasive species, etc. These risks are acknowledged in the current version of the BiOp but it is unknown how the potential benefits and risks were balanced in the effects analyses. Another consideration is that while Delta Smelt may be the target species for these potential food resource enhancements, other species will also compete for these resources. Will the food enhancements selectively favor Delta Smelt or simply augment the populations of their competitors?

3 Additional Thoughts, Concerns, and Suggestions for Improvements to the Analyses

- Over 4,400 pages of required and supplemental review materials were provided and 10-13 days is an inadequate amount of time to conduct a comprehensive review of any species in a system as complex as the Bay-Delta.

- Qualitative analyses of effects require an independent reviewer to have more insight into the process used by the Service and this is not necessarily apparent from reading the BiOp.

- Conclusions and ITS should have been provided to reviewers. This is an essential component of evaluating how the best scientific information was applied in the effects analyses.

- There has been a tendency in the Long-Term Operations to push biological thresholds to the limits in order to allow more exports. At low population sizes this places protected species in the path of jeopardy; a wrong guess on the part of water operators or consulting teams of experts could be the final straw leading to extinction.

- It was unclear why the BiOp now views Delta Smelt spawning migrations as dispersal. Perhaps it seems to fit better with the idea that Delta Smelt habitat expands and contracts seasonally. The seasonally changing size and quality of habitat is intuitively attractive but the idea that Delta Smelt are simply randomly dispersing toward spawning areas is not. It seems more likely that there is some cue that synchronizes the movement of Delta Smelt toward specific spawning areas. At low population abundance it could be especially important for some directed mechanism to coordinate the population's spawning effort.

- The predator reduction elements of the action may have little effect on survival of Delta Smelt. Predator hotspots are natural features of most landscapes and predator populations tend to be self-regulated. The effects are unknown and it was unclear how these proposed elements were handled in the effects analyses.

- The plan to maintain and rear Delta Smelt in hatcheries to augment wild populations is the "Hail Mary" pass of the PA. If the low abundance of Delta Smelt is due to a lack of suitable habitat, field augmentation will not likely succeed. Also, as was recognized when salvaged Delta Smelt were reintroduced to the system, they were susceptible to mortality during and after transport. When hatchery fish are introduced to the system, it will likely be at limited locations where they could be subject to immediate predation. The effort to rear Delta Smelt may simply be an exercise in food enhancement for predators. Finally, lessons learned from hatchery rearing of other species, such as salmonids would also apply.

- Table 5-7 and 5-9 in the BiOp are the same.

4 References

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Moyle, P.B., Brown, L.R., Durand, J.R. and Hobbs, J.A. 2016. Delta Smelt: Life history and decline of a once-abundant species in the San Francisco Estuary. San Francisco Estuary & Watershed Science 14(2). https://doi.org/10.15447/sfews.2016v14iss2art6

Reis, G.J., Howard, J.K. and Rosenfield, J.A. 2019. Clarifying effects of environmental protections on freshwater flows to – and water exports from – the San Francisco Bay Estuary. San Francisco Estuary & Watershed Science 17(1). https://doi.org/10.15447/sfews.2019v17iss1art1

4.1 Materials Provided Prior to the Review

US Fish and Wildlife Service. 2019a. San Francisco Bay-Delta Fish and Wildlife Office. *BIOLOGICAL OPINION For the Reinitiation of Consultation on the Coordinated Operations of the Central Valley Project and State Water Project*. (Draft, July 30, 2019) (247 pp.).

US Fish and Wildlife Service. 2019b. *DRAFT - Summary of Modifications to Chapter 4 (Proposed Action) from the Biological Opinion Assessment from January 31, 2019 to July 30, 2019. (5 pp.)*

US Fish and Wildlife Service. 2019c. "Independent Peer Review of the Draft Delta Smelt Effects Analysis for the Reinitiation of Consultation on the Coordinated Long-Term Operation of the Central Valley Project and State Water Project." Matthew L. Nobriga to Cheryl Wapnick Propst. (4 pp.).

4.2 Supplemental Materials Review

State of California Natural Resources Agency. 2009. Department of Water Resources. *Quantification of Pre-Screen Loss of Juvenile Steelhead in Clifton Court Forebay*. By Kevin W. Clark, Mark D. Bowen, Ryan B. Mayfield, Katherine P. Zehfuss, Justin D. Taplin, and Charles H. Hanson. Sacramento, CA. (1,045 pp.).

US Bureau of Reclamation. 2019a. *Chapter 4 Draft Proposed Action-Peer Review Version*. 4-1-4-83. (83 pp.)

US Bureau of Reclamation. 2019b. *Appendix D Modeling*. Reclamation ROC on LTO Modeling to Support the January 2019 BA Qualitative Analysis: Without Action, Current Operations, and Proposed Action Scenarios. (1,798 pp.).

US Bureau of Reclamation. 2019c. *Reinitiation of Consultation on the Coordinated Long-Term Operation of the Central Valley Project and State Water Project, Appendix A-Appendix H. (299 pp.)*.

US Bureau of Reclamation. 2019d. *Final Biological Assessment: Reinitiation of Consultation on the Coordinated Long-Term Operation of the Central Valley Project and State Water Project*. 1-2-8-69. (875 pp.).

US Fish and Wildlife Service. 2019d. *Independent Review of the Coordinated Long Term Operation of the Central Valley Project and State Water Project*. By Ronald T. Kneib, PhD, Ernst Peebles, PhD, and Joseph E. Merz, PhD. (64 pp.).

US Fish and Wildlife Service. 2019e. *U.S. Fish and Wildlife Service Response to April 2019 Peer Reviewer Comments on Draft Delta Smelt Effects Analysis*. 1-42.

4.3 Data Assessed

Information from Table 5-2 of the BiOp was used in a heuristic exercise in Appendix A of this review.

Appendix A
A Simple Example of an Alternative Interpretation of the Effect of a 10% Loss Limit on a Declining Population

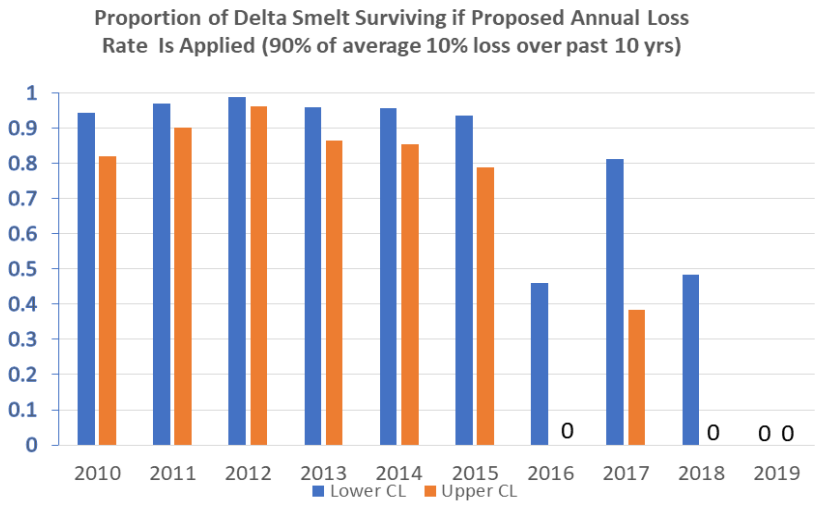
The following is a simple heuristic exercise to demonstrate how a Project Action element might have an alternative interpretation in terms of its effect on the extant population abundance of Delta Smelt. Appendix 2 in the BiOp provides a compelling case supporting the plausibility (not likelihood) that an annual 10% entrainment loss of Age-0 Delta Smelt could be achieved by OMR management in the Project Action. Salvage is no longer considered a reasonable index of entrainment losses because of the extremely low abundance of Delta Smelt in recent years. Consequently, a relationship between OMR flow and Age-0 Delta Smelt entrainment is modeled under different mortality and adult distribution assumptions. What is not included is a consideration of how these relationships might change as the population declines.

The Summary of Modifications to Chapter 4 of the PA from the Biological Assessment from January 2019 to July 2019 includes Real-Time OMR Restrictions and Performance Objectives including a goal to avoid exceeding an annual loss threshold equal to 90% of the greatest entrainment loss that occurred in the historical record from 2010 through 2018. For purposes of this heuristic exercise, I used the abundance estimates of adult Delta Smelt shown in Table 5-2 of the BiOp on the simplifying assumption that there was a proportional relationship between Age-0 Delta Smelt and the adult population. Furthermore, I assumed that the confidence limits around estimates of adult and Age-0 Delta Smelt were similar.

In most of the years shown in Table 5-2 of the BiOp, Delta Smelt abundance was considerably greater than it is today, or is expected to be in the near future (to 2030). A 10% annual loss rate at high population abundance is a substantially greater take than a 10% loss at a very low population abundance. The upper and lower 95% confidence limits on the abundance estimates in Table 5-2 of

the BiOp for the past 10 years (2010-2019) was used to provide a high and a low value in a range of losses that might have been experienced in each year. For example, in 2010, the lower and upper confidence limits were 161,753 and 374,582, respectively. Assuming 10% mortality, an annual incidental take range of 16,175 to 37,458 could be attributable to water operations in 2010. If we apply this to each year in turn and then average the values across years, we obtain an annual average take range of 15,274 to 50,149. By applying the proposed cumulative loss threshold of 90% of the losses, the annual 10 year average range becomes 13,747 to 45,134. Subtracting each of these values from the mean abundance estimate in Table 5-2 of the BiOp provides an estimate of the minimum and maximum loss that would be acceptable in each year. Figure 1 of the current Appendix shows the annual proportional survival of Delta Smelt under the proposed loss threshold.

