PUBLIC POLICY INSTITUTE OF CALIFORNIA

Managing California's Freshwater Ecosystems

Lessons from the 2012–16 Drought

Technical Appendix

Eight Case Studies of Environmental Water Management during the 2012–16 Drought

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Introduction

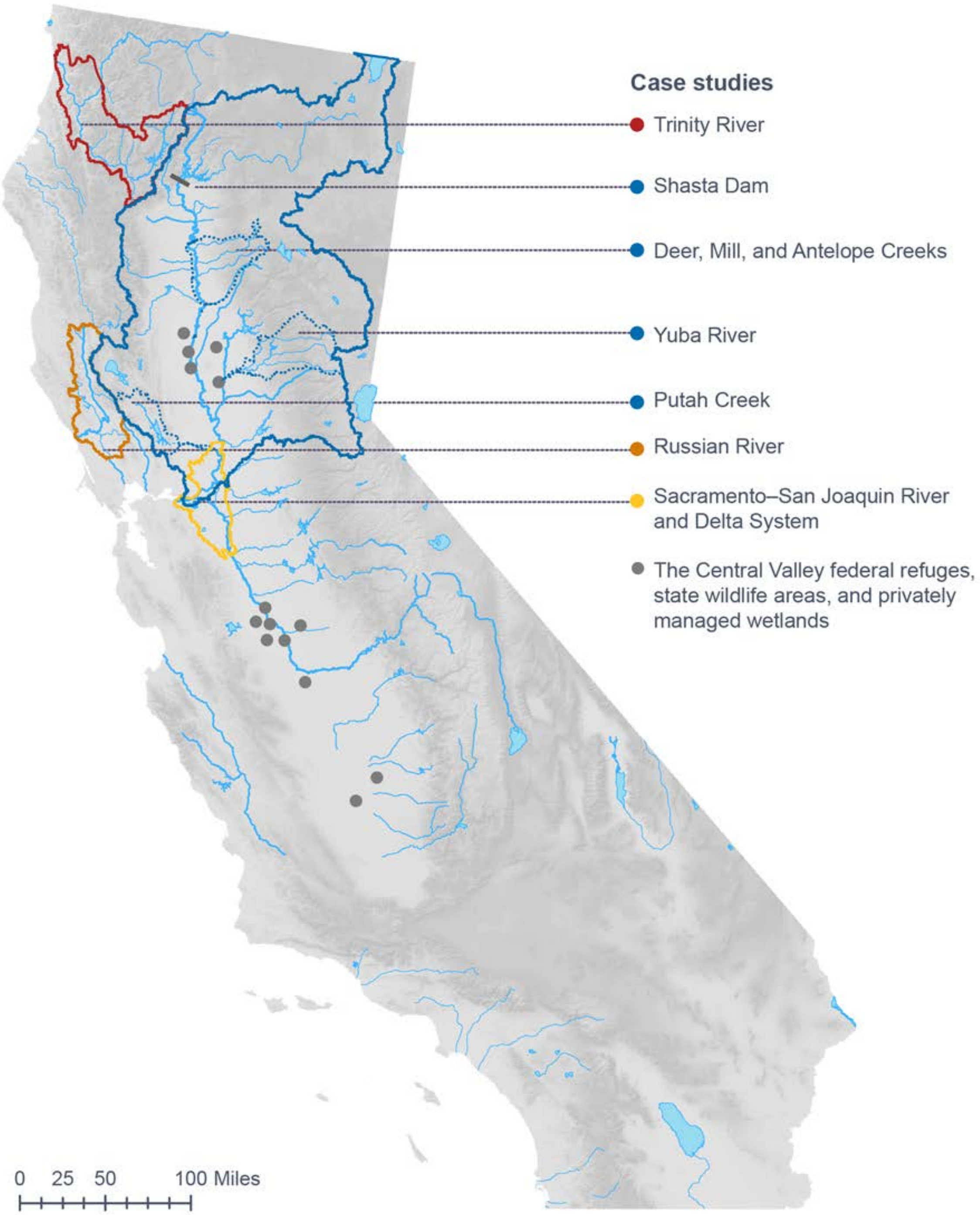
California water management requires balancing the competing demands of the environment, individuals, businesses, and farms. During times of water scarcity—such as the 2012–16 drought—most water uses are reduced as supplies decline. Diminished stream flows and reductions in supply to wetlands affect California's aquatic ecosystems. These effects are often compounded by other stressors such as increased temperatures and invasive species. The specific effects of the drought on aquatic ecosystems vary in watersheds across the state depending on the location, hydrology, resident species, and the scale to which the watershed's resources are managed and regulated. This technical appendix provides an overview of drought impacts, management practices, and lessons learned from a variety of watersheds around the state.

We have chosen eight case studies to explore how the environmental plans and regulations put in place put in place before the latest drought influenced the management and allocation of ecosystem water (Figure A1). These case studies represent a variety of institutional responses during drought in major rivers, tributaries, and wetlands that provide critical habitat for native fish and migratory birds. The case studies support our analysis and recommendations in the main report, *Managing California's Freshwater Ecosystems: Lessons from the 2012–16 Drought*.

The eight case studies can be grouped into three categories:

- Managing waterways with significant surface reservoir storage ("regulated" waterways)
  - The Trinity River
  - Shasta Dam operations (Sacramento River)
  - The Yuba River
  - Putah Creek
  - Sacramento–San Joaquin River and Delta system
- Managing waterways without significant surface reservoir storage ("unregulated" waterways)
  - Deer, Mill, and Antelope Creeks
  - The Russian River
- Managing wetlands

FIGURE A1
Map of case studies



SOURCES: PPIC using data from USGS Watershed Boundary Dataset, USGS National Hydrography Dataset, California Department of Fish and Wildlife California Lakes Dataset, GreenInfo Network California Protected Areas Data, State of California Geoportal Imagery, Base Map, Elevation and Land Cover Datasets.

Each case study is organized by the following aspects, to facilitate side-by-side comparison:

- **Background.** Critical information needed to understand the case study, including location, sources of water, the history of water development and use, aquatic and terrestrial species and other resources at issue during drought, and main water user conflicts.
- **Institutional framework and environmental challenges.** An overview of key state, federal, and/or local institutions responsible for or affecting water management in the study area, and the aspects of planning, regulation, or agreements that are relevant for managing water for the environment.
- **The latest drought.** The timeline of key events related to water management during the drought, and consequences for water quality, fish and wildlife, and water supply.
- **Lessons.** A summary of the important consequences of decision makers' and other parties' responses to drought, including key issues that inform efforts to reform environmental water management accounting, planning, and flow allocation—the three areas for reform highlighted in the main report.

References used in developing each case study are provided at the end of this appendix.

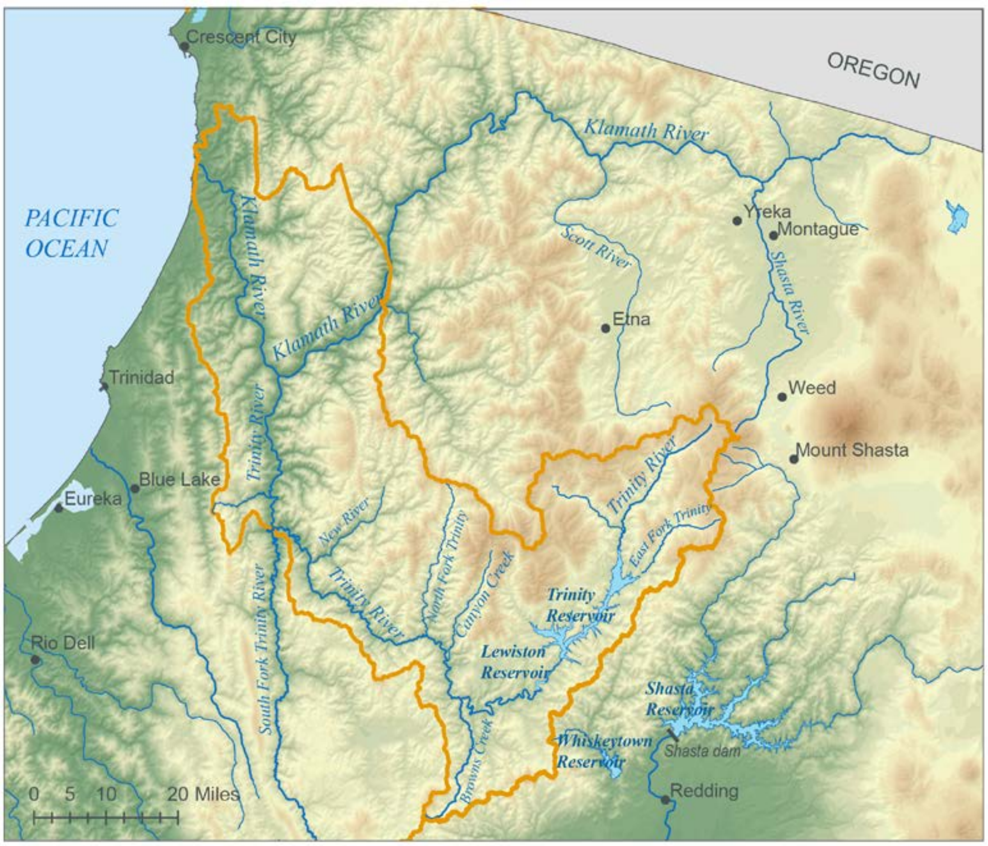
Case Studies

The Trinity River

Background

The Trinity River originates in Northern California's Scott Mountains in Trinity County (Figure A2). The Trinity is the largest tributary to the Klamath River. Upstream of the confluence with the Klamath, the Trinity River passes through the Hoopa Valley Indian Reservation. Downstream the combined waters of the Trinity and Klamath flow through the Yurok Reservation. The Trinity and Klamath watersheds support Chinook and coho salmon, steelhead, Pacific lamprey, green sturgeon, and numerous resident native fishes. Before logging and dam construction altered their aquatic habitat, more than 500,000 spring- and fall-run Chinook salmon spawned in the Trinity and Klamath River tributaries (Moyle 2002).

FIGURE A2
Trinity River watershed



SOURCE: PPIC. For a detailed list of sources, see Figure 1.

In 1962, the US Bureau of Reclamation (USBR) began impounding water in Trinity Reservoir on the upper Trinity River. This 2.45 million acre-feet capacity reservoir is part of the federal Central Valley Project (CVP). USBR diverts water from the Trinity Reservoir at Lewistown Reservoir (located eight miles downstream of Trinity Dam) through a tunnel beneath the Coast Range and into Whiskeytown Reservoir. USBR then releases the water into the Sacramento River system for distribution to the CVP contractors and to meet Delta water quality and outflow requirements (USBR 2013).