Figure 1. Proportional annual survival of Delta Smelt 2010-2019 using an estimated loss threshold similar to that proposed in the July 30, 2019 modification to Chapter 4 of the BA.



Note(s), Losses were calculated based on lower (conservative) and upper 95% confidence limits of the abundance estimates then applied to the mean abundance value in Table 5.2 of the BiOp. The adverse impact is substantially greater at recent low levels of abundance.

Note that the population is resilient to this level of loss pressure from 2010 to 2015, but when population size declined in later years, Delta Smelt were driven to extinction at the high end of the annual loss range in 2016, 2018 and 2019. Even at the low end of the loss range (based on the lower 95% confidence limit), the population is driven to extinction in 2019. If the acceptable threshold loss is reduced to 20% of the 10-year average annual loss, the population still goes extinct in 2019 at the

high end of the loss estimate range. It is not until the acceptable threshold loss is reduced to 10% of the 10-year annual average loss that Delta Smelt survive in all years. Step declines in abundance of Delta Smelt have become a feature of their population in recent history. This is a very simple example of how apparently stable but repeated pressure on the population over time (i.e., cumulative effects) can produce instability when an ecological threshold is crossed.

As a population approaches a low level of abundance, management actions should not aim to seek the maximum mortality rate the population can sustain, thereby risking crossing an ecological threshold, but rather aim to minimize the mortality rate until the population can recover.

Independent Review of the Coordinated Long-Term Operation of the Central Valley Project and State Water Project

Prepared for:
National Marine Fisheries Service
U.S. Fish and Wildlife Service

By:
Joseph E. Merz, Ph.D.
Cramer Fish Sciences
3300 Industrial Blvd #100
West Sacramento, CA 95691

Executive Summary

I was asked to provide a second review, as an independent scientist, on whether the revised biological opinion is scientifically sound and the conclusions are based on the best available scientific information as it pertains to delta smelt; scientifically defensible. Relevant background materials and sections of the biological opinion to be reviewed were provided.

I appreciate the effort USFWS staff put into responding and editing this document related to comments made by the reviewing team. Information provided in this second draft is more clearly organized than the first draft. I greatly appreciate inclusion of the Delta smelt life cycle in the analysis. I would still recommend a Gannt chart to associate specific PA's with life cycle of fish. This may not work with all PA's but may overall help understand the timing of Actions in relationship to life stages etc. The draft sections use reasonable science, including modeling, to predict entrainment effects and generally where X2 is, and delta out flow etc. The model outcomes and depictions of those outcomes have been markedly improved. Updated BiOP now has a more fully developed depiction of the delta smelt life cycle. However, the timing and effects of each component of the PA as it relates to delta smelt are still not clearly demonstrated.

Tables and figures more adequately explain information being described (but see specific comments below). Acronyms and initials should still be clearly spelled out in captions.

In short, I believe that the revised BiOP provides enough information to demonstrate that the status of delta smelt critical habitat under the PA will most likely be degraded by cumulative effects under the early long-term. However, there continues to be a lack of information on the overall PA effects, in measurable terms, other than estimated percent change to outflow.

Specifically, the section on effects of Proposed Restoration of 8,000 acres of Tidal Habitat is still not well articulated. How will information from previously constructed habitat be used to inform the rest of the construction? What happens if the Tidal restorations don't work? What is the timeline? Describe general Adaptive Management process to inform this. If this is mitigation, what happens if restoration/enhancement actions do not work? Other than "increase available food web production for delta smelt" there is little indication of measurable goals and how they will benefit delta smelt other than a quantity of 8,000 acres. Mitigation has specific ramifications under adaptive management and there is insufficient information to understand how success is determined and what will be done if different trajectory occurs. In short, Adaptive Management (AM) is mentioned 6 times in document but not clearly articulated. What will the general AM process be for the PA? I have little legal expertise in the ESA area. However, I wonder if hatchery supplementation can be used to mitigate for wild fish loss due to PA? Again, is hatchery for purpose of PA or was it developed for past effects? These issues require clarification.

This report shall be prefaced with an Executive Summary providing a concise summary of the findings and recommendations and specify whether the science reviewed is the best scientific information available.

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APPENDICES

1 Introduction

Report Content

1. The reviewer report shall consist of an Executive Summary, Background, General Observations, Description of the Review Activities, Summary of Findings for each specific question in which the weaknesses and strengths are described, and Conclusions and Recommendations in accordance with the questions posed.
   a. The Executive Summary should provide a concise summary of the reviewer's findings and recommendations, and whether the science reviewed is the best available science.
   b. Reviewers should describe the review activities completed during the review period, including providing a brief summary of the science, conclusions, and recommendations discussed during the conference call(s) with the other reviewers.
   c. Reviewers should discuss their independent views on each specific question even if these were consistent with those of other reviewers, and especially where there were divergent views.
   d. Reviewers should elaborate on any points they feel might require further clarification.
   e. Reviewers should include a bibliography for all background materials reviewed, including materials provided prior to the review, supplemental materials reviewed, and any additional data sources referred to.
   f. The independent report shall be a stand-alone document for others to understand the weaknesses and strengths of the science reviewed. The independent report shall be an independent peer review of each specific question posed and shall not simply repeat the contents of the biological opinion sections.

1.1 Background

I was asked to provide a second independent review on whether the draft biological opinion (BiOP) is scientifically sound and the conclusions are based on the best available scientific information as it pertains to Delta smelt; scientifically defensible. Relevant sections of the BiOP to be reviewed and supplemental material were provided. I also participated in a single conference call with the other reviewers and USFWS and USBOR representatives for discussion of key questions prior to submitting my second individual review.

Under section 7 consultation, the USFWS has been given the daunting task of evaluating the ROC PA effects on listed species and designated critical habitat of several species, including delta smelt, under a very tight timeline and changing information. I commend the Service on work completed under this schedule. An analysis and conclusion of whether the entire ROC action, as described in the PA, is likely to jeopardize the continued existence of listed species or result in the destruction or adverse modification of their critical habitat are meant to be provided within the BiOP.

This review of the second draft BiOp section on delta smelt was submitted using the format provided, addresses questions posed by USFWS and was delivered electronically to the Atkins Designated Project Manager, Cheryl Propst, for consolidation with other review reports. This continues to be an overwhelming amount of information to digest under the timeframe given.

1.2 General Observations

I appreciate the effort USFWS staff put into responding and editing this document related to comments made by the reviewing team. Information provided in this second draft is more clearly organized than the first draft.

A BiOp usually includes conservation recommendations that further recovery of the specific ESA-listed species as well as Reasonable and Prudent measures, as needed, to minimize any harmful effects, and may require monitoring and reporting to ensure that the action is implemented as described. While these general components appear in areas of the provided sections, they are not clearly articulated in the document.

Species Legal Status and Life Cycle Summary- There has been significant improvement to this section. Including the description of delta smelt life history adapted to seasonal events in the environment (Phenology). I believe some of my comments about the Lake Washington story were taken to mean that I believe the SFE food web works like a temperate lake. That was not my intent; Lake Washington was more an illustration for describing timing, frequency and duration of disturbance that helps maintain ecosystem function and productivity. For instance, phenology also plays a critical role in the California Current System, in which ecosystem productivity and structure is driven largely by the seasonal cycle of coastal upwelling. The impact of an anomalous seasonal cycle such as delayed onset of coastal upwelling (Schwing et al. 2006), can result in: anomalously warm sea surface temperatures (Kosro et al. 2006; Pierce et al. 2006),low surface chlorophyll levels (Thomas and Brickley 2006), spatial redistribution of zooplankton species (Mackas et al. 2006), low rockfish recruitment and lack of forage species (Brodeur et al., 2006). These concepts can help describe how climate and altered flow timing can result in changes to the phenology of the system. Again, Winder and Schindler (2004) provide an excellent example of depicting seasonality of the Lake Washington trophic interactions and how climate change is altering/decoupling these relationships.

I greatly appreciate inclusion of the Delta smelt life cycle in the analysis. I would still recommend a Gannt chart to associate specific PA's with life cycle of fish. This may not work with all PA's but may overall help understand the timing of Actions in relationship to life stages etc.

The Tidal Habitat Restoration- How much of the 8,000 acres has been built to date? How will information from previously constructed habitat be used to inform the rest of the construction? What happens if the Tidal restorations don't work? What is the timeline? Describe general adaptive management process to inform this. If this is mitigation, what happens if they do not work? Other than "increase available food web production for delta smelt" there is little indication of measurable goals and how they will benefit delta smelt other than a measure of 8,000 acres. Mitigation has specific ramification under adaptive management. There simply is not enough information here to understand how success is determined and what will be done if different trajectory occurs. In short,

Adaptive Management is mentioned 6 times in document but not clearly articulated. What will the general AM process be for the PA?

In theory benefits of 8,000 acres of restoration is plausible. However, there is no clear evidence to suggest that this habitat enhancement will mitigate or mediate flow effects. Again, it is unclear what the purpose of these restoration-enhancement actions are for. Are they mitigation for previous operation impacts? If so, how can they be used to mitigate for PA? That is, shouldn't these actions be associated with past impacts that have simply not been implemented yet? Therefore, aren't they associated with Baseline? If I am confusing this, I would suggest it will be confusing to others.

I have little legal expertise in the ESA area. However, I wonder if hatchery supplementation can be used to mitigate for wild fish loss due to PA? Again, is hatchery for purpose of PA or was it developed for past effects? This appears to me to require better clarification.