Institutional Framework and Environmental Challenges

USBR operates the Trinity River Diversion project pursuant to water rights permits issued by the California State Water Resources Control Board (State Water Board) and a series of federal laws that seek to accommodate the CVP's water supply operations and the water demands of water-right holders, tribal interests, fisheries, and other ecological functions downstream.[1] These include:

- The Trinity River Diversion Act of 1955 statute by which Congress authorized the Trinity Project. This law directs USBR "to adopt appropriate measures to insure the preservation and propagation of fish and wildlife."
- The Trinity River Basin Fish and Wildlife Management Act of 1984, which instructs USBR to "formulate and implement a fish and wildlife management program for the Trinity River Basin designed to restore the fish and wildlife populations" to pre-project levels.
- The Central Valley Project Improvement Act of 1992, which requires USBR "to protect, restore, and enhance fish, wildlife, and associated habitats in the Central Valley and Trinity River basins," while also seeking "to achieve a reasonable balance among competing demands for use of Central Valley Project water."
- The Trinity River Basin Fish and Wildlife Management Reauthorization Act of 1996, which extends the 1984 statute's mandate to "rehabilitate fish habitats in the Trinity River" to include the combined Trinity and Klamath Rivers below their confluence.[2]

Despite these laws, the operation of the Trinity River Diversion project (TRD) has had dire consequences for the salmon fishery on the Trinity and lower Klamath Rivers. From 1964 (the first year the project became fully operational) through 1997, USBR diverted an average of 988,000 acre-feet annually (afa)—about 68 percent of the Trinity River's flow.[3] As described by the US Court of Appeals in 2004:

> "The TRD radically altered the Trinity River environment, destroying or degrading river habitats that supported once-abundant fish populations. The TRD dams blocked 109 miles of upstream habitat previously used by salmon and steelhead for spawning and rearing. Low water flows imposed what was essentially extreme drought conditions for more than thirty years. Without the large spring melt-off flows, heavy vegetation grew on the banks, narrowing the river channels, making the banks steeper, and preventing the river channel from changing shape. Water velocities under these conditions became faster and more uniform, with fewer shallow areas adjoining the banks and pools. Decreased flows also meant that fine sediment trapped in the spaces between the riverbed rocks was not flushed away, spoiling spawning grounds by decreasing oxygen flows to eggs and trapping young fish. Releases from the dams affected water temperature—water was too hot during the winter months, owing to the lack of flow, and too cold during the summer because water is released from lower, cooler

[1] These laws are summarized in *San Luis & Delta Water Authority v. Haugrud* (U.S. Court of Appeals 2017).

[2] Although most species of Pacific Coast salmon and steelhead are listed as either endangered or threatened under the federal Endangered Species Act, the National Marine Fisheries Service (NMFS) declined to list the Klamath and Trinity River Chinook salmon and steelhead for protection under the act. It did list the Klamath and Trinity River Coho as threatened in 1997 (NMFS 2016). In 2011, in response to a new petition to list the Chinook Salmon, NMFS concluded that the Upper-Klamath River and Trinity River fall-run and spring-run Chinook were a single evolutionary significant unit (ESU) and that listing was not warranted because "the ESU is currently at a low risk of extinction within the next 100 years" (NMFS 2011).

USBR is required to consult with NMFS, however, to ensure that its TRD operations do not jeopardize Sacramento River winter-run Chinook salmon, which is listed as an endangered species. The salmonid biological opinion for CVP operations thus places temperature limitations on the discharge of water that USBR diverts from Trinity Reservoir into the Sacramento River system. Trinity River diversions also contribute to flows into the Sacramento–San Joaquin River Delta. Consequently, the biological opinion issued by the USFWS to protect water quality for the delta smelt, which is listed as threatened, also includes TRD operations (US Court of Appeals 2004).

[3] Diversions were higher during the first 10 years of project operations, averaging almost 1.28 million afa or 88 percent of the flow of the river (US Court of Appeals 2004).

parts of Trinity Reservoir. Unseasonable temperatures signaled the fish to migrate to the ocean at the wrong times, or failed to trigger smoltification."

The US Fish and Wildlife Service (USFWS) estimated that by 1980, 80-90 percent of aquatic habitat had been lost or degraded and that the population of native Trinity River salmonids had declined by 60-80 percent (US Court of Appeals 2004). The California Department of Fish and Wildlife has operated a fish hatchery on the Trinity River since 1964, which releases several million Chinook, coho, and steelhead smolts into the river each year (California Hatchery Scientific Review Group 2012). Today, almost all salmonids in the Trinity River system are hatchery fish (Moyle 2002).

In an effort to protect the salmon and steelhead and to comply with the legislative directives described above, USBR has set aside defined quantities of water for release into the Trinity River below Lewiston Dam. Releases from Lewiston "can play an important role in regulating water temperatures downstream in the mainstem Trinity and lower Klamath rivers" (Magneson and Chamberlain 2015).

In 1980 following the recommendations of the Trinity River Basin Fish and Wildlife Task Force, Secretary of the Interior Cecil Andrus directed USBR to release 287,000 afa and to gradually increase these releases to 340,000 afa. USBR retained authority to release less water in dry years. The CVPIA, enacted in 1992, required USBR to release a minimum of 340,000 afa in all years.[4] In 2000, following a multi-year analysis conducted by the US Fish and Wildlife Service in consultation with the Yurok and Hoopa Valley Tribes, Trinity County, and other parties, Secretary of the Interior Bruce Babbitt significantly increased the minimum release requirements—from 369,000 afa in critically dry years to 815,000 afa in extremely wet years (US Court of Appeals 2017).[5]

Secretary Babbitt's decision created a Trinity River Restoration Program (TRRP) administered by USBR and the USFWS in consultation with the Trinity Management Council, comprising the Yurok and Hoopa Valley Tribes, Trinity County, the California Department of Water Resources, the California Department of Fish and Wildlife, the US Forest Service, and the National Marine Fisheries Service. The Program's restoration strategy has several integrated elements:

- **Flow Management.** The TRRP manages the environmental water stored in Trinity and Lewiston Reservoirs to create a variable flow regime based on five water year types to mimic natural flows.
- **Habitat Improvements.** The program has reshaped the Trinity River at 47 locations to promote physical processes that will create and maintain riparian and fish habitat. It has also augmented gravels and reduced fine sediment loading below Lewiston Dam to improve spawning habitat and to enhance habitat connectivity within and between the tributaries and the main stem of the river. In addition, the TRRP has modified structures in the Trinity River floodplain to facilitate peak flows.
- **Monitoring and Assessment.** Active monitoring and assessment is included to promote adaptive management, environmental compliance, and real-time protection of fisheries.

[4] This statutory obligation lasted from 1992 through 1996, pending additional study and negotiation of a long term flow agreement between USBR and the Hoopa Valley Tribe. The CVPIA provided, however, that if the parties did not come to an agreement the 340,000 afa release requirement would remain in effect "unless increased by an Act of Congress, appropriate judicial decree, or agreement between the Secretary and the Hoopa Valley Tribe." (CVPIA §3406(b)(23)).
[5] The full Restoration Release Water Volume Allocation is: Extremely Wet (815,000 afa), Wet (701,000 afa), Normal (647,000 afa), Dry (453,000 afa), and Critically Dry (369,000). These releases are based on forecasted annual river runoff classifications that range from more than 2 million afa (extremely wet) to less than 650,000 afa (critically dry) (TRRP 2016a).

The TRRP “does not strive to recreate pre-dam conditions. Rather, the goal is to create a dynamic alluvial channel that exhibits all the characteristics of the pre-dam river but at a smaller scale” (TRRP 2016b).

Although the flow regime created by the TRRP has restored a measure of balance to the system, the Trinity and Klamath River fishery nonetheless has suffered severe stress during California’s most recent droughts. When flows in the Klamath River below the confluence are low in the summer and fall, water temperatures rise and available habitat for adult salmon declines. Under these conditions, algae blooms form and draw oxygen from the river that the fish need for their survival. The low flows also cause Chinook salmon, which are returning from the ocean to spawn in the Klamath and Trinity tributaries, to crowd together in thermal refuges (i.e., pools of cooler water) and languish in the lower stretch of the river where they become susceptible to disease (NRC 2004).

In September 2002, more than 33,000 salmon died in the lower Klamath River as they returned to spawn. About 95 percent of the lost fish were Chinook salmon; the remainder were steelhead and a few coho. The most likely causes of this unprecedented fish die-off were a combination of low flows, high water temperatures, diminished levels of dissolved oxygen, and two pathogens (the bacterium *columnaris* and a protozoan known as “*Ich*”) that infested the salmonids’ gills (NRC 2004).[6]

The Latest Drought

To guard against a recurrence of these conditions in 2012, USBR released 39,000 acre-feet of water from Lewiston Dam to augment the minimum releases required by the flow regime established under the TRRP. The following year, USBR planned to augment late summer flows by 62,000 acre-feet. Because of litigation filed by CVP agricultural contractors, however, USBR only released an additional 17,500 acre-feet.[7] Then the drought worsened.

- **January 2014.** The Trinity-Klamath River watershed (along with most of California) moved from severe to extreme drought and then in June into a sustained period of exceptional drought. USBR announced that it would deliver no water to most CVP agricultural contractors located south of the Delta and would cut Sacramento Basin deliveries by 25 percent (USBR 2017b). As summer approached, concern arose that low flows and rising temperatures in the lower Klamath River could result in a fish kill rivaling that of 2002.
- **July 2014.** Secretary of the Interior Sally Jewel rejected pleas by the Yurok and Hoopa Valley Tribes, Trinity County, fisheries biologists, and environmental groups to increase Trinity River releases beyond the restoration flows to protect in-migrating Chinook salmon. USBR explained that it would “release extra water into the Klamath-Trinity system once salmon start dying from drought-related disease, but not before” (Spencer 2014). Its spokesman said that this decision was made to accommodate USBR’s CVP water supply commitments and its other obligations, including protecting the Klamath-Trinity River fisheries, during severe drought: “‘When you look at the need and demand for water, it’s for every requirement out there, whether it is drinking water, species, power, agriculture or flow in the rivers. The best use of that water was part of that discussion—how can we use this water and still meet all the needs that are there?’” (Spencer 2014).
- **August 2014.** As conditions in the lower Klamath River deteriorated, Chinook salmon began to die from gill rot caused by *Ich* infestation, reduced oxygen levels, and other factors related to low flows and high

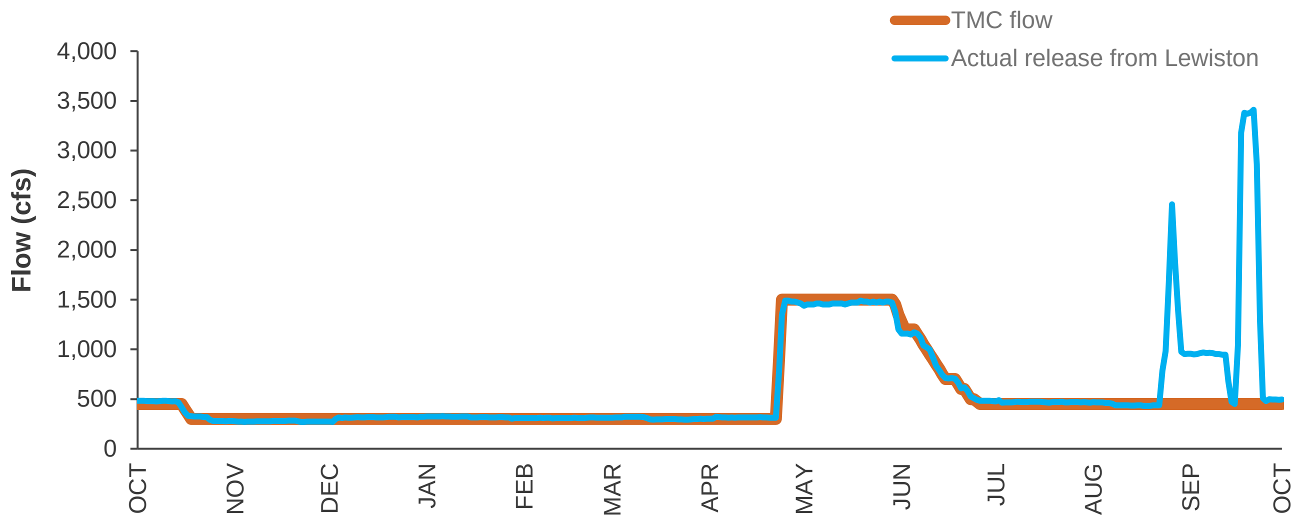
[6] *Ich* is shorthand for *Ichthyophthirius multifiliis*. The protozoa attach themselves to fish in warm, slow-moving waters and pass from host to host when fish are in close proximity to one another. “The classic sign of an *Ich* infection is the presence of small white spots on the skin or fins. . . . By the time the white spots are visible to the naked eye, the infected fish is very sick. . . . If the parasite is only present in the gills, white spots may not be seen at all, but fish will die in large numbers” (Francis-Floyd et al. 2016).