1.3 Review Activities

1. Contacted by Atkins to review document.
2. Agreed to making second review.
3. Downloaded relevant information.
4. Reviewed Information.
5. Compared against previous comments from past reviewers.
6. Began writing review and searching for relevant supporting information.
7. Participated in conference call.
8. Used information from phone call to inform my review.
9. Completed review.
10. Formatted Reviewer response template.
11. Submitted to Atkins.

2 Responses to Questions

Please number figures and tables consecutively and use the following formats.

Table 1
Sample Table

Column Header	Column Header	Column Header	Column Header
Text			
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Notes:
Sources or explanations.

Figure 1
Sample Figure

Note(s), source, attribution, or caption text

2.1 Question 1: How well does the BiOp use best available scientific and commercial information? Specifically:

The draft sections use reasonable science and meaningful modeling to predict entrainment effects and generally where X2 is, and delta out flow etc. Please see specific comments below.

2.1.1 Do the analyses in the status of the species and critical habitat, and environmental baseline sections reflect the best available scientific and commercial information?

There has been significant improvements made here.

2.1.2 Are assumptions in the effects analysis clearly stated and reasonable based on current scientific thinking?

In general, yes. However, there is still uncertainty to outcomes of specific actions. See specific comments below.

2.1.3 Are there alternative interpretations of the best available scientific information with respect to species status, critical habitat, and effects of the proposed action that are equally well supported by the data (i.e., scientific information, analyses) that were not presented in the biological opinion that merit consideration.

See specific comments below.

2.2 Question 2: Does the BiOp adequately analyze effects of the proposed action on delta smelt and critical habitat?

The hatchery and restoration actions are still not well defined. Even though it is suggested these will be reviewed at a later date, the process of how it is incorporated and evaluated in the BiOp is unclear.

2.2.1 Did the Service adequately analyze effects for both standard/site-specific (described at a site-specific level with no future consultation required) and programmatic (which require future consultation before they can be implemented) components of the proposed action?

In general, yes. But see specific comments below.

2.2.2 Are the methods utilized appropriate to determine if the proposed action is likely to jeopardize delta smelt or adversely modify its critical habitat?

Yes, but see specific comments below for clarification.

2.3 Question 3: How well does the BiOp incorporate new actions added to the Proposed Action by Reclamation, particularly the Delta Smelt Summer-Fall Habitat action?

This was not well incorporated into the BiOp. Specific language: "However, the Delta Smelt Summer-Fall Habitat Action was not included in the modeling and would improve conditions to various degrees depending on water year type and the specifics of its implementation".

3 Additional Thoughts, Concerns, and Suggestions for Improvements to the Analyses

3.1 Specific comments associated with Biop Sections

The North Delta Arc is mentioned twice in the document but other than citing Moyle (2010) and using it as a reference to where restoration is proposed, it is not well described. I suggest provided an illustration of it in a map (perhaps figure 5-1). Are there no conceptual models of how the restored 8000 acres will function?

Table 5-1. Spawning substrate is conjecture at this point. Should be careful to exclude habitat until this is verified. Under larval and juvenile transport, remove "of" from "Most delta smelt that survive to the juvenile life stage do eventually inhabit water that is in the 0.5 to 6 ppt range, due to either or both of downstream movement or decreasing outflow (Bush 2017).

Figure 5-4. Estimated delta outflow is only one aspect of hydrologic function. The annual flow variance is also critical to environmental triggers. Note that the hydrograph sine wave is dampened. Flow variance appears to trigger movement and influence health of other estuary fish species (Zeug et al.).

Page 65- No mention of turbidity. Suspended fine sediment and biologically-driven turbidity most-likely had a strong influence on macrophyte vs phytoplankton primary production.

Page 67- The changes discussed above have continued to lower Delta outflow (Hutton et al. 2017a,b; Reis et al. 2019; Figures 5-8 and 5-9), though D-1641 appears to have halted the trend for years in which the eight river index is lower than 20 MAF (middle panel of Figure 5-8). – Again, I believe a discussion of changes to flow variance and timing is also warranted.

Page 78 – Climate change- Because turbidity is a major theme of this document and wind is a component of fine sediment suspension in some areas of the Estuary, I would suggest touching on future scenarios for climate change and wind. Examples- Snyder et al. (2003) : Modeling scenarios suggest future wind strength increase along California coast may have far reaching effects: land temperatures are increasing at a faster rate than ocean temperatures, and this thermal gradient is driving increased winds; increases in wind speeds of up to 2 meters per second, which is a large change in relation to current average wind speeds of about 5 meters per second. One effect of these increased winds may be earlier and more intense upwelling of cold water along the coast. An enhanced sea breeze during the warm months of the year has a cooling effect along the coast. Such a cooling trend could have many ramifications, particularly for coastal species adapted to seasonal changes in temperatures and fog – since fog has a profound effect on solar radiation and has demonstrated change over time in Central Valley, this seems relevant to the climate change section.

SAV discussion Page 87- Light is observed to be one of the more determining factors for Egeria densa growth success. Bini and Thomaz (2005) found that the levels of the light attenuation coefficient (k) were rarely more than 1.5 m-1, but E. densa can survive in a broad range of light. They also determined that the Secchi depth showed that the plants were more likely to grow in areas with values greater than 1 m in depth, so little turbidity and little phytoplankton in the water. Bini and Thomaz (2005) as cited in Darrin 2009. Therefore, it suggests that E. densa isn't just influencing water clarity but water clarity is influencing ability of E. densa to proliferate. Suggests suspension of fine sediment and increased phytoplankton might also reduce macrophyte coverage.

Page 89 Turbidity- I am restating this from comments on first draft. Turbidity is the measure of relative clarity of a liquid. It is an optical characteristic of water and is a measurement of the amount of light scattered by material in the water when a light is shined through the water sample. The higher the intensity of scattered light, the higher the turbidity. Material that causes water to be turbid include clay, silt, very tiny inorganic and organic matter, algae, dissolved colored organic compounds, and plankton and other microscopic organisms. Turbidity should be viewed as a measurement of what causes it. Again, the Lake Washington story provides an example of how complex this subject is (please see other citations below). Within the BiOP (and many discussions of delta smelt), turbidity seems to be considered a habitat parameter, more so than the parameters that create turbidity or other conditions that tend to correlate with turbidity. For instance, lake turnover is typically a period of low water clarity and often corresponds with re-suspension of nutrients vital to the food web. Is it possible that relatively low turbidity may be an indication of reduced seasonal disturbance of the estuary that supports seasonal productivity? How might climate change affect this? Again, how might the PA influence this?

Page 98 – Year-to-year variation is an important environmental variable. Variance drives important aspects of life cycle, especially in a Mediterranean climate (MC). How will PA further effect the seasonal variation and timing of nutrient and sediment inputs? Gasith and Resh (1999) give an excellent account of MC aquatic communities undergo a yearly cycle whereby abiotic (environmental) controls that dominate during floods are reduced when the discharge declines, which is also a time when biotic controls (e.g. predation, competition) can become important. As the dry season progresses, habitat conditions become harsher; environmental pressures may again become the more important regulators of stream populations and community structure. In contrast to the synchronous input of autumn litterfall in forested temperate streams, riparian input to Mediterranean-type streams is more protracted, with fall and possibly spring peaks occurring in streams in the Northern Hemisphere and a summer peak existing in their Southern Hemisphere counterparts. Again, it appears that this wet and dry seasonality is the template of the system that should be given more discussion in the BO.

Page 108 – avoid colloquial expressions - is currently doing a "poor job" of serving its intended conservation role. Clearly articulate this. Similarly on page 130: "It is located about halfway down the Old River corridor…"

Page 108- include flow variability and timing to "As described above, those changes have stemmed from chronic low outflow, species invasions and associated changes in how the upper estuary food web functions, declining prey availability, high water temperatures, declining water turbidity, and localized contaminant exposure and accumulation by delta smelt.

RPA 4 Page 111 – Wouldn't restoration of 8,000 acres of relatively shallow water habitat potentially influence turbidity? Shallow, moderately eutrophic lakes are suggested to occur in two alternative stable states, one characterized by high transparency and abundant submerged vegetation (clearwater state), the other by low transparency and high phytoplankton densities (turbid state)(Scheffer et al., 1993; Scheffer, 1998). Light availability is a key factor for the outcome of interactions between submerged macrophytes and phytoplankton, and submerged macrophytes are able to improve their own light availability by different feedback mechanisms (Scheffer et al. 1993).

see: Blindow, I., Hargeby, A. and Andersson, G., 2002. Seasonal changes of mechanisms maintaining clear water in a shallow lake with abundant Chara vegetation. Aquatic Botany, 72(3-4), pp.315-334.

Page 129 it states "If the frequency of the Integrated Early Winter Pulse Protection action is greater than the RPA Action 1, we expect the projects will meet a 14-day -2,000 cfs OMR target more often than under the COS. Therefore, the PA may provide more protection for adult delta smelt dispersing in the early winter months than the COS condition." Explain how will this finally be determined. How will this be incorporated into adaptive management if it does or does not meet needs?

Page 132: singular: larva; plural: larvae

Page 132: Can hatchery fish be used as a replacement for wild, ESA-listed fish? I don't know the legal ramifications of this but I assume hatchery production cannot be used to mitigate for habitat degradation and unsure if it is appropriate for actual "take" of wild fish either.

Page 134: Mississippi silverside (Menidia beryllina) – Inland Silverside

Page 134: does take of hatchery fish equate to wild take?

Page 137: "Reclamation's Proposed Action to expand the transfer window to July 1 to November 30 could result in additional pumping…" this language is confusing. provide the original period and then state specifically how it is expanded.

Page 137: First time "Microcystis bloom" is mentioned. Should be discussed in background information.

Page 147: "Additionally food enhancement actions, described at a programmatic level at this time, may provide additional food availability for delta smelt. The structured decision making process called for under this action will help to refine the potential benefits that may be realized." How would USFWS incorporate information from future research and actions into assessment?

Page 148: Delta Fish Species Conservation Hatchery- Provide more information to discuss possible positive and negative impacts associated with hatchery production. This also seems to cloud the purpose of the hatchery. Is it to help rebuild depleted delta smelt stock or to mitigate for the PA? Artificial propagation is a potential mechanism to aid recovery of U.S. Endangered Species Act (ESA)-listed stocks. Theoretically, one of the fastest ways to amplify population numbers for depleted stocks is through culture and release of hatchery-propagated fish. However, past attempts to use supplementation (i.e., the use of artificial propagation in an attempt to maintain or increase natural production) to rebuild naturally spawning populations of Pacific salmon have often yielded poor results. One solution is to develop protocols that increase fitness of hatchery-reared fish, thereby improving survival. A framework of conservation hatchery strategies to reduce potential impacts of artificial propagation on the biology and behavior of fish is presented. Operational guidelines for conservation hatcheries to help mitigate the unnatural conditioning provided by hatchery rearing are discussed and contrasted to those for production hatchery operation.

Page 148 - Tidal Habitat Restoration (8,000 acres)- how much has been constructed so far and what has been learned from it? Adaptive management? How much of the 8,000 acres has been built to date? How will information from previously constructed habitat be used to inform the rest of the construction? What happens if the Tidal restorations don't work? What is the timeline? Describe general adaptive management process to inform this. If this is mitigation, what happens if they do not work? Other than "increase available food web production for delta smelt" there is little indication of measurable goals and how they will benefit delta smelt other than a measure of 8,000 acres. Mitigation has specific ramifications under adaptive management. Insufficient information here to understand how success is determined and what will be done if different trajectory occurs.

Page 153: Simonis and Merz (2018) found that juvenile smelt preferred slightly saline, turbid, generally slow-moving water with ample copepod prey. However, poor swimming capabilities reduced juvenile smelt capacity to mix throughout the estuary and find optimal habitat, emphasizing the importance of accounting for spatiotemporal autocorrelation in species distribution models. Therefore, food must be produced where juveniles can access, or find within their poor swimming abilities. So either habitat is so amazing that it increases overall estuary prey availability or is built so that it provides food where each life stage would be expected to access it. Make sure that habitat rehabilitation takes availability and location to where life stage is expected to benefit into account.

Page 153: Adaptive Management is mentioned 6 times in document but not clearly articulated. What will the general AM process be for the PA?

Page 154: In discussion of re-connecting Shipping Channel to mainstem Sacramento River, include turbidity effects as potential outcome from flushing or moving water through the Shipping Channel.

Table 5-8. "OMR flows modeled to be more negative than COS. OMR management may reduce frequency and duration of those increases." In both cases, this does not read as neutral.

Page 169: Check throughout document "Old and Middle Rivers" should be "Old and Middle rivers"

Figure 5-47: Spell out acronyms and initials in figure titles. Makes it easier for review and for figures to stand alone.

Page 172: add timing to: Improve flow conditions – suitable flow conditions (i.e., velocity, [delta] freshwater outflow, salinity, tidal energy, flow suitable for spawning migration, to trigger movement to spawning areas, and egg incubation)

174: "However, the negative effect of this increase of entrainment will be minimized when supplementation of the wild delta smelt population occurs". I don't think this has been demonstrated by a hatchery program to date. Furthermore, it is unclear whether a hatchery operation can be proposed to mitigate for potential negative impacts from PA on Critical Habitat or direct take of wild DS. This is outside of my legal knowledge but does seem to create an issue.

Page 187: "Another key component of the FCCL and conservation hatchery project elements is the development of a supplementation strategy and genetics plan. The implementation of a supplementation program will provide benefits by maintaining a genetic bank and reintroducing individuals to alleviate effects of further population decline". Where is the information that supports these statements? The timing of this is confusing. Perhaps a time line might explain the process for habitat construction and completion; plan for hatchery supplementation including tracking success. How will hatchery fish be tracked for instance?

"The goal of this restoration program is to provide food web benefits to delta smelt in the North Delta Arc." Other than this single sentence and a reference to Moyle (2010), there is no clear description of this action. This should be more clearly described including timing, how projects are designed, how many there are etc. So the assumption is that these are simply food production areas and provide no physical habitat for DS? How much food does a viable DS population need? What examples of success have been demonstrated to date?

"The expected food production benefit of this action is anticipated to help sustain larger numbers of delta smelt in this area to reduce resource competition linked to food availability". However, the document states later that "The PA targets appropriate actions to improve delta smelt habitat, although the magnitude and timing of any benefits of habitat restoration and food web studies to delta smelt are uncertain." How is this reconciled?

"While the scale and timing of hotspot removal is not yet identified, it is assumed this action may reduce the congregation of predators in the Delta, but it is not known to what extent that will affect reproduction". Isn't a component of this action already occurring? How will this information inform adaptive management?

Page 188: "Reclamation proposes to limit effects to larval delta smelt by operating to avoid no greater than 10 % loss of the modeled larval and juvenile cohort". How was it determined that no greater that 10% loss is acceptable? Appendix 2 does not clarify this.

Page 189: PCE 2 – Water quality, "Sediment loading from the Sacramento River watershed continues to decline, reducing sediment load available for resuspension and turbid conditions, which likely reduces cover from predators and the light scatter that larvae need to find prey". I do not argue that turbidity does not influence DS success. However, the studies I have seen of turbidity effect on DS have used algae to create the independent variable. Examples are: Hasenbein et al. 2013; Baskerville-Bridges et al. 2004; Ferrari et al 2014. Therefore, I reiterate my previous comments: Turbidity is the measure of relative clarity of a liquid. It is an optical characteristic of water and is a measurement of the amount of light scattered by material in the water when a light is shined through the water sample. The higher the intensity of scattered light, the higher the turbidity. Material that causes water to be turbid include clay, silt, very tiny inorganic and organic matter, algae, dissolved colored organic compounds, and plankton and other microscopic organisms. Turbidity should be viewed as a measurement of what causes it. Again, the Lake Washington story provides an example of how complex this subject is (in this situation, turbidity was caused by both suspended particulates and phytoplankton). Within the BiOP (and many discussions of delta smelt), turbidity seems to be considered a habitat parameter, more so than the parameters that create turbidity or other conditions that tend to correlate with turbidity. For instance, lake turnover is typically a period of low water clarity and often corresponds with re-suspension of nutrients vital to the food web. Is it possible that relatively low turbidity may be an indication of reduced seasonal disturbance of the estuary that supports seasonal productivity? How might climate change affect this? Again, how might the PA influence this? Couldn't a shift to high phytoplankton production potentially support reduction of macrophytes?

Page 190- PCE 3 – River flow: Page 190- PCE 3 – River flow: While not directly synonymous with shallow lake ecology, I think much of what Scheffer and van Ness (2007) discuss is relevant to our understanding and management of vegetation- food pathways in the Delta and the assumption that aquatic vegetation hinders DS recovery. In short: theory inspired by observations that lakes tend to shift rather abruptly between a clear and turbid state; once lakes turned turbid, they subsequently resisted recolonization by aquatic macrophytes (Phillips et al., 1978; Meijer et al., 1989). Research revealed that both turbid and clear state were stabilized by a number of mechanisms (Moss 1988; Jeppesen 1998; Scheffer 1998). For instance, in turbid state, fish promote phytoplankton growth by

recycling nutrients and controlling zooplankton development that could otherwise help clear the water of phytoplankton. Also fish and waves may stir up sediments in shallow lakes with little or no vegetation. In this situation, light limitation and sediment disturbance make it difficult for submerged plants to settle. On the other hand, once submerged plants are abundant, they can greatly reduce turbidity by a suit of mechanisms resulting in control of excessive phytoplankton development and prevention of wave resuspension of sediments. This suggests more than one mechanism to influence turbidity and macrophyte proliferation beyond what is discussed in BiOp.

Page 190: Are there any assumptions of how the Voluntary Agreements to Improve Habitat and Flow in the Delta and its Watersheds might affect success of each life stage? Seems that this should be at least acknowledged.

Page 190- Summary of the Effects of the Proposed Action on Delta Smelt Critical Habitat: Under USFWS section 7 ba guideline, it states "Describe how the action may affect each protected resource - This section should document your conclusion and supporting rationale." In theory benefits of 8,000 acres of restoration is plausible. However, there is no clear evidence to suggest that this habitat enhancement will mitigate or mediate flow effects. Again, it is unclear what the purpose of these restoration-enhancement actions are for. Are they mitigation for previous operation impacts? If so, how can they be used to mitigate for PA? That is, shouldn't these actions be associated with past impacts that have simply not been implemented yet? Therefore, aren't they associated with Baseline? If I am confusing this, I would suggest it will be confusing to others.

Page 191- Summary of Aggregate Effects for Critical Habitat: Again, are the habitat enhancement actions meant to improve the current condition or mitigate future impacts?

Is DWR's proposed sediment reintroduction to recreate historic conditions that benefitted delta smelt part of the BA? Not enough information to evaluate.

Page 192: I have little legal expertise in this area. However, I wonder if hatchery supplementation can be used to mitigate for wild fish loss due to PA? Again, is hatchery for purpose of PA or was it developed for past effects? This appears to me to require better clarification.