[7] A federal court ruled in October 2014 that the 1955 Trinity River Diversion Act granted USBR discretion “to adopt appropriate measures to insure the preservation and propagation of fish” and that the additional releases fell within this authority even though they exceeded the flow regime established in 2000 (U.S. Court of Appeals 2017).

water temperatures (Parrish 2014). In mid-August, USBR responded and released additional water from Lewiston Reservoir. When conditions deteriorated again in mid-September, USBR again augmented instream flows. These two sets of supplementary releases totaled 64,800 acre-feet (Figure A3) (TRRP 2015, Sylvester 2015).

FIGURE A3

2014 flow releases in the Trinity River



SOURCE: Trinity Management Council.

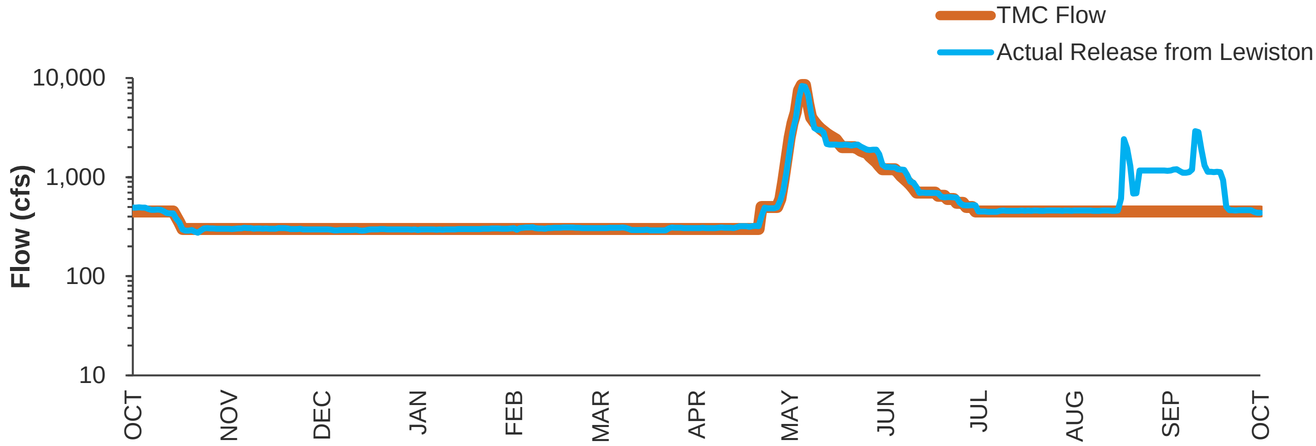
NOTES: Actual versus planned flow releases. Planned flows from the Trinity Management Council 2014 Restoration Flow Recommendation.

This sequence of events largely repeated itself in 2015, although the first evidence of *Ich* infestation in biopsied fish appeared in July (Houston 2015a). As in 2014, USBR initially declined to augment flows to protect spawning Chinook salmon, but it later adopted a three-tiered process to determine the need for supplemental flows.[8] From mid-August through mid-September USBR augmented flows by 47,900 acre-feet to protect the returning salmon from *Ich* infestation. It also released an additional 9,500 acre-feet for the Hoopa Boat Dance Ceremony (Figure A4) (TRRP 2016a).[9]

[8] These included: preventative base flows up to 40,000 acre-feet beginning in mid-August to reduce average water temperatures in the lower Klamath River to below 23 degrees Celsius (73.4° F), preventative pulse flows up to 10,000 acre-feet to flush the river of parasites before the bulk of returning Chinook salmon entered the river, and emergency flows up to 34,000 acre-feet to combat a "confirmed, continued rate of *Ich* infection" (USBR 2016).

[9] The Hoopa Valley and Yurok Tribes each conduct boat dances in the late summer. In odd-numbered years, USBR releases water to support the Hoopa Boa Dance. "Flows typically reach 2-3,000 cfs with about a 1 week total period for ramping up, holding for a day or two, then ramping back down again to summer base-flow. These flow releases are separate and apart from the Trinity River Restoration Program flow release, and do not count toward the restoration water allotment" (TRRP n.d.).

FIGURE A4
2015 flow releases in the Trinity River



SOURCE: Trinity Management Council.
NOTES: Actual versus planned flow releases. Log scale is used for the Y axis.

Although 2016 was a wet year in the basin, the risks to returning Chinook salmon persisted. USBR, largely adhering to the criteria that governed 2015 supplemental releases, augmented scheduled restoration flows in late summer and early fall by 39,200 acre-feet when *Ich* were detected in salmon passing through the Yurok Reservation (*California Water News Daily* 2016, USBR 2016, TRRP 2017).

Lessons

In many respects, the Trinity River Restoration Program is a useful model for the Ecosystem Water Budgets proposed in the main report. The program has brought together the constituencies most interested in the shared use of the waters of the Trinity River system, and it has produced a set of biological and operational objectives to accommodate the competing interests of CVP water supply and in-basin ecological management. In addition to a series of habitat improvements, the TRRP includes a water budget that allocates a percentage of stored water to environmental uses and a variable water release schedule that seeks to protect critical fisheries needs during drought and enhance system-wide ecological functions during periods of relative water abundance.

The restoration flow regime—coupled with the emergency late summer and early fall flow augmentation releases—prevented massive fish die-offs as occurred in 2002 (Houston 2015b). And USBR and the TRRP accomplished this under extremely challenging conditions. Trinity Reservoir began the critically dry water year of 2014 with a volume of 1.3 million acre-feet (about 53% of capacity) and ended the year at 605,600 acre-feet (TRRP 2015). By the end of 2015, the volume had dropped to 545,000 acre-feet (22% of capacity) (TRRP 2016a). Reservoir water temperatures were so warm during the summer and early-fall that USBR had to use the auxiliary bypass to access colder water near the bottom of the reservoir in an attempt to lower water temperatures (or at least not to exacerbate high temperatures) in the Trinity River (USBR 2016). In addition, USBR operated the TRD in both years while litigation was pending that attempted to force it to divert even more water into the Sacramento River system to supply CVP agricultural contractors (US Court of Appeals 2017).[10]

[10] The actual allocation of TRD water was:

	Inflow to Reservoirs	*Changes in Storage*	*Diversions to CVP System*	*Instream Releases*
Water Year 2014 (Critical)	396,200 af	- 695,600 af	618,600 af	435,300 af
Water Year 2015 (Dry)	899,800 af	- 58,500 af	450,000 af	508,000 af

Instream Releases include restoration flows, augmentation flows, and (for 2015) Hoopa Boat Dance flows. Sources: (TRRP 2015 & 2016a)

Even so, there were several significant flaws in the program. First, the restoration flow schedule was inadequate to protect returning Chinook salmon from significant risk of *Ich* infestation. USBR and the TRRP should have learned this from the 2002 die-off and the near misses of 2012 and 2013. As an allocation of water to ecological uses, the restoration release schedule was "underfunded"—at least in dry and critically dry years, and probably in normal to wet years immediately following drought. The flow schedule also did not include an adequate margin of safety to account for hydrologic uncertainty, anticipated changes in the timing and numbers of returning salmon spawning, variable weather and water temperatures, and the biological responses of Chinook salmon to water conditions in the lower Klamath River.

Second, USBR's decision to wait until *Ich* infestation became manifest placed an inordinate risk on the Trinity and lowerKlamath River fishery.[11] *Ich* spreads quickly in warm, slow-moving water as the parasites are able to catch up to the fish and move from host-to-host as the salmon crowd together waiting for colder water to flow downriver (USBR 2016). Although supplemental releases can increase flows and reduce water temperatures to make the river less hospitable to the protozoa, it takes two to four days for reservoir releases to reach segments of the lower Trinity and Klamath Rivers where the Chinook salmon are under threat (Eureka Times Standard 2014). By this time, the *Ich* infestation can become widespread as it did in 2002. Moreover, USBR's ability to influence river water temperatures may be limited by water temperatures in its upstream reservoirs and by weather conditions along the coast (Magneson and Chamberlain 2015).

USBR largely succeeded in protecting the fall-run Chinook in the severe drought years of 2014 and 2015, but it did so only after taking the fish up to the edge of survival. USBR had to scramble to prepare supplemental environmental assessments to support the emergency augmentation releases. That left all interested parties—the Yurok and Hoopa Valley Tribes, Trinity County, fish advocates, and CVP contractors—uncertain of the eventual allocation of stored water. In addition, all parties probably benefitted from a combination of good fortune—that *Ich* did not spread faster among the host salmon, that the remaining water in Trinity Reservoir was cool enough to reduce temperatures in the lower Klamath, and that coastal weather conditions were favorable.

Third, the program suffered from the absence of independent management of the water stored and released for fisheries protection. The base restoration flows were established following negotiations among the interested parties, and the TRRP is administered jointly by USBR and the USFWS. But all decisions regarding the necessity, volume, and timing of augmentation releases were made by USBR, which has countervailing and sometimes conflicting obligations to deliver scarce supplies to its CVP contractors. USBR's role as environmental water steward is therefore inherently compromised by its role as water purveyor. This conflict illustrates the need for an independent environmental water trustee within each watershed.

Finally, the program was allowed to function without significant oversight under California law. The State Water Board *was* actively engaged in supervising USBR's protection of salmon in the Sacramento River, seeking to ensure that the transbasin diversion of Trinity River did not contribute to an exceedance of temperature standards in the Sacramento River (CSWRCB 2017, see also the Shasta case study below), but the board had little engagement on the effort to protect Chinook salmon in the Trinity River system itself.

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[11] USBR's criteria for releasing preventative pulse flows in 2015 and 2016 were: the "presence of low-level infections of *Ich* (less than 30 *Ich* per gill) on three or more fall-run adult salmon . . . captured in the lower Klamath River on one day during the peak of fall run migration" *and* forecasted precipitation levels that, "in consideration of real-time conditions, would be inadequate to fulfill the 5,000 cfs level target necessary to avoid a fish die-off." The criteria for emergency flows during these two years were: "diagnosis of severe *Ich* (30 or more parasites on a gill arch) infection" in at least 5 percent of adult salmonids *or* "observed mortality of greater than 50 dead adult salmonids in a 20 kilometer reach in 24 hours coupled with the confirmed presence of *Ich* by the USFWS Fish Health Center" (USBR 2016).