Page 193: "Overall, the expansion of the FCCL and operation of a conservation hatchery for delta smelt will support our work to stabilize and improve population health". Again, this suggests the hatchery is proposed to mitigate for current population conditions. this clouds how it can be included in the PA.

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4.1 Materials Provided Prior to the Review

4.2 Supplemental Materials Review

4.3 Data Assessed

Appendix A
Appendix Title

Independent Review of the Coordinated Long-Term Operation of the Central Valley Project and State Water Project

Prepared for:
National Marine Fisheries Service
U.S. Fish and Wildlife Service

By:
Ernst Peebles, Ph.D.
3017 Seventh Avenue North, St. Petersburg, FL 33713

Executive Summary

It is my opinion that the best available information was generally used in preparing the US Fish and Wildlife Services Biological Opinion (BiOp) on Delta Smelt, with certain exceptions. The BiOp is generally based on good information, although some specifics were missing.

The success of the PA appears promising, but will depend on presently unavailable information, notably (1) lack of more specific information on Delta Smelt spawning habitat, (2) knowing whether or not operational aspects of the PA, including food enhancement actions and SMSCG operations, will improve Delta Smelt critical habitat in a manner that is understood in a process-based manner, and (3) knowing whether efforts at future stock enhancement will work.

In many cases, the interpretation of critical habitat is commendably process-based rather than being simply correlative. In other cases, the Service sensibly refrained from assuming too much about future operational effects of the PA, as studies of these have only recently begun (Delta Smelt food enhancement actions) or have not begun (stock enhancement via hatchery-raised fish). In the BiOp's effects analyses, Delta Smelt salvage was presented as being numerically inconsequential (i.e., no real potential for improving Delta Smelt abundance).

In this review, I suggest that information presented by ICF (2017, Figures 52-94), rather than by the BiOp, may have influenced interpretation of the effectiveness of the Fall X2 action within the BiOp. These figures are based on prey-organism density (i.e., the number of individual prey organisms per unit volume or unit area) rather than total abundance of such organisms within the LSZ; the latter would be more informative.

Additional research attention needs to be directed toward processes that support Delta Smelt success in different habitat settings, particularly as these relate to prey access under the PA. Some of this can be approached using experiments with hatchery-reared Delta Smelt.

It is commendable that researchers have been engaging approaches suggested by Reed et al. (2012), developing hypotheses/predictions based on the conceptual model for Delta Smelt (MAST 2015) that can be applied to adaptive management and can contribute to new PAs, and also that vital rates and condition indicators are being used as performance measures.

At a time when Delta Smelt numbers are perilously low, ceasing supportive actions such as the Fall X2 adaptive management action may not be prudent, even if the conclusions presented by ICF (2017) seem to make a case that X2 has a questionable relationship with Delta Smelt stock-recruitment.

A number of recommendations are made in this review, including requests for more comprehensive information on the data types and analyses used in preparing the BiOp and clarification of the types

of data that will be considered by the Delta Coordination Team while evaluating the management of the SMSCG.

When investigating the pelagic organism decline, I also suggest that all energy pathways should be considered, not just plankton-based ones. Specifically, different forms of benthically based primary production should be evaluated in regard to Delta Smelt production.

TABLE OF CONTENTS

1 Introduction

In this second phase of the review process for the BiOp, **text from the original review is retained and is underlined**. New text is not underlined.

1.1 Background

The Delta Smelt appears to be at a critically important crossroads regarding both its status and the development of scientific knowledge that affects its management as a federally listed, threatened species. Recent years have yielded an abundance of new insights into how the Delta Smelt uses habitat. As a result, the new Proposed Action (PA) for Delta Smelt management has become more adaptive and better informed.

1.2 General Observations

Many aspects of the PA, such as entrainment modeling, have evolved into more-or-less established routines over the years, whereas other aspects of the PA are based on the evaluation of ecosystem processes that are, in turn, based on newer information and insights. In general, I have found the quality of science that contributes to Delta Smelt management to be very high.

1.3 Review Activities

The review approach used here was to first read materials that influenced the US Fish and Wildlife Service's ("Service") most recent Biological Opinion (BiOp) on the US Bureau of Reclamation's ("Reclamation") revised PA for Delta Smelt, including Reclamation's Biological Assessment and the materials listed at the end of this document under "Materials Provided Prior to the Review." These readings were followed by reading the BiOp itself, including the two appendices listed under "Supplemental Materials Review." At the request of Anchor QEA, questions were developed from these readings that would later be asked of Service personnel during a conference call on April 19, 2019. The list of questions was submitted to Anchor QEA one day prior to the conference call for submission to Service personnel. The first part of the conference call involved introductions among the three reviewers (Ernst Peebles, Ronald Kneib, Joseph Merz) followed by a general discussion of the state of knowledge of Delta Smelt and some known processes that might affect its status. The most notable concern that I raised during the call involved the lack of knowledge about how benthic processes might affect Delta Smelt. The other two reviewers concurred with my concern, and I have elaborated on this topic within this review document. There were no substantive disagreements among the three reviewers during the conference call. The second part of the conference call entailed asking Service personnel our pre-prepared questions. I found their answers to be

satisfactory and informative. After the conference call, we were given one week, as determined previously, to prepare our respective reports.

The version of the BiOp that was used for the initial review was substantially revised and sent out for a second review that maintained the same format as the first one (described above). The second review was conducted from July 31 through August 12, 2019, with four reviewers (Ernst Peebles, Ronald Kneib, Joseph Merz, and Mike Chotkowski) participating. While the recent revisions to the BiOp clearly involved a good-faith effort to accommodate the comments and suggestions that were made during the first review, the provided version also contained a large amount of new information that the reviewers had not seen before.

The first step in my review process was to conduct electronic document comparisons to identify the changes that had been made. This was followed by verification that all of my original comments and suggestions had been addressed, which was facilitated by a Peer Reviewer Comment Disposition Table that was provided to the reviewers by the Service. Within that table, the Service identified 20 topics among my original comments and suggestions; these 20 topics were found to be comprehensive in representing my original review (i.e., I found that nothing was omitted). These topics have been numbered in this version of the review as (1), (2), (3) … (20).

Among the 20 identified topics, responses by the Service indicated "comment noted" (five topics), recognition that the comments did not need to addressed in the revised BiOp (four topics), statements indicating agreement with the comments, but with no action taken (four topics), and an explanation that the Service was limited by the level of detail provided to it by Reclamation (one topic). Collectively, I defer to the Service's judgment on these 14 topics. The remaining six topics involved actions by the Service in the form of edits to the BiOp. Four of these six actions were deemed acceptable, leaving two related topics, (13) and (15), that required additional comments during the second review. Both of these topics involve energy pathways and trophic relationships. The Service was responsive to these two topics in their revision of the BiOp, but I felt that additional information needed to be considered by Service scientists, after which the Service can use its own judgment regarding how or whether to reach a solution.

The set of questions presented to the reviewers was revised for the second review, and this included two new questions that were addressed in this review for the first time:

> 2.1.3 Are there alternative interpretations of the best available scientific information with respect to species status, critical habitat, and effects of the proposed action that are equally well supported by the data (i.e., scientific information, analyses) that were not presented in the biological opinion that merit consideration?

2.3 Question 3: How well does the BiOp incorporate new actions added to the Proposed Action by Reclamation, particularly the Delta Smelt Summer-Fall Habitat action?

Finally, the rather extensive new text in the revised BiOp was reviewed for the first time, and a new series of topics for consideration was placed within Section 3, "Additional Thoughts, Concerns, and Suggestions for Improvements to the Analyses."

2 Responses to Questions

2.1 Question 1: How well does the BiOp use best available scientific and commercial information? Specifically:

2.1.1 Do the analyses in the status of the species and critical habitat, and environmental baseline sections reflect the best available scientific and commercial information?

The general answer to this question is yes, the best available information was used, given exceptions that are discussed in Sections 2.1.1 and 2.1.2. Some important types of information are not available at present, including (1) lack of more specific information on Delta Smelt spawning habitat, (2) whether or not operational aspects of the PA, including food enhancement actions and SMSCG operations, will improve critical habitat in a manner that is understood in a process-based manner, and (3) whether efforts at future stock enhancements using hatchery-raised Delta Smelt will work.

(1) There is considerable information available on the status of the Delta Smelt, its critical habitat, and the environmental baseline, and the BiOp makes good use of this information. The BiOp cannot make use of unavailable, yet important, information, notably the lack of more specific information on Delta Smelt spawning habitat (i.e., spawning-habitat characteristics and geographic locations). Likewise, the BiOp statement "*The degree to which movement of delta smelt around the LSZ is constrained by opening and closing the SMSCG is unknown*" identifies another important piece of information on critical habitat that is unavailable (p. 25, Draft Delta Smelt Effects Analysis). This latter type of information is important because the success of the PA, in part, hinges on beneficial aspects of SMSCG operations, yet these beneficial processes are not explicitly known. The BiOp is based on good information, but the success of the PA depends on important, yet unavailable, information.

(1) USFWS response: "Comment noted"

(1) Reviewer comments on USFWS response/revisions:

In the new statement (p. 74, bold type added) 'Under the "without action" scenario described in the BA, the status of the delta smelt would be improved because there would be no entrainment

or salvage loss, OMR flows would generally be positive, Delta outflow would likely be higher in the spring and lower in the summer and fall, the location of X2 and the low salinity zone would likely be more favorable for delta smelt during some seasons and hydrologic year types, more sediment supply in the winter and spring would increase turbidity, and **there would be more spawning substrate during the high-flow winter/spring period**,' it is not clear why the amount of spawning substrate would increase during high-flow periods. High flows can be depositional, erosional, or can change the amount of available shallow-water habitat simply by elevating water levels in relation to the local hypsographic curve. Because interactions between these three processes can be very complex, the support for this statement is not clear (the BA seems to indicate there will be more sand deposition under high flows, at least at some locations). Also, the process wherein high flows elevate water levels relative to the hypsographic curve diminishes in strength as the cross-sectional area of the estuary increases in the seaward direction due to the presence of drowned-river-valley geomorphologies. If Delta Smelt take advantage of high flows that deepen shoreline banks/ledges and thereby increase the amount of available spawning habitat, then the advantage will diminish downstream where cross-sectional areas are larger. However, I got the impression (based on the BA) that this statement is a reference to new sand deposition under high-inflow conditions; this statement needs clarification/expansion, and if it is, in fact, an allusion to sand deposition, then more discussion of spatial variation needs to be discussed, specifically regarding what we know and what we don't, along with acknowledgments of uncertainty.

(2) In some cases, a single gear type, data type, or analysis is used to characterize information for which there are multiple gear types, data types, or analyses available (e.g., Figure 4, Draft Delta Smelt Status and Critical Habitat). It would be helpful if these other types of information could be acknowledged in the document as having been considered during BiOp development. Otherwise, the reader cannot determine the extent of the information considered.

(2) USFWS response: "We added graphics to show other surveys. Figure 4 was deleted from subsequent drafts."

(3) The 2016 changes to the Delta Smelt critical habitat definition (Table 2, Draft Delta Smelt Status and Critical Habitat) were particularly useful for orientation purposes, and are appreciated. The evolution of guidelines within this table is evidence of clear progress.

(3) USFWS response: "We appreciate the positive feedback."

(4) The interpretation of critical habitat is commendably process-based rather than being simply correlative. Reduced prey availability is acknowledged as a likely cause of Delta Smelt decline, and it is also acknowledged that the Delta Smelt declines did not coincide with the overbite clam invasion (one major Delta Smelt decline preceded the clam invasion and a second occurred 15 yrs after the invasion). The recognition that refuges from strong tidal flows are part of the Delta Smelt habitat definition is also important in a process-based sense, as strong tidal flows would tend to disperse the Delta Smelt's zooplankton prey. Likewise, process-based support for turbidity as a critical habitat element was offered in the suggestion that darkfield (caused by turbidity) is a better visual environment for Delta Smelt detection of transparent organisms (planktonic prey) than brightfield; this could be explored experimentally using hatchery-reared Delta Smelt. The Service already plans to use cultured fish enclosures to investigate the possibility that Delta Smelt use turbidity to hide from predators or to minimize competition. Turbidity in the LSZ is not simply characterized as a water-quality parameter, but is instead described as turbidity fronts that move with X2, where vertical haloclines exist in the water column. Regarding salinity, the critical habitat description observed "*This contrast between where most wild delta smelt are found and what laboratory research indicates they can easily tolerate suggests one of two things. Either there is a persistent laboratory artifact, or it may be evidence that delta smelt's distribution along the estuary salinity gradient is due to a factor or factors other than salinity per se.*" Given the history of habitat analysis in estuaries, the latter part of this suggestion is particularly progressive.

(4) USFWS response: "We appreciate the positive feedback. We clarified that the darkfield comment has been tested for first-feeding larvae."

2.1.2 Are assumptions in the effects analysis clearly stated and reasonable based on current scientific thinking?

(5) The entrainment portion of the effects analysis appears to be based on well-established methods, models, and associated assumptions. It is recognized that larger Delta Smelt can modulate their positions within the Delta rather than being incorrectly assumed to act as passive particles. Other aspects of the effects analysis, notably larval entrainment into the CVP and SWP canals and the absence of information on predation studies in the vicinity of

Clifton Court Forebay, prevented assessment of any assumptions that would be associated with these analyses. Salvage was presented as being numerically inconsequential (i.e., no real potential for improving Delta Smelt abundance in the LSZ area), and was thus not examined closely. The Service sensibly refrained from assuming too much about future operational effects of the SMSCG and the food enhancement actions, as studies of these have only recently begun. The idea of stock enhancement via hatchery-raised fish has not been implemented, and so no assumptions were made about its effects, either. These approaches appear reasonable, given that the present lack of information will be addressed using an adaptive management approach, as suggested by Reed et al. (2012).

(5) USFWS response: "We apologize that the larval entrainment analysis was not ready in time for this review. Beyond that, the positive feedback is helpful and appreciated."

2.1.3 Are there alternative interpretations of the best available scientific information with respect to species status, critical habitat, and effects of the proposed action that are equally well supported by the data (i.e., scientific information, analyses) that were not presented in the biological opinion that merit consideration.

Regarding the Delta Smelt's apparent lack of shift to higher salinities after the overbite clam invasion (Figure 5-24 and text on p. 107-108), truly pelagic species (those which depend solely on dynamic habitat) are capable of quickly adapting to changing hydraulic and prey-field conditions. While the Delta Smelt may be a pelagic species under the definitions used in the BiOp, the species remains physiographically tied to landward spawning habitats (i.e., stationary habitats). Anchovies, in contrast, may move their spawning habitats seaward whenever river flows increase (Peebles et al. 1995, Peebles 2002). The Delta Smelt can't do this because it relies on a combination of dynamic and stationary habitats during its life cycle. The fact that larvae remain near spawning grounds (p. 157, 2nd paragraph) is further evidence that this species is tied to stationary (immovable) habitats at the landward end of its range.

The description of the loss of mining-related sediment (bottom of p. 89 and top of p. 152) gives the impression that Delta Smelt were dependent on it for PCE 2-water (i.e., turbidity). Whereas the system of dams in the Central Valley permanently decreased sediment loads to the valley, hydraulic mining only increased sediment loads for the period of time mentioned here (1850s-1990s). Because the Delta Smelt evolved to occupy the Delta long before mining ever started, mining-related

sediments, at best, served to offset the permanent loss of sediments that was associated with construction of the Central Valley dam system.

2.2 Question 2: Does the BiOp adequately analyze effects of the proposed action on delta smelt and critical habitat?

(6) As mentioned in Section 2.1.2, some effects were not analyzed (i.e., certain types of entrainment and predation abatement), and several other aspects of the PA are either too new to be analyzed (i.e., food enhancement actions) or have not been tested at all (i.e., stock enhancement).

(6) USFWS response: "Subsequent drafts were edited to address this comment."

2.2.1 Did the Service adequately analyze effects for both standard/site-specific (described at a site-specific level with no future consultation required) and programmatic (which require future consultation before they can be implemented) components of the proposed action?

I am not an expert on the types of models that were used to estimate entrainment, and therefore will not evaluate those. I did appreciate that it was recognized that the larger stages of Delta Smelt are capable of modulating their upstream-downstream positions via selective tidal stream transport ("tidal surfing") and by taking advantage of winter storms during their dispersal period (i.e., they are not passive particles).

(7) Lack of information on larval entrainment into the CVP and SWP canals appears to be a primary shortcoming of the effects analysis. Likewise, the absence of information on predation analyses in the vicinity of Clifton Court Forebay also prevented assessment (p. 16).

(7) USFWS response: "Subsequent drafts were edited to address this comment."

(8) The significance of the salvage analysis was greatly diminished by the statement "*The salvage of delta smelt does not return meaningful numbers of delta smelt back into the Delta and current TFCF and Skinner Fish Facility protocols dictate that delta smelt that are subsampled*

for fish counts are euthanized and retained in order to determine gender and sexual maturation of each individual" (p. 18).

(8) USFWS response: "This sentence was intentional and meant to plainly state the implications of three things: low abundance, high pre-screen loss, and successful recent management strategies."

(9) All of the relevant Delta operations appear to have been carefully treated, yet from the perspective of Delta Smelt, the PA has particular emphasis on SMSCG operation. However, the fundamental processes that influence Delta Smelt interaction with Suisun Marsh (such as movement, feeding, predator avoidance) are poorly understood at present, and thus a realistic effects assessment of this part of the PA cannot be made (this problem is discussed in more detail at the end of Section 2.2.2). Given this lack of information, it appears that management of the SMSCG will be monitored, and possibly modified, on an annual basis by a Delta Coordination Team. Additional detail on this adaptive management process, including the types of data that will be considered by the team, is needed.

(9) USFWS response: "The Service analyzed the actions that were proposed at the level of detail we received from Reclamation.

(10) There is a similar lack of information of the various food enhancement actions (Suisun Marsh, Ship Channel, Colusa Basin) that prevents assessment of the associated effects, and this is acknowledged in the document (p. 26). It is not clear how these will be adaptively managed.

(10) USFWS response: "Comment noted"

(11) In regard to introduction of cultured Delta Smelt into the Delta, the assessment takes a progressive approach in its ambition to preserve the existing genetic diversity of Delta Smelt. Field tests of the predation competence of released fish are also both planned and warranted.

(11) USFWS response: "We appreciate the positive feedback."

2.2.2 Are the methods utilized appropriate to determine if the proposed action is likely to jeopardize delta smelt or adversely modify its critical habitat?

(12) Under most considerations, the answer to this question is yes. An exception is data presented by ICF (2017, Figures 52-94) rather than by the BiOp, which may have influenced interpretation of the effectiveness of the Fall X2 action within the BiOp. Those figures generally show little or no responsiveness between X2 and the densities of several Delta Smelt prey types (copepods, mysids, and amphipods). The problem is density (i.e., the number of individual organisms per unit volume or unit area) does not completely represent the abundance of prey within the LSZ. Prey abundance within the LSZ would be better portrayed as the product of density and the size of the LSZ, with the size of the LSZ represented as volume (copepods, mysids) or possibly area (amphipods). Because the size of the LSZ increases dramatically as X2 moves downstream, the effect of Fall X2 (and other X2-based actions) on prey abundance in Delta Smelt critical habitat is likely to be much larger than what is suggested by these figures.