Nor did any state agency seek to enforce the requirements of section 5937 of the California Fish and Game Code, which requires all dam operators to "allow sufficient water at all times to pass through . . . the dam to keep in good condition any fish that may be planted or exist below the dam." The federal courts have held that this statute is fully applicable to the CVP, including the TRD (US Court of Appeals 2017).[12] A more robust and proactive Ecosystem Water Budget for the Trinity River would incorporate section 5937 and provide for sufficient flows to maintain the salmonid fishery in "good condition," not simply to authorize *post hoc* emergency releases to protect the fish only when they are at risk of dying in large numbers.

Three key lessons emerge from the Trinity River that can guide improvements for managing freshwater ecosystems statewide:

- **Accounting.** The TRRP benefitted from numerous studies of the biological needs of migrating salmon, analyses of the quantity of water needed to protect and enhance fisheries habitat, and iterative determinations of the appropriate CVP water contributions to achieve these purposes.
- **Planning.** The TRRP brought together the parties most interested in shared water management to set ecological objectives before the drought. In practice, however, there was little coordinated involvement of key parties in implementation of the TRRP during periods of greatest stress on returning Chinook salmon.
- **Flow allocation and management.** The TRRP includes a water budget that allocates a percentage of stored water to environmental uses and a variable water release schedule to protect fisheries during drought and to enhance system-wide ecological functions during periods of relative water abundance. But the flow schedule did not include an adequate margin of safety to account for hydrologic uncertainty, anticipated changes in the timing and numbers of returning salmon spawning, variable weather and water temperatures, and the biological responses of Chinook salmon to water conditions in the lower Klamath River.

Shasta Dam and Reservoir Operations

Background

Shasta Dam stands among the world's largest dams. At 4.5 million acre-feet of storage capacity, Shasta Reservoir is the largest in California, providing an average of approximately 10 percent of the state's developed surface water and 10 percent of the state's large reservoir hydropower capacity (California Energy Commission 2017). Owned and operated by the US Bureau of Reclamation (USBR), it provides water for the Central Valley Project (CVP), with the bulk of the water going to irrigators in the Central Valley (Water Education Foundation 2017). Shasta impounds the waters of the Pit and McCloud rivers and the headwaters of the Sacramento River (Figure A5).

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[12] The California Department of Fish and Wildlife did argue as *amicus curiae* in this litigation that §5937 applies to USBR's Trinity River operations and therefore supported augmented releases to protect Chinook salmon, but it did not take its own action to enforce the statute's mandates (U.S. Court of Appeals 2017).

FIGURE A5
Sacramento River watershed and Shasta Dam

SOURCE: PPIC. For a detailed list of sources, see Figure 1.

Institutional Framework and Environmental Challenges

Shasta Reservoir plays a key role in regulating flows to meet multiple water quality and environmental flow needs. In concert with other CVP and State Water Project (SWP) reservoirs, water is released from Shasta reservoir to reduce salinity intrusion into the Sacramento-San Joaquin Delta. Salinity standards associated with State Water Board Decision 1641 are designed to protect water quality for agriculture and urban uses both within the Delta and through Delta exports.

Shasta reservoir releases are also used to support water quality and Delta outflow for multiple fishes listed as threatened or endangered under the federal and state Endangered Species Acts. Water releases from the dam contribute to meet Delta outflow standards for anadromous fishes (salmon, steelhead, sturgeon) and pelagic fishes (delta smelt) in the Delta. Under the current Biological Opinion (BiOp) of the National Marine Fisheries Service, and the State Water Board's Water Right Orders 90-05 and 91-01 that modified USBR's water rights, reservoir operators must also manage releases into the Sacramento River to meet summer and early fall temperature and flow standards immediately downstream of Keswick Dam (which re-regulates hydropower releases from Shasta). These flow and temperature standards are principally set to a maximum of 56ºF to support winter-run Chinook salmon *(Oncorhynchus tshawytscha)*, although other fish species also benefit.

Winter-run Chinook salmon are federally listed as endangered, and are close to extinction. Access to their historic spawning grounds on the upper Sacramento River is currently blocked by Keswick and Shasta Dams. In contrast to other salmon in California, which spawn and rear during cool months, winter-run Chinook spawn during the summer and emerge as fry in the late summer and early fall. This reflects their historic adaptation to reliably cold, spring-fed tributaries in the upper Sacramento River. The current population of winter-run is confined to a short reach of the Sacramento River immediately downstream of Keswick Dam. Given the high summertime air temperatures of this area, the fish are entirely reliant on cold water releases from Shasta to support development of eggs and fry.

Shasta Reservoir, like all other large reservoirs in the region, stratifies during the summer, with warm water on top and dense, cold water—derived principally from winter and spring inflows—on the bottom. To regulate temperatures of releases, reservoir operators use a temperature control device (TCD) that allows them to siphon and blend warm and cold water from various reservoir elevations for releases. In this way, they can conserve cold water as the reservoir is drawn down over the course of the summer, preserving cold water for late summer and early fall.

Conserving this cold water pool is challenging during droughts for several reasons. First, in warm droughts the temperature of the cold water pool is higher, reflecting warmer winter and spring inflows, while high summer temperatures make the surface layer warmer. This means it takes proportionally more water from the (warmer) cold water pool to meet temperature standards. Second, competing demand for—cold water, Delta outflows, and irrigation—tend to be highest during drought. Third, carryover storage is often reduced during sequential years of drought, limiting the total quantity of cold water available. Reservoir operators often try to optimize releases to meet all these objectives, but significant tradeoffs often must be made.

The Latest Drought

During the summer and fall of 2014 and 2015, reservoir operators did not meet temperature standards for winter-run Chinook salmon. Federal and state fish agencies estimated roughly 95 percent mortality for eggs and fry in both years. Since the fish has a short life cycle—three years—the loss of two successive cohorts has put great pressure on the total population. Currently, conservation hatcheries (i.e., hatcheries whose purpose is to help preserve the wild species) are sustaining these fishes, albeit at very low numbers. The risk of extinction is high.

The warm water releases from Shasta Reservoir during summer and fall of 2014 and 2015 are the result of record-setting dry and warm conditions, technical issues in monitoring and modeling the cold water pool, and choices made by USBR on balancing demands for hydropower, irrigation supplies, Delta water quality, and winter-run Chinook. The timeline of key events shown here revolves principally around the Temporary Urgency Change Petition (TUCP) actions by the State Water Board.[13]

- **January 2014.** Governor Brown issued a Drought Emergency Proclamation Order giving greater flexibility to state agencies to respond to TUCPs and other requests for changes in operations. Based on limited carryover storage in CVP and SWP reservoirs and the potential for a third year of drought, USBR and DWR submitted a TUCP to the State Water Board to modify Delta outflow and salinity standards, along with Delta Cross Channel (DCC) gate closure objectives. The goal was to preserve water to address competing water quality (temperature and salinity) demands for the Delta and winter-run Chinook and to preserve cold water for later in the summer as well as supplies for settlement and exchange contractors

[13] This information can be found at the State Water Project and Central Valley Temporary Urgency Change Petition website.

whose allocations were at 75 percent.[14] The board's executive director approved the petition on February 7th and issued a temporary urgency change (TUC) order. The order limited pumping in the Delta to health and safety levels when the original standards were not met.

- **February 2014.** USBR proposed to meet 100 percent of supply for settlement contractors (1.2 maf), 50 percent of municipal and industrial uses, and 60 thousand acre-feet (taf) for north-of-Delta wildlife refuges.
- **March 2014.** A Bureau and DWR request was approved to modify the TUC order to allow for a reduction in outflow and salinity standards in the Delta to conserve water stored in reservoirs, meet contract obligations, and supply water for health and public safety. Later in the month, a memo from USBR to the State Water Board highlighted the challenges of managing temperatures. Challenges included uncertainties about the ability to effectively operate the TCD and weaknesses in their temperature model, particularly for late summer/early fall in warm, dry years.
- **April 2014.** USBR and DWR sought a 180-day extension of the TUC order with modifications that would relax salinity and outflow standards in the Delta and reduce flow requirements for the Sacramento River, with assurances that the projects would meet temperature and flow standards in the fall. In May the State Water Board approved the extension of the modified TUC order.
- **May through mid-August 2014.** USBR significantly increased hydropower generation and flow releases to meet downstream objectives, including deliveries to irrigators. This drew down the available cold water pool along with overall reservoir volume. The TCD functioned normally during this time, maintaining water temperatures.
- **Late-August to Early-September 2014.** Operation of the TCD to access the limited remaining cold water pool did not match model projections. Ad hoc attempts to tap into the cold water pool exacerbated temperature conditions and the reservoir became too low and too warm to protect downstream temperatures.
- **Mid-September through October 2104.** Exhaustion of the cold water pool led to significant and sustained exceedance of temperature standards below Keswick Dam and loss of 95 percent of winter-run Chinook eggs and fry.[15]
- **January 2015.** In anticipation of another dry and warm year, and in response to low carryover storage from the previous year, USBR and DWR submitted a TUCP seeking modifications of their water right permits to allow reduced Delta outflow and salinity standards to preserve more storage in project reservoirs. State and federal fish agencies concurred with the TUCP as consistent with state and federal endangered species acts and federal BiOps. The board approved the TUCP with minor modifications.
- **March–April 2015.** The board updated the TUC order to create more flexibility for Delta operations. A condition of approval included a requirement that USBR conduct a detailed review of modeling and operation errors that had led to loss of winter-run Chinook in 2014. USBR also recalibrated its temperature probes in Lake Shasta and discovered unusually high temperatures within cold water pool for the second year in a row. It delayed including these warm temperatures in the model forecast runs used to project supplies for water users, however, to await additional data collection in mid-May. When these runs were completed in May, they indicated extreme difficulty in achieving temperature objectives.[16]

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[14] USBR has an obligation to deliver a minimum of 75 percent of the stated contract amounts to two groups of CVP contractors who held pre-project water rights. These priority contractors include the Sacramento River Water Rights Settlement contractors and the San Joaquin River Exchange Contractors. The other CVP and SWP contractors have no minimum water service rights during severe drought. In 2014 and 2015, CVP water service contractors located south of the Delta received no project water, while SWP contractors who rely on Delta exports received 5 percent of their state contractual entitlements in 2014 and 20 percent in 2015 (USBR 2016; MWD 2016).

[15] As reported in NOAA Fisheries *Priority Actions: 2016–2020 Sacramento River Winter-run Chinook salmon*.

[16] Based on transcripts of June 16, 2015 *Media Call: Federal and State Officials Discuss Sacramento River Temperature Management* in Maven Notes blog.

- **May 2015.** A memo from the State Water Board to USBR reinforced the importance of avoiding temperature model and control problems experienced in 2014. The memo noted that USBR had offered assurances in earlier meetings that it could meet temperature and water supply goals, *even though conditions would be no different than the previous year*. USBR and DWR submitted a TUCP to cover project operations from June through September. These focused on reducing Delta outflows and salinity standards to create more flexibility in export pumping and reservoir storage. The board suspended USBR's proposed temperature management plan, concluding that it was inadequate. This followed a workshop on May 20th in which plan approach and assumption deficiencies were discussed, including assurances by USBR that it would meet temperature goals.
- **June 2015.** A Shasta Temperature Management Plan was developed with the direct cooperation of all regulatory and management agencies (including the State Water Board).[17] The plan concluded that it was not possible to meet water temperature standards due to the warmth of the reservoir. It also identified large model uncertainties and developed prescriptions to minimize impacts on winter-run Chinook salmon. The plan proposed to operate the reservoirs more conservatively than in previous years by reducing outflows and preserving cold water. Despite known consequences for eggs and fry, the plan proposed raising the temperature target from 56ºF to 57º or 58ºF depending on conditions. The CVP contractors were consulted extensively on this and demonstrated a willingness to delay deliveries to improve operational flexibility. The board approved this plan on June 25th. Although USBR generally met the plan's objectives, with temperatures varying between 56º and 58ºF, the sustained elevated temperatures again led to more than 95 percent mortality of winter-run Chinook eggs and fry below Shasta dam.[18]

USBR, the state and federal fish agencies, and the State Water Board were faced with an exceptionally difficult set of tradeoffs between water supply/hydropower objectives, Delta outflow, water quality and fish objectives, and winter-run Chinook salmon survival downstream of the dam. All of this took place during unprecedented high temperatures and low runoff into all project reservoirs. That said, the decisions USBR made during 2014 favored minimizing impacts of water supply to CVP exchange and settlement contractors. In 2015, there were significant effects on the CVP exchange and settlement contractors from efforts to maintain cold water releases from Shasta—principally a shift in the timing of water deliveries, which reduced the availability of surface supplies during the main irrigation season. Later releases were used for flooding of rice fields and some limited south-of-Delta uses.

Lessons

By late spring of 2015 USBR changed its approach to the Shasta Reservoir challenges. It expanded cooperation with regulatory agencies as well as with stakeholder groups. USBR also demonstrated a more nimble response to information and conducted multiple reviews of the technical support for decision making.

Through its regulatory powers, the State Water Board played a central role in managing releases from Shasta Reservoir and balancing competing demands for water supply and ecosystem protection. The use of emergency powers and the ability of the board's executive director to make decisions quickly during the drought both proved very helpful in managing an unfolding crisis. The board also played a central role in requiring greater transparency, cooperation, and technical investments from USBR.

Ultimately, however, the agencies—in the face of unprecedented water scarcity and high temperatures—failed to achieve the key environmental objective of not jeopardizing endangered winter-run Chinook salmon. Regardless

[17] Letter from Ron Milligan of USBR of Reclamation to Tom Howard of the State Water Resources Control Board.
[18] March 18, 2016 presentation by Garwen Yip to the State Water Board.

of the circumstances, the loss of two successive cohorts threatens the species with extinction. Responsibility for this failure is shared by all agencies involved, including the state and federal fish agencies, which generally supported USBR's actions.

Several key lessons emerge that could guide improvements for managing freshwater ecosystems statewide:

- **Accounting.** This crisis revealed weaknesses in USBR's investments in technology to support decision making, including modeling, hydrologic and water quality information, and the infrastructure to implement it. The drought exposed glaring deficiencies in its collection and dissemination of information on reservoir temperatures, as well as reservoir models that are incapable of projecting drought conditions. A lack of necessary transparency meant other agencies could not independently evaluate the data in order to assess the water management decisions. It also showed how institutions can be slow to reveal their uncertainties about information (temperature profiles for the reservoir, for example) and to incorporate this into their planning. Modernizing approaches to data collection, modeling, and dissemination are essential to effective drought management and response.
- **Planning.** All aspects of the challenges of managing high temperatures and low inflows to Shasta Reservoir were predictable, particularly in light of long term trends in warming and increasing climatic variability. Yet USBR and all the regulatory agencies have maintained an approach that is too ad hoc to protect species from jeopardy. More scenario development and testing, along with priority setting, would have helped prepare for this drought emergency at Shasta Reservoir. Going forward, advanced planning involving the various parties could help improve cooperation and openness among USBR, the state and federal regulators, and the CVP contractors and other stakeholders.
- **Flow allocation and management.** USBR's efforts—particularly in the early stages of the drought—demonstrated that its priorities were to deliver water to the exchange and settlement contractors, who have senior contract obligations within the CVP.[19] USBR attempted to provide as much water as possible, while minimally meeting environmental objectives. This allowed for little room for error. In general, the environmental benefits of cold water management and Delta outflows are not well integrated into priority setting. USBR—and the state and federal regulators—need to establish clearly articulated priorities for drought emergencies when there are limited options.

The Yuba River[20]

Background

The Yuba River is a tributary of the Feather River and is a significant part of the Sacramento River system (Figure A6). Two high dams—Englebright on the main stem and New Bullards Bar on the North Yuba—block fish passage to the upper parts of the Yuba watershed. The lower Yuba River is used as spawning and rearing habitat by a number of anadromous fish species, most notably Central Valley steelhead and Central Valley spring-run Chinook salmon (Lower Yuba River Management Team, Chapter 5, 2013). Management of flows and water on the lower Yuba is dominated by the Yuba County Water Agency (YCWA), which provides approximately 300,000 afa to eight local water agencies (Yuba County Water Agency 2016) and controls hydropower and water supply operations from New Bullards Bar.

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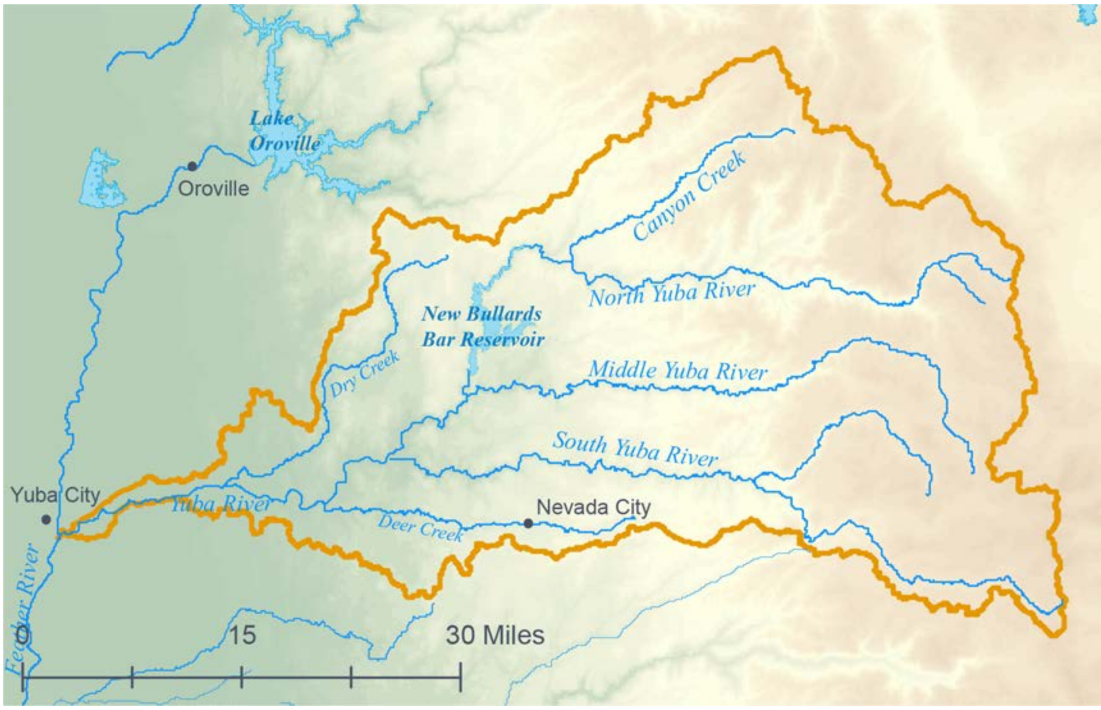
[19] The Sacramento River Water Rights Settlement Contractors and the Exchange Contractors in the San Joaquin Valley held pre-project water rights. Their contracts grant them preferential rights to available CVP supplies in recognition of their senior water rights.
[20] This case study summarizes findings from a longer article by Ugai (2017) featured in *West Northwest Journal of Environmental Law and Policy*.

FIGURE A6
Yuba River watershed



SOURCE: PPIC. For a detailed list of sources, see Figure 1.

Institutional Framework and Environmental Challenges

In 2007, YWCA, several state agencies, and environmental organizations entered into the Yuba River Accord (YRA), an agreement that resolved disputes about water rights and flow targets designed to protect salmon and steelhead.[21] The YRA created a system that maintained higher environmental flows during the drought while also supplying water users. In addition, the collaborative stakeholder process created as part of the accord allowed parties to avoid a potential flow catastrophe at the height of the drought during 2014.

The YRA was created out of conflict. In the 1990s, the California Department of Fish and Wildlife (CDFW) issued a fisheries management plan for the lower Yuba River, proposing a significant increase in minimum flows to protect salmon and steelhead habitat. In 2003, the State Water Board amended YCWA's water rights to implement those higher flows requirements. YCWA sued to challenge that order, as did several other water providers and conservation organizations. Efforts to reach a negotiated resolution to the litigation ultimately culminated in the YRA in 2006. In 2008, the State Water Board formalized terms of the accord into an order amending YCWA's water rights.

The YRA includes improved flows for the Yuba, which are incorporated into a seven-tier flow schedule. The schedule calibrates flow to hydrologic conditions—from Schedule 1 flows in a wet year to much lower "conference year" flows for the driest years. The accord also includes several management measures to enhance flows during dry years. The first is the use of water transfers to augment flows. DWR signed a long term purchase agreement to buy water from the YCWA for transfer to the CVP and SWP (initially through the Environmental Water Account created by the 2000 CALFED record of decision). In dry years, DWR can also purchase water from YCWA for south-of-Delta water users, and delivery of that water to the Delta is simultaneously used to

[21] For a summary of key provisions, see Lauer and McClurg 2009.

augment Yuba River flows. Flows released to meet YRA targets can be included in the water transferred to the CVP and SWP.

The accord also includes a surface and ground water conjunctive use program. Under this program, YCWA farmers pump groundwater in lieu of using surface water in dry years, to free up surface water for downstream transfers. The aquifer is maintained through recharge during wet years.

The Latest Drought

The parties involved in managing the Yuba watershed narrowly avoided a significant flow crisis during the driest period of the recent drought, which exposed a flaw in the accord's methodology. The watershed experienced very wet weather during the fall of 2012, followed by one of the driest years recorded between January 2013 and January 2014. These conditions (very wet, followed by dry) caused the index which is used to determine the flow schedule to remain artificially high, and flows remained at Schedule 2 (the second wettest) through early 2014. These higher flows in late winter and early spring would have risked draining New Bullards Bar Reservoir (the primary water storage reservoir in the system) to zero pool by August. Had the accord's methodology remained in place, the accord would not have mandated "conference year" (most extreme drought) flows until April at the earliest and therefore jeopardized flow targets for later in the summer (Ugai 2017).

The YWCA, joined by conservation groups and water users, filed a temporary urgency change petition (TUCP) with the State Water Board, requesting permission to reduce flows to conference year levels in February to avoid draining New Bullards Bar Reservoir and to maintain at least those minimum flows through the summer and early fall. The success of the accord—along with the information and personal relationships developed during its development and implementation—allowed stakeholders to unite behind the proposal. The board promptly approved the TUCP. Fortunately, the watershed benefitted from a late spring storm in 2014, which mitigated the crisis before the summer (Ugai 2017).