The above consideration is analogous to the concept of nitrogen loading in estuaries, as chemical concentrations and organism densities are analogous units of measure. In its simplest form, nitrogen loading is the product of nitrogen concentration and freshwater-inflow volume. This simple calculation can expose counterintuitive results, such as cases where large volumes of low-concentration nitrogen result in larger loadings than small volumes of high-concentration nitrogen. Likewise, large volumes of low-density copepods may contain more total copepod prey than small volumes of high-density copepods.

(12) USFWS response: "We agree…"

(13) Mysids and amphipods are recognized as being prey types used by Delta Smelt (Slater and Baxter 2014, Hammock et al. 2017), yet both mysids and amphipods are benthically associated (i.e., bottom-associated). The role of water management on different forms of benthic primary production appears to have been largely overlooked by studies of the general ecology of the LSZ. Some forms of benthic primary production are imported to estuarine sediments or to the sediment-water interface, rather than being produced there. These include phytodetritus (i.e., phytoplankton cells that have sunk to the bottom and are decomposing there), vascular wetland detritus (i.e., decomposing marsh-grass litter), and allochthonous (imported) vascular plant detritus from the watershed (i.e., decomposing

agricultural and riparian plant litter). Other forms of benthic primary production are more truly benthic in origin, such as benthic diatoms, benthic macroalgae, and rooted aquatic vegetation, inclusive of exotics. The idea that benthic diatoms are limited to the intertidal zone needs to be abandoned, particularly as decreasing turbidity in the LSZ (Figure 14, lower left panel, Draft Delta Smelt Status and Critical Habitat) has improved the light environment for benthic primary producers. Benthic diatoms can be the dominant primary producers in shallow waters, or even in waters >100 m depth on the continental shelf (Cahoon et al. 1990). Any or all of the above forms of benthic primary production can be important within the energy pathways that support individual species at higher trophic positions such as Delta Smelt, although typically one or a few are more important than others.

The significance of benthic production is that even classically pelagic species such as Delta Smelt can be dependent on benthic energy pathways at least part of the time (Rooney at al. 2006), which is reflected in the occasional presence of mysids and amphipods in the Delta Smelt's diet (Slater and Baxter 2014, Hammock et al. 2017), with amphipods, in particular, being strongly associated with benthic primary productivity of one form or another. Although the routine energy pathways that support pelagic species such as Delta Smelt may be primarily plankton-based, plankton production is closely linked to freshwater inflow patterns and is thus sporadic and unreliable over time. During times when plankton production is low, pelagic fishes such as Delta Smelt may be supported by benthic energy pathways (Slater and Baxter 2014), and this possibility makes such pathways potentially critical to their survival (Vander Zanden and Vadeboncoeur 2002, Rooney et al. 2006, Higgins and Vander Zanden 2010). Benthic prey such as mysids and amphipods are typically physically larger than planktonic prey species such as copepods, and both this larger body size and the more stable nature of their own benthic primary-producer food base (i.e., their basal resource) tend to allow their abundances to be more stable over time, making them more available as a food resource at times when plankton-based prey are less available (Rooney et al. 2006).

An organism's dependence on benthic prey can be somewhat cryptic, wherein trophic intermediates mask the benthic dependence. For example, individual Blackfin Tuna (another classically pelagic species) may have isotopic signatures that suggest substantial dependence on benthic energy pathways, yet this species is known to primarily feed in the water column rather than at the bottom. Diet analyses have revealed that squids are an important diet item for Blackfin Tuna, and squids prey heavily on benthic shrimps and crabs, therein establishing the connection between Blackfin Tuna and benthic energy pathways. The Delta Smelt, on the other hand, has direct evidence of occasional dependence on benthic energy pathways in the form of direct consumption of benthically associated mysids and amphipods (Hammock et al. 2015). When investigating the pelagic organism decline (e.g., Figure 4, Draft Delta Smelt

Status and Critical Habitat), all energy pathways should be considered, not just plankton-based ones.

(13) USFWS response: "Subsequent drafts were edited to address this comment"

(13) Reviewer comments on USFWS response/revisions:

As mentioned above, there is tremendous potential for benthic/epiphytic processes to periodically subsidize the energy pathways that support Delta Smelt biomass, and these subsidies may occur at critical times of need, yet such pathways remain underemphasized and understudied. This was partly addressed (middle of p. 98); additional discussion of this prospect is included in the following two paragraphs.

It is common for estuarine amphipods to rise into the water column (p. 93-94) to relocate to newly formed depositional areas, where they feed on deposited detritus and other organic materials; their successive landward movements via repeated use of selective tidal stream transport (STST, or "tidal surfing") diminish in terms of distance of upstream travel, but ultimately place them within depositional habitats. This behavior results in the amphipods spending a great deal of time in the water column, especially when the water is dimly lit. Being in the water column may make the amphipods more available as prey for Delta Smelt, but the amphipods are nevertheless energetically tied to benthic basal resources, despite their spending a great deal of time in the water column (i.e., they are still energetically tied to primary production that is bottom-associated: vascular plant detritus, phytodetritus, or benthic microalgae, as opposed to phytoplankton). Mysids, on the other hand, are harder to generalize, as some species are herbivorous, some are predatory, and some are omnivorous. They also use STST, which likely increases their availability to Delta Smelt. Thus, depending on mysid species, they may or may not link Delta Smelt to benthically driven energy pathways.

Jassby et al. (1993) estimated benthic microalgae to be responsible for nearly 30% of the autochthonous primary production in upper San Francisco Bay, inclusive of Delta Smelt habitat (their Table 3). Light penetration has since improved as turbidity has decreased within the LSZ (i.e., Jassby et al.'s parameter z_p has increased), and so this ~30% contribution has likely increased dramatically. Jassby et al. (1993) provided no estimate for epiphytic microalgae associated with SAV and the zones of emergent grass stems (in marshes) that are near the surface and within the photic zone. Even if the photic zone is just a few centimeters deep, these substrates, when added together, can provide very large surface areas for epiphytic production.

(14) Another observation that supports investigation of periodic benthic dependence by Delta Smelt is the fact that the calanoid copepod genus *Pseudodiaptomus* is generally considered to be demersal (i.e., bottom oriented). *Psuedodiaptomus forbesi* is an exotic calanoid copepod from Asia that has replaced a large part of the biomass of the native calanoid copepod *Eurytemora affinis* within the LSZ (Draft Delta Smelt Status and Critical Habitat). Thus, the Delta Smelt has had one of its more important planktonic prey items replaced by a more bottom-oriented one. What effect has this change had on Delta Smelt feeding?

(14) USFWS response: "We agree with the comment, but think feeding selectivities have only been evaluated in lab settings where *P. forbesi* cannot invoke this behavior (e.g., Meng and Orsi 1991 for striped bass larvae and Sullivan et al. 2016 for delta smelt and striped bass). We did not add discussion of this issue because we felt it would be unnecessarily speculative."

(15) While most species of fish appear to be dependent on a combination of plankton-based and benthos-based energy pathways (Higgins and Vander Zanden 2010, Zeug et al. 2017), there is variability among individual species regarding their capacity for adaptive trophic behaviors that help them cope with changing energy pathways and available prey types (Valdovinos et al. 2010; see also Figure 2, Vander Zanden and Vadeboncoeur 2002). Higgins and Vander Zanden (2010) stated *"…the inability of some fish species (e.g., obligate planktivores or deepwater benthic fish) to fully utilize benthic–littoral energy pathways may result in declines in individual body condition, reproduction, and recruitment …"*. In this statement, "benthic-littoral energy pathways" acknowledges the tendency for shoreline (littoral) prey communities, particularly along shorelines that are made structurally complex by emergent, submerged, or floating shoreline vegetation, to resemble benthic prey communities.

(15) USFWS response: "To address this comment, we added text and supporting data about the diversity of delta smelt prey and how prey use changes as the fish get older. This also addressed similar comments by Dr. Merz."

(15) See "Reviewer comments on USFWS response/revisions" for topic (13) above.

(16) In the PA, attention is being directed to prey production in the North Delta Habitat Arc (Cache Slough Complex through Suisun Marsh) where Delta Smelt have been most persistently observed. The 2016 floodplain fish food augmentation effort (ICF 2017) appears to have successfully increased fish food availability in the Sacramento River, notably as the result of rice farmers retaining and releasing water and by flushing other quiescent areas such as the Ship Channel into Delta Smelt habitat.

(16) USFWS response: "No comment to address here"

(17) It is commendable that researchers have been engaging approaches suggested by Reed et al. (2012), developing hypotheses/predictions based on the conceptual model for Delta Smelt (MAST 2015) that can be applied to adaptive management and can contribute to new PAs, and also that vital rates and condition indicators are being used as performance measures (p. 25, Draft Delta Smelt Effects Analysis, Hammock et al. 2015, Sommer and Conrad 2018, Sommer et al. 2019). For example, Hammock et al. (2015) found Delta Smelt within Suisun Marsh to have relatively high stomach fullness and relatively low incidence of histopathological lesions than Delta Smelt from other areas associated with the LSZ. This is interesting because Suisun Marsh has a large ratio of shoreline length to open water area, and this physiographic condition tends to favor benthic-littoral energy pathways, as discussed above (see Figure 2, Vander Zanden and Vadeboncoeur 2002).