In April 2015, YCWA announced its first surface water delivery reductions in its history, but growers felt they could still plant most of their crop due to healthy groundwater supplies.

Lessons

The Yuba River Accord provides significant benefits to fish habitat and to water users. Compared to the State Water Board's 2003 order, which had approximately doubled flows over previous levels, under the YRA approximately 32 percent more water is available for instream flows to support fish during wet years and 15 percent more in dry years. Meanwhile, water users benefit in several ways from the accord. The active groundwater recharge and conjunctive management programs provide a relatively stable and secure source of water during droughts, minimizing the impacts on irrigation. The transfers of environmental water to the CVP and SWP provide revenue to mitigate the impacts of drought, fund the conjunctive management program, and support flood management investments in the watershed.

Several key lessons emerge that could guide improvements for managing freshwater ecosystems statewide:

- **Accounting.** To date, the accounting and methodology of the accord have functioned well. The exposed flaw in the methodology for setting the flow schedule was quickly corrected because of a sound foundation of data and collaborative process established by the accord.
- **Planning.** A key aspect of the accord is assessing water availability during both wet and dry years, and setting flow targets across a range of hydrologic conditions. This planning creates achievable flow targets, provides certainty for water users, and offers a clear course of action during droughts.

- **Flow allocation and management.** Conjunctive management of surface water and groundwater is central to the accord's ability to achieve higher flows during dry years without disrupting water use. This has been made possible by an aggressive aquifer restoration and recharge program. In addition, the transfers provide revenue and augment flows during dry years. The accord creates a system to manage water during wet years in part to prepare for dry years, and is an excellent example of how flexible flow management can play a role in environmental protection during droughts.

Putah Creek

Background

Lower Putah Creek flows along the border between Yolo and Solano Counties, originating at Monticello Dam and ending in the Yolo Bypass (Figure A8). The Solano County Water Agency (SCWA) manages it as part of the Solano Water Project. Lower Putah Creek emerged from the Coast Range when large winter and spring floods created meandering, multiple channels that supported about 22,000 acres of riparian forest in the rich soils creating by the floodwaters. Starting in the 19th century, the creek was altered and confined to one channel through the construction of levees to prevent annual flooding. Confinement caused the creek to down-cut, creating a narrow, canyon-like incision in the agricultural landscape. For flood control, the channel was cleared of vegetation and little attention was paid to the needs of the native plants and animals.

This changed with the construction of Monticello Dam in 1957, which created Berryessa Reservoir, one the larger reservoirs in California. Water first flows for about eight miles to Solano Reservoir, from which the water is diverted through the Putah South Canal for agricultural and urban uses, mainly in Solano County. The inter-reservoir reach, with high flows in summer and cold temperatures in winter, supports naturally spawning trout and a blue-ribbon catch-and-release fishery. Flows in the lower creek are managed for native fishes, including a run of Chinook salmon. Riparian habitat along the corridor of the inter-reservoir and lower creeks also serves a wide diversity of plants and animals, and is a recreational amenity to the local communities.

FIGURE A7
Putah Creek watershed

SOURCE: PPIC. For a detailed list of sources, see Figure 1.

Institutional Framework and Environmental Challenges

The construction of the Solano Project (Monticello Dam, Putah Diversion Dam, and Putah South Canal) significantly altered the flow of water and riparian habitat along lower Putah Creek. Until recently, the creek only flowed continuously for about four miles downstream of the dam in most years. Below this point, there were no guaranteed flows, and the creek flowed only intermittently.

During an extended drought in the 1980s, the drying creek and dying fish caught the attention of the newly formed Putah Creek Council, a nonprofit environmental organization, as well as biologists from UC Davis (UCD) who used the creek for teaching and research. The Council, UCD, and the City of Davis sued SCWA and the Solano Irrigation District to compel them to release more flows for the creek. The lawsuit was based on the public trust doctrine and section 5937 of the California Fish and Game Code, which states that dam owners must release or bypass water to maintain fish "in good condition" below their dams. Following a trial in 1996, Judge Richard Park ruled that SCWA diversions violated the public trust and section 5937 because of the harm they were causing to the fish. The parties agreed to settle the litigation in 2000 (Gray 2012).[22]

The 2000 settlement agreement guaranteed that Putah Creek would become a living stream with a flow regime that favored native fishes, including Chinook salmon. The major elements of the agreement were:

- Establishment of a replicated natural flow regime by the Solano County Water Agency that provides minimum flows to keep the stream alive to Highway 80 at all times, increased flows in spring to favor spawning by native fishes, and a fall pulse flow to attract spawning Chinook salmon.
- Allowance for minimum flows during extended drought, tied to reservoir water levels.
- Designation of a "Stream Keeper," who is responsible for working with SCWA, landowners, and other interested parties to implement the 2000 agreement and to raise funds for restoration projects. This position provides for some drought-proofing of the creek by ensuring that essential habitat is in good condition.
- Creation of the Lower Putah Creek Coordinating committee (LPCCC), which comprises representatives from SCWA, UCD, PCC, and the City of Davis and is funded by SCWA.

The flow regime established for Putah Creek has been highly successful, with native fishes becoming re-established in much of the lower creek and a fishery for non-native fishes developing in the lowermost reaches. In addition, hundreds of Chinook salmon now use the creek for spawning. The flows also resulted in improvement of riparian habitats, causing an increase in riparian birds, mammals, and plants (unpublished data, M. Truan and A. Engilis, UCD).

Equally importantly, the assurance that Putah Creek was now a living stream made it an asset to local communities and landowners. This resulted in major cleanup of the creek, removing trash and invasive weeds, led by the Putah Creek Council and LPCCC. The Stream Keeper, Rich Marovich, also raised more than $13 million in state funds for creek restoration projects. The cities of Winters and Davis both established new parks along the creek, and Winters initiated an annual Salmon Festival to celebrate return of the salmon. Much of this happened with the strong support of the SCWA, which had taken full responsibility for returning the fish in the creek to good condition. In fact, the agency has exceeded the requirements of the settlement agreement by improving spawning habitat for salmon. In 2009, SCWA won the City of Davis Environmental Award for environmental leadership even though the City of Davis was a plaintiff in the water litigation of the 1990s. The creek has become

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[22] While the Putah Creek judgment did not set a formal legal precedent, it did result in an expanded definition of section 5937's requirement that fish below dams must be maintained in "good condition" that has been used in other actions, including the settlement agreement that restored flows and habitat in the San Joaquin River (Bork et al. 2012).

an excellent example of reconciliation ecology, balancing competing demands for water for fish and people, while supporting a novel ecosystem with attributes favoring native biota (Moyle 2012).

In any given year, the minimum downstream flows for lower Putah Creek are met through a combination of reservoir spills from Lake Berryessa, tributary contributions downstream of Monticello Dam, and stored water releases from Monticello Dam. In wet years, reservoir spills and tributary contributions typically provide most of the water needed to satisfy minimum downstream flow requirements. Conversely, in dry years most of the water is provided via releases of stored water. From a water supply reliability perspective, SCWA is most interested in the amount of stored water required to meet the minimum downstream flow requirements. Operationally, the releases to Lower Putah Creek consist of three components:

- **Carriage water.** Water that ultimately evaporates or percolates into the ground before reaching the Yolo Bypass. This is the water that is required simply to keep the stream channel wet.
- **Downstream water rights.** Water that will be diverted by creekside water users located between the diversion dam and Yolo Bypass.
- **Environmental compliance water.** Water that must remain in the stream to satisfy downstream flow requirements at the various compliance points.

The settlement agreement also provides for drought relief based on how much water is stored in Lake Berryessa at the beginning of the summer. The environmental flows are curtailed under severe drought, with only 1 cubic foot per second (cfs) at Highway 80 required to (minimally) maintain a live stream in the Putah Creek channel. The parties to the settlement agreed that all water users, including the environment, should share the pain during severe drought.

The Latest Drought

Management of Putah Creek has made it remarkably drought resistant, and native biota thrived during the 2012-16 drought, unlike most other watersheds and wetlands in California. Storage in Lake Berryessa did not drop low enough for drought measures to go into effect. This was due to the relatively large size of the reservoir, conservation measures taken by SCWA and its customers, and sufficient, if small, rainfall in the watershed.

The 2012-2016 drought validated the salmon attraction flows specified in the Putah Creek Accord. Record runs of fall-run Chinook salmon in 2014 and 2015 occurred mostly before natural runoff events, thus relying on the 5-day pulse flow and brief but substantial releases from breached beaver dams. Most of the salmon were of hatchery origin, in part the result of increased trucking of juvenile salmon from hatcheries for release in downstream areas—mainly in the San Francisco Estuary—because of poor conditions in the rivers for out-migrants. This resulted in many of the returning adults straying to new areas because they were unable to find their way back to the hatcheries.

The salmon came up Putah Creek because it was one of the few places during the dry fall period that indicated to fish that a living stream was available for spawning. During this time SCWA discovered that naturally cemented gravels could be loosened with an excavator and restored to viable spawning habitat. This meant that the most of the increasing numbers of spawning Chinook salmon could find places to spawn, increasing the likelihood that naturally spawned individuals could contribute to future runs. The drought also provide an opportunity for an extended season to control invasive riparian weeds in the winter months, when herbicides used to control Himalayan blackberry and giant reed (*Arundo*) could be applied without damage to dormant native vegetation.

Lessons

Drought has played an important role in the management of Putah Creek. The initial awakening of citizen interest took place during drought in the late 1980s when the poor condition of the creek became even worse. Much of the recovery phase occurred during the dry years that followed the 2000 settlement agreement, when flows and restoration activities allowed native fish, bird, and plant populations to expand. Lake Berryessa's size also enables the SCWA to store water to supply demands within its service area for five or more years, even with no rainfall, which has enabled the agency to release water for instream uses even during severe drought.

The drought validated the salmon attraction flows specified in the Putah Creek Accord. Record runs of fall-run Chinook salmon in 2014 and 2015 occurred mostly before natural runoff events, thus relying on the 5-day pulse flow and brief but substantial releases from breached beaver dams. During this time SCWA discovered that naturally cemented gravels could be loosened with an excavator and restored to viable spawning habitat. The three-fold increase in spawning Chinook salmon that has occurred in each of the prior three years would not have been possible without restoring previously cemented gravels. The drought increased the number of stray fish. Rivers were too warm for direct releases from the hatcheries, so fish were released to the Delta and other estuaries where they lacked a sense of natal origin.

After the 1996 trial, SCWA switched from being strongly opposed to releasing water for fish to being a willing, even enthusiastic, supporter of improving ecosystem functions, working with all parties to the settlement agreement to do the most good with the water available. A good indication of the change in attitudes is that all parties agreed that the Stream Keeper should become a direct employee of SCWA. The agency has also funded additional studies of salmon and aquatic ecology in lower Putah Creek and has been the manager of restoration grant funds described above. SCWA and other stakeholders also have endeavored to improve public outreach and to work more closely with the scientific community to ensure that projects that alter habitat have a firm basis in science.[23]

Putah Creek has also been a test for managing rivers based on several new concepts: the natural flow regime, novel ecosystems, and reconciliation ecology. The combination has resulted in recognition that the creek has been irreversibly altered from its historic condition, with about half its biota being non-native species, so that there is great flexibility in management. Stakeholders are making choices as to what they want the creek to be like, recognizing there will always be a need for intense management, starting with flows and guided by science.

Several key lessons emerge that could guide improvements for managing freshwater ecosystems statewide:

- **Accounting.** One of the main purposes of the Lower Putah Creek Coordinating Committee has been to make sure appropriate monitoring takes place in the creek corridor, as a way to tell how the reconciled creek is working. It helps that they have money from SCWA to pay for monitoring. The monitoring of fish has resulted in the creek being one of the best documented cases where a natural flow regime has been implemented, resulting in thriving populations of native fishes. Monitoring of plants, birds, and other wildlife is ongoing as well. It has documented successes in bringing such species as western bluebirds and Swainsons hawks back to the creek corridor in abundance.
- **Planning.** The settlement agreement accounts for all year types and provides for drought relief based on how much water is in storage at the beginning of the summer. This reduces surprises and conflict between the water users and environment. Monitoring demonstrates the value of restoration projects. This has enabled the Stream Keeper to obtain grant funds for restoration. The success of Putah Creek as a reconciled

[23] Indeed, SCWA has been so engaged in improving the ecosystem of lower Putah Creek that some citizens have resisted changes to their familiar creek and are calling for a halt to restoration actions for a few years.

ecosystem stems in good part from the involvement in the planning process of almost all stakeholders, starting with the SCWA and the three original plaintiffs to the 1996 lawsuit (UC Davis, Putah Creek Council, and City of Davis). The Stream Keeper provides outreach to landowners along the creek and holds public meeting on the project, keeping the process as open as possible.

- **Flow allocation and management.** The Putah Creek settlement created a flow regime to which the native biota are adapted, but also accommodated water users. With a negotiated flow regime that achieves a series of ecosystem functions, all parties are better able to prepare for and respond to the exigencies of drought so that water costs to agencies and water users can be kept at reasonable levels, while also protecting the environment. The successful implementation of the settlement also shows the value of assigning responsibility for flow management and restoration to a single individual or entity. Employing a Stream Keeper to manage and supervise the creek provides leadership for ecosystem projects and adaptive management of the biota. Both are essential to prepare for and respond to drought.

The Sacramento–San Joaquin River and Delta Ecosystem

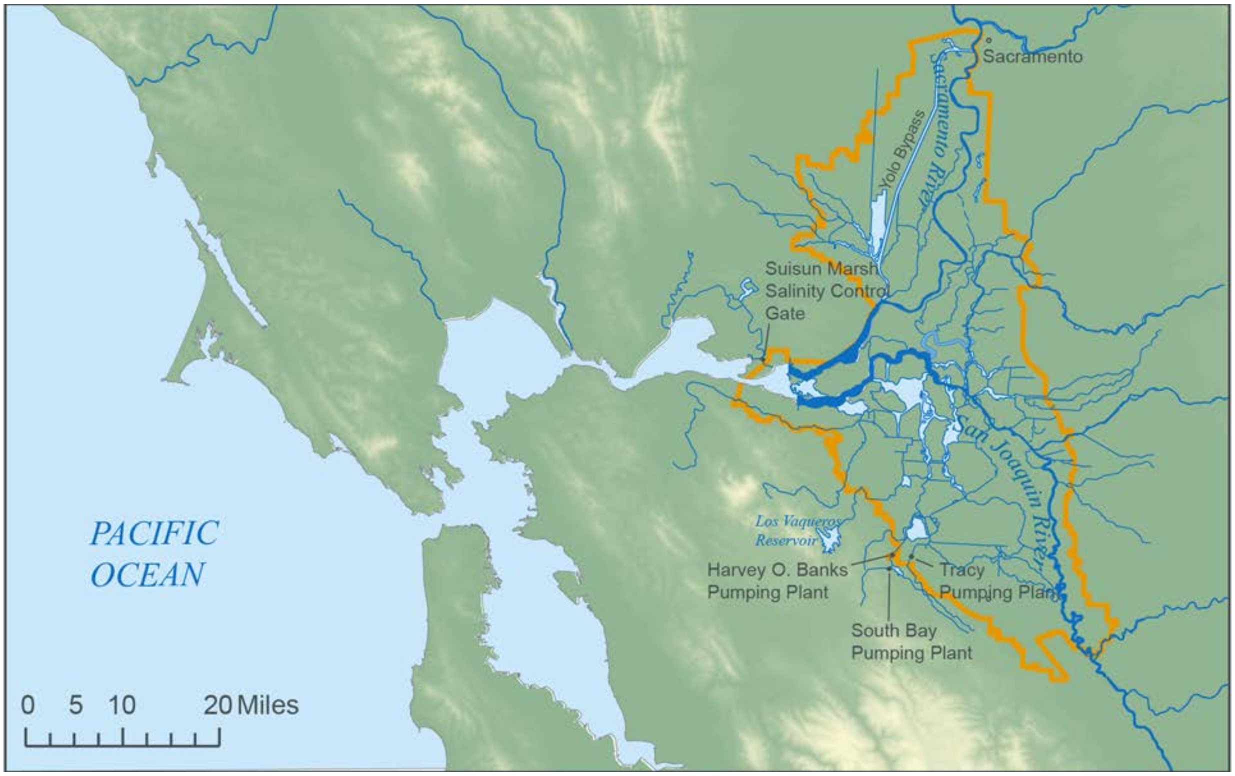
Background

The Sacramento–San Joaquin Delta is the hub of California's water supply system and, arguably, the state's greatest water management challenge.[24] The Delta receives runoff from the Coast Ranges, Sierra Nevada, and the Central Valley and is the freshwater head of the San Francisco Estuary (Figure A8). The Delta is a highly altered and intensively managed landscape. More than 90 percent of its historic tidal marshes have been reclaimed, all waterways are channelized and bound by levees, and roughly half of its average annual inflow is diverted for use upstream.

Delta diversions account for approximately 15 percent of the state's water supply, providing water to 25 million residents in the Bay Area and southern California and 3 million acres of farmland in the San Joaquin Valley. Ecosystem conditions in the Delta have changed dramatically, leading to a long term decline in native fishes, with listings of multiple species as threatened or endangered under state and federal Endangered Species Acts. The causes of this decline are many, but habitat loss and changes in flows are routinely cited as the primary cause (Moyle 2013). The conflicts between water supply operations and efforts to maintain native fishes have been at the center of controversy over the Delta for several decades.

[24] For a summary of Delta challenges and recommendations for reform, see Mount, Jeffrey, Caitrin Chappelle, Brian Gray, Ellen Hanak and Jay Lund. 2016. *The Sacramento–San Joaquin Delta*. Public Policy Institute of California.

FIGURE A8
Sacramento–San Joaquin River and Delta watershed



SOURCE: PPIC. For a detailed list of sources, see Figure 1.

Institutional Framework

Management of the Delta is complicated, with multiple, overlapping federal, state, and local responsibilities. As outlined in a companion report (Gartrell et al. 2017), inflow to the Delta is apportioned in four ways: (1) water used by diverters in the Delta; (2) water exported by the Central Valley Project (CVP) and State Water Project (SWP) for delivery to farms and cities in northern and southern California; (3) "system water" needed to protect water quality from excess salinity to support in-Delta diversions and exports; and (4) "ecosystem water" required by the State Water Board's Water Quality Control Plan for the Delta Estuary, Water Rights Decision 1641 governing CVP and SWP operations, and the 2008 federal Biological Opinions protecting listed fishes.[25] In addition to these managed flows, the Delta receives considerable volumes of unmanaged flows, typically during winter and spring. This "uncaptured water" provides incidental benefit to water users and the environment by freshening the Delta and San Francisco Bay (Cloern et al. 2017).

During drought, most natural runoff is diverted by riparian and senior appropriative water-right holders in and upstream of the Delta. To export water from the south Delta, the CVP and SWP must release additional water from project reservoirs, both to supply their contractors and to maintain water quality for in-Delta diversions and project exports. As droughts persist into multiple consecutive years, the water stored in project reservoirs is depleted, which makes it increasingly difficult to supply the needs of in-Delta diversions and project exports, along with outflow to maintain low salinities. This difficulty is compounded by the need to maintain cold water reserves in reservoirs to meet flow and temperature standards for salmon and steelhead (see the Shasta Dam case study). This often leads to reductions in water service to CVP and SWP contractors during severe drought.

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[25] "Ecosystem water" includes outflow required by regulations along with outflow created by limits on export pumping by the CVP and SWP.

During drought, Delta outflow also generates significant controversy because it is viewed by some as "wasted to the sea," rather than delivered to valuable economic uses on farms and in cities. Yet there are many misconceptions about its role. Stakeholders and water users tend to conflate outflow needed to maintain salinity levels to allow for in-Delta diversions and south Delta exports ("system water") with outflow needed to meet regulatory standards to benefit native fishes ("ecosystem water"). This stems, in part, from current accounting practices at the Department of Water Resources (DWR) that lumps system water and ecosystem water into a single class of "environmental" water. As outlined below, during the height of the 2012-2016 drought, water for the ecosystem made up a very small fraction of Delta outflow.

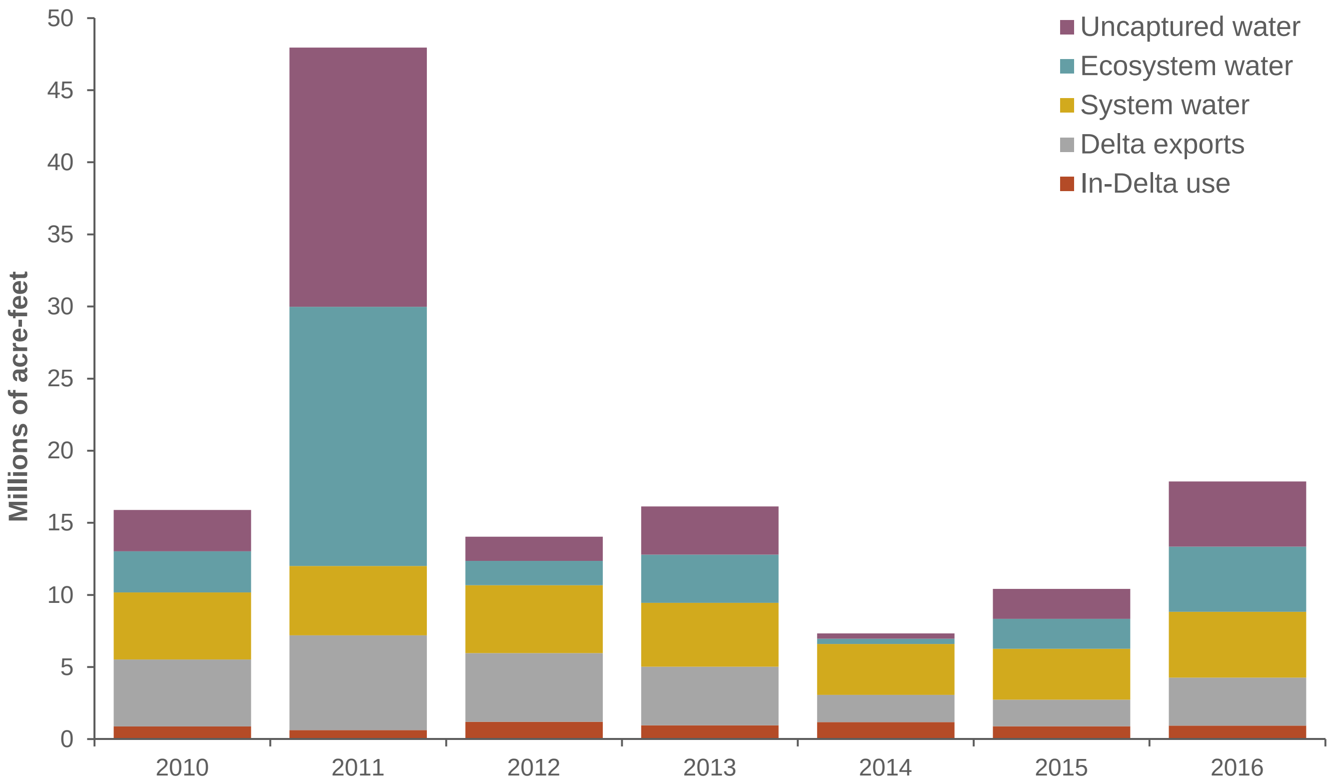
Although the CVP and SWP are responsible for maintaining both system and ecosystem flows in the Delta, they may seek to relax salinity and flow standards during drought emergencies by submitting Temporary Urgency Change Petitions (TUCPs) to the State Water Board. The board has authority to grant temporary urgency change orders altering water quality and flow, and temperature standards, as well as relaxing operational requirements (such as timing limits on export pumping and closure of the Delta Cross-Channel) for up to 180 days.