Ultimately, however, the "*degree to which movement of delta smelt around the LSZ is constrained by opening and closing the SMSCG is unknown*" (p. 25, Draft Delta Smelt Effects Analysis), as is whether the Delta Smelt is capable of exploiting benthic-littoral energy pathways, as suggested by Slater and Baxter (2014), in a manner that improves vital rates or body condition. The latter issue could be addressed using experiments with hatchery-reared Delta Smelt. In general, additional research attention needs to be directed toward processes that support Delta Smelt success in different habitat settings, particularly as these relate to prey access under the PA. For example, was the Delta Smelt response in Suisun Marsh (Sommer and Conrad 2018, Sommer et al. 2019) due to active habitat selection (i.e., for lower salinity, higher turbidity, suitable temperatures, quiescent waters) via swimming, advection of Delta Smelt into a larger area of habitat, better in situ survival due to increased productivity (higher chlorophyll a concentrations in Suisun Marsh) and associated prey availability, or a combination of these processes?

(17) USFWS response: "We appreciate the positive feedback, however, no comment to address here; the question at the end would be for DWR researchers."

(18) At a time when Delta Smelt numbers are perilously low, ceasing supportive actions such as the Fall X2 adaptive management action may not be prudent, even if the conclusions presented by ICF (2017) seem to make a case that X2 has a questionable relationship with Delta Smelt stock-recruitment (however, see the first paragraph of this section as it relates to ICF's third conclusion). X2 does appear to interact with turbidity at some locations (ICF 2017). In regard to the high river flows of 2011, implementation of the Fall X2 action was coincident with successful Delta Smelt recruitment, leading to the highest Delta Smelt abundances observed in many years.

(18) USFWS response: "Comment noted"

2.3 Question 3: How well does the BiOp incorporate new actions added to the Proposed Action by Reclamation, particularly the Delta Smelt Summer-Fall Habitat action?

My original review included comments on these actions within topics (1), (9), (10), (12), (16), and (17). Topics (13) and (15) are also related, albeit more tangentially. All of these comments still stand within the context of this second review. The expectations for the outcomes of the Summer-Fall habitat action are based on sound ecological principles, but have little or no data to support individual components. If I were to identify important oversights regarding these actions, these would include (a) categorizing the Delta Smelt as "pelagic" tends to conceptually overshadow its strong ties to stationary habitats (PCE 1) such as spawning habitats and possibly to marsh-based or other shallow-water primary productivity sources that subsidize Delta Smelt biomass [see third paragraph in my new comments to topic (13)], and (b) although these ties to stationary habitats may be reconciled through (potentially expensive) migration, dependence on stationary habitat distinguishes the Delta Smelt from most other pelagic species that simply move back and forth as freshwater flows to the estuary increase and decrease. Given the Delta Smelt's ties to stationary habitats, scientists should look for evidence whether X2, when positioned too far downstream, is detrimental to Delta Smelt. Some might see this as anathema to the overall history of interpreting X2 effects on Delta Smelt, but the relationship should be re-examined anyway.

Given the very low recent abundance-index values for Delta Smelt, taking new, ecologically sound steps toward recovery are justified, even if supporting data are lacking. Requiring solid uncertainty estimates for these actions before they can be implemented would seem to be neither reasonable nor prudent. I noticed that flooding rice fields for food enhancement is not mentioned in the BiOp, and presume this is due to the associated risk from agricultural chemicals and/or the difficulty of making such a voluntary partnership part of a programmatic action. Regardless of the actual implementation details, enhancement of PCEs (notably stationary habitats, food, turbidity, and temperature) is a defendable approach.

3 Additional Thoughts, Concerns, and Suggestions for Improvements to the Analyses

(19) The introduction of slow-moving water from the Ship Channel and flooded rice fields has the potential to introduce copepods as well as phytoplankton into the LSZ. Achieving this objective (i.e., introducing copepods instead of just phytoplankton) would depend on the length of time that the fields remained flooded relative to the subitaneous generation times of the copepods; copepod generation times are temperature dependent.

(19) USFWS response: "Comment noted."

(20) Hatchery-raised Delta Smelt could be used to compare the condition of fish fed copepods vs. those fed mysids or amphipods. Because mysids and amphipods are larger than copepods, younger Delta Smelt are likely to be gape-limited and older ones may experience long handling times while consuming such prey. Feeding experiments could determine the extent of these potential restrictions. It is likely that these larger prey types will only be relevant to Delta Smelt during times of year when the fish are larger.

(20) USFWS response: "Comment noted."

Note that the following six paragraphs repeat previous material in summary fashion.

In some cases, a single gear type, data type, or analysis is used to characterize information for which there are multiple gear types, data types, or analyses available (e.g., Figure 4, Draft Delta Smelt Status and Critical Habitat). It would be helpful if these other types of information could be acknowledged in the BiOp as having been considered during its development. Otherwise, the reader cannot determine the extent of the information considered.

It appears that management of the SMSCG will be monitored, and possibly modified, on an annual basis by a Delta Coordination Team. Additional detail on this process, including the types of data that will be considered by the team, needs to be presented. A similar request can be made for the food enhancement actions in Cache Slough, the Ship Channel, and the Colusa area.

Prey abundance within the LSZ, as characterized by ICF (2017), rather than the BiOp, would be better portrayed as the product of density and the size of the LSZ, with the size of the LSZ represented as volume (copepods, mysids) or possibly area (amphipods).

When investigating the pelagic organism decline (e.g., Figure 4, Draft Delta Smelt Status and Critical Habitat), all energy pathways should be considered, not just plankton-based ones. Specifically, different forms of benthically based primary production should be evaluated in regard to Delta Smelt production.

It is commendable that researchers have been engaging approaches suggested by Reed et al. (2012), developing hypotheses/predictions based on the conceptual model for Delta Smelt (MAST 2015) that can be applied to adaptive management and can contribute to new PAs, and also that vital rates and condition indicators are being used as performance measures.

At a time when Delta Smelt numbers are perilously low, ceasing supportive actions such as the Fall X2 adaptive management action may not be prudent, even if the conclusions presented by ICF (2017) seem to make a case that X2 has a questionable relationship with Delta Smelt stock-recruitment.

Other reviewer responses to new material in the revised BiOp:

There was a considerable amount of new material in the revised BiOp that the reviewers saw for the first time during the second phase of this review. Below are comments derived from this new material.

In the new statement (p. 81, bold type added) 'In the Service's 2008 BiOp, the RPA required protection of all life stages from entrainment and augmentation of Delta outflow during the fall of Wet or Above-Normal years as classified by the State of California (Service 2008). The expansion of entrainment protection for delta smelt in the 2008 BiOp was in response to large increases in juvenile and adult salvage in the early 2000s (Kimmerer 2008; Brown et al. 2009). **The fall X2 requirement was in response to increased fall exports that had reduced variability in Delta outflow during the fall months and were anticipated to reduce it further (Feyrer et al. 2011)**,' is not clear. I could not locate support for this statement within Feyrer et al. (2011). As written, the statement suggests that reduced fall flows (higher outflow and X2) resulted in higher entrainment, and so increased fall flows may have been intended to reduce entrainment. Even if that was the sole intent of increased fall flows/lower X2, the action could have had other positive effects, whether known or unknown (e.g., future size-specific fecundity could have increased due to better fall feeding conditions by future spawners).

In the new statement (p. 81-82, bold type added) 'The current estimated **delta smelt population sizes are so low that it seems unlikely the species can be** habitat- or **food-limited** even though both physical and food web-related habitat attributes have degraded over time,' it should be recognized that other species also consume the same prey as Delta Smelt. The new statement (p. 82, bold type added) 'The extremely low 2018-2019 abundance indices reflect decades of habitat change and marginalization by **non-native species that** prey on and **out-compete delta smelt**' is consistent with this idea, but appears to conflict with the previous statement.

The new statement (p. 82, bold type added) 'When fish populations reach very low levels, they can fall victim to demographic problems (often termed Allee effects in the scientific literature). These include problems concentrating enough individuals in particular locations for successful spawning, successful feeding, or **maintaining large enough shoals or schools to provide effective protection from predators** (Liermann and Hilborn 2001; Keith and Hutchings 2012),' applies to all life stages, not just older fish. For example, if the spawning stock cannot produce enough eggs or larvae to overwhelm egg or larval predators, then all eggs or larvae will be eaten and there will be no juvenile recruitment.

The new statement (p. 84, bold type added) 'In addition, semi-anadromy and partial diadromy are scale-dependent terms which have caused confusion among researchers and managers alike. For instance, some individual delta smelt clearly migrate between fresh and brackish water during their lives (Bush 2017). **Other individuals could appear to have done so based on otolith microchemistry but in reality have moved very little and simply experienced annual salinity variation**, which can be very high in much of the range of delta smelt (see Hammock et al. 2019)' points out a common data-interpretation problem wherein natural tags cannot distinguish the subject animal's movement from water-mass movement or prey movement (i.e., when prey movement to a stationary predator affects the predator's stable isotopes). This is a reviewer comment rather than a constructive criticism of the statement.

The new statement (p. 87) 'SAV tends to grow where tidal current velocities are low' may be true within the action area, but it is not true in all estuaries. Florida has spring-fed estuaries where SAV growth is luxuriant in fast-flowing, spring-fed waters. The same lack of generality is true for turbidity (p. 89), which can be dominated by phytoplankton or precipitates/flocculants in some estuaries (i.e., not river-borne sediments or re-suspended bed loads).

4 References

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4.2 Supplemental Materials Review

Appendix 1 TN_40_2008_BiOp_effect_from_pop_dynamics_persp_v4_FebMar.pdf

Appendix 2 TN 37__v5.pdf

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