The Latest Drought

The drought had significant consequences for the water availability in the Delta. Figure A9 summarizes the volume of inflow and how it was partitioned during the drought.

FIGURE A9

Assignment of inflow to the Delta from 2010–16.



SOURCE: Gartrell et al. (2017).

NOTE: This graph depicts how inflow was apportioned in the Delta to various uses.

The decline in Delta inflows from 2012 to 2015 (the lowest year during this drought) reflects the limited precipitation in the Sacramento–San Joaquin River basins and the drawdown of water stored in upstream CVP and SWP reservoirs. By 2014—the third consecutive dry year—there was great pressure on project operators to meet multiple, often conflicting goals. But there were no contingency plans in place before the drought to aid decision making.

In January 2014, USBR and DWR submitted a TUCP to the State Water Board to relax four provisions of Decision 1641 after record low precipitation that month.[26] The petition proposed changes in requirements for Delta outflow, salinity levels, flow on the Sacramento and San Joaquin Rivers, and Delta Cross-Channel operations. The purpose was to conserve water in storage that would be needed later to meet temperature requirements in the Sacramento River for migrating salmon, to control salinity in the Delta for exports and in-Delta users, and to meet minimum health and safety requirements for the projects' urban water contractors.

At the time of the petition, volumes in Shasta, Oroville, and Folsom reservoirs were about 3 million acre-feet (maf) and were forecasted to drop to dead-pool storage levels (about 1.4 maf) by mid-July based on meeting regulatory requirements and minimum supply needs. At this point, the CVP and SWP would no longer be able to control salinity in the Delta, nor would USBR be able to release water from Shasta to protect winter-run Chinook salmon on the Sacramento River.

In a series of 2014 Orders, the State Water Board: (1) reduced the requirement of a minimum Delta outflow in February from 7,100 cubic feet per second (cfs) to 3,000 cfs, which saved up to 0.23 maf of stored water; (2) allowed the Delta Cross-Channel gates to be open to help meet salinity control in the Delta;[27] (3) limited exports to health and safety levels (1,500 cfs) when D1641 flow and salinity standards were not being met; (4) reduced the required flow in the lower Sacramento River from September through November 15; (5) moved the compliance point for a key Delta water quality standard upstream to Three Mile Slough on the Sacramento River; and (6) reduced San Joaquin River inflow requirements in October to conserve storage in New Melones reservoir. The board also required USBR and DWR to develop better estimates of water balances in CVP and SWP facilities, along with quarterly drought contingency plans.

At the start of the 2015 calendar year, conditions had not substantially improved. USBR and DWR again submitted TUCPs seeking similar reductions in water quality and outflow standards as in 2014. Their primary stated goals were to retain water in project reservoirs to meet downstream flow and temperature standards and Delta water quality requirements, while also fulfilling their contractual water service obligations and supplying water for public health and safety.[28] The projects also sought greater flexibility in their operations to take advantage of storm related inflows.

The State Water Board approved the TUCP on February 3rd and amended it a month later to reduce impacts of project operations on delta smelt. Throughout March, the Bureau and DWR submitted amended TUCPs to further relax salinity and outflow standards in the Delta and to increase exports. The board issued a new TUC order in April. In it, the board limited the projects' full request to relax the salinity, outflow, and pumping standards, and it

[26] All 2014-2016 TUCPs and change orders related to CVP and SWP operations are summarized on the State Water Board's website.

[27] The board coordinated this aspect of the TUC orders with National Marine Fisheries Service to ensure that the Delta Cross-Channel was closed when needed to protect migrating salmon.

[28] USBR has an obligation to deliver a minimum of 75percent of the stated contract amounts to two groups of CVP contractors who held pre-project water rights. These priority contractors include the Sacramento River Water Rights Settlement contractors and the San Joaquin River Exchange Contractors. The other CVP and SWP contractors have no minimum water service rights during severe drought. In 2014 and 2015, CVP water service contractors located south of the Delta received no project water, while SWP contractors who rely on Delta exports received 5 percent of their state contractual entitlements in 2014 and 20 percent in 2015 (USBR 2016; MWD 2016).

raised concerns over USBR's temperature management efforts, including Shasta and New Melones Reservoirs. It also required USBR to provide a temperature management plan for approval by the board's executive director.

By spring 2015, it was growing more difficult to manage salinity in the Delta due to the accumulated depletions of reservoir storage and—in the case of Shasta and New Melones Reservoirs—the need to manage water temperatures in the Sacramento River and the lower San Joaquin and south Delta. In May, the board issued a water quality certification to DWR that allowed the construction of a rock barrier in West False River in the south Delta to reduce the amount of outflow needed to maintain salinity standards for export pumping.

In July, the State Water Board extended the TUC order for the remainder of the summer and into early fall. This order required substantial improvements in coordination between the projects and the state and federal fisheries agencies, and greater investments in planning, monitoring, modeling, and reporting.

USBR and DWR operated the projects under the July TUC orders throughout the summer of 2015. The rock barriers were removed in the early fall. Then late fall and early winter rains eased conditions more generally. Although drought contingency planning continued into 2016, no further TUCPs were submitted to the board.

The State Water Board's analysis of the water supply consequences of these orders concluded that they increased water available for CVP and SWP exports by approximately 400,000 acre-feet in 2014 and 688,000 acre-feet in 2015.[29] Although these estimates were short of initial expectations—and some arrived late in the irrigation season—the additional water was nonetheless important for the CVP and SWP contractors.

Based on the analysis in our companion report (Gartrell et al. 2017), most inflow and outflow during the driest years of the drought was used to maintain salinities for in-Delta uses and exports. In 2015, when outflow from the Delta was lowest (Figure A9), ecosystem outflow was approximately 500,000 acre-feet (and largely occurred in the spring). In contrast, system outflow was 3.5 million acre-feet—seven times the ecosystem outflow. Under DWR's existing accounting protocols, however, almost all of this outflow is assigned to environmental water, fueling debate over priorities during drought.[30]

During the critical drought years of 2014 and 2015, the State Water Board issued TUC orders that reallocated ecosystem water from the uses specified under Decision 1641 to project exports. All decisions—whether to reserve greater amounts of water in reservoirs to meet temperature standards or to reduce salinity and outflow standards to improve export yields—shifted water away from the Delta ecosystem. In some cases, the tradeoff was between competing ecosystem needs, such as temperature control for salmon in the Sacramento River vs. Delta water quality and flows for resident species. Even in these cases water maintained in storage was available for late release and eventual exports.

The ecological consequences of these tradeoffs are yet to be well documented. During the 2014-2015 water years, fish monitoring by the California Department of Fish and Wildlife showed historically low population levels, including delta smelt and longfin smelt, Sacramento splittail, and American shad and striped bass juveniles. Additionally, efforts to manage temperatures to conserve Sacramento River winter-run Chinook salmon were unsuccessful in both years, leading to loss of 95 percent of eggs and fry in 2014 and 98 percent in 2015 (see Shasta Dam case study).[31] The long term consequences of these low population numbers are not yet known.

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[29] A PowerPoint presentation summarizing these results is available at: www.waterboards.ca.gov/waterrights/water_issues/programs/drought/docs/workshops/swrcb_staff_pres_session1b.pdf.

[30] We address this in more detail in the main report, Reform Proposal 1.

[31] These figures are summarized in the 2016 drought contingency plan presented by DWR and the Bureau to the State Water Board.

Lessons

The 2012–2016 drought tested the laws, regulations, and institutions designed to manage the balance between water allocated for farms and cities and water allocated to support ecosystem health. Extraordinary efforts were made by the CVP and SWP operators, water users, state and federal fish agencies, and the central player—the State Water Board—to minimize impacts of extreme water shortages and tenuous water quality. Although unprecedented levels of cooperation occurred among agencies, a series of key takeaways should inform the preparation for future droughts. These include:

- **Accounting.** The "water wasted to the sea" political fights during the drought distracted from efforts to manage water efficiently and effectively for all uses. The claimed environmental use of water—which was mostly for maintaining salinities for in-Delta use and exports—became a scapegoat for some water users. The managerial and regulatory efforts to manage this crisis would have been better served by more accurate accounting that distinguished between necessary system and ecosystem water. There should also be greater transparency on the data, methods, and assumptions used to determine how much water is available in the system so that users, control agencies, and others can better independently evaluate availability. In addition, important lessons for the management of the Delta could be gleaned from the way the system was altered during the drought. The salinity barriers showed the potential—indeed the likelihood—of altering the geometry of channels in the future to manage for droughts as well as flows and water quality generally. But there was a lack of monitoring and science around the 2015 barrier, which is a lost opportunity for more fundamental thinking about and understanding of Delta ecological and water quality processes.
- **Planning.** Most of the issues faced during the drought were predictable. The challenges of managing cold water pools, the difficulty associated with maintaining Delta salinity, the risk of drought impacts on the Delta ecosystem, and the likely tradeoffs between water supply and aquatic habitat (and sometimes between the species themselves) were all predictable consequences of extended drought. Moreover, the warm nature of this drought—although unprecedented—should also have been anticipated in light of the predicted hydrologic effects of climate warming.

  The projects' heavy reliance on TUCPs also reflected a lack of advanced planning and scenario testing. It forced the State Water Board to make critical decisions on the fly without adequate information on the likely effects of the proposed changes on the ecology of the Delta. Indeed, detailed drought contingency planning and public discussion of risks and trade-offs did not occur until late in 2014, and only then under compulsion from the Board. Better CVP and SWP planning—including dry runs to anticipate and identify the most severe ecological stresses and difficult tradeoffs—would have helped mitigate both drought effects and controversy.
- **Allocation.** The current approach to environmental management of the Delta is based principally on minimum standards. When water availability declines, there is pressure to relax these standards to make more water available for agricultural and domestic uses. This process creates uncertainty, both for water supply and for ecological stewardship. Creation of defined water budgets for the rivers of the Sacramento and San Joaquin River systems, and for the Delta itself, would reduce this uncertainty and better protect the ecological health of the system.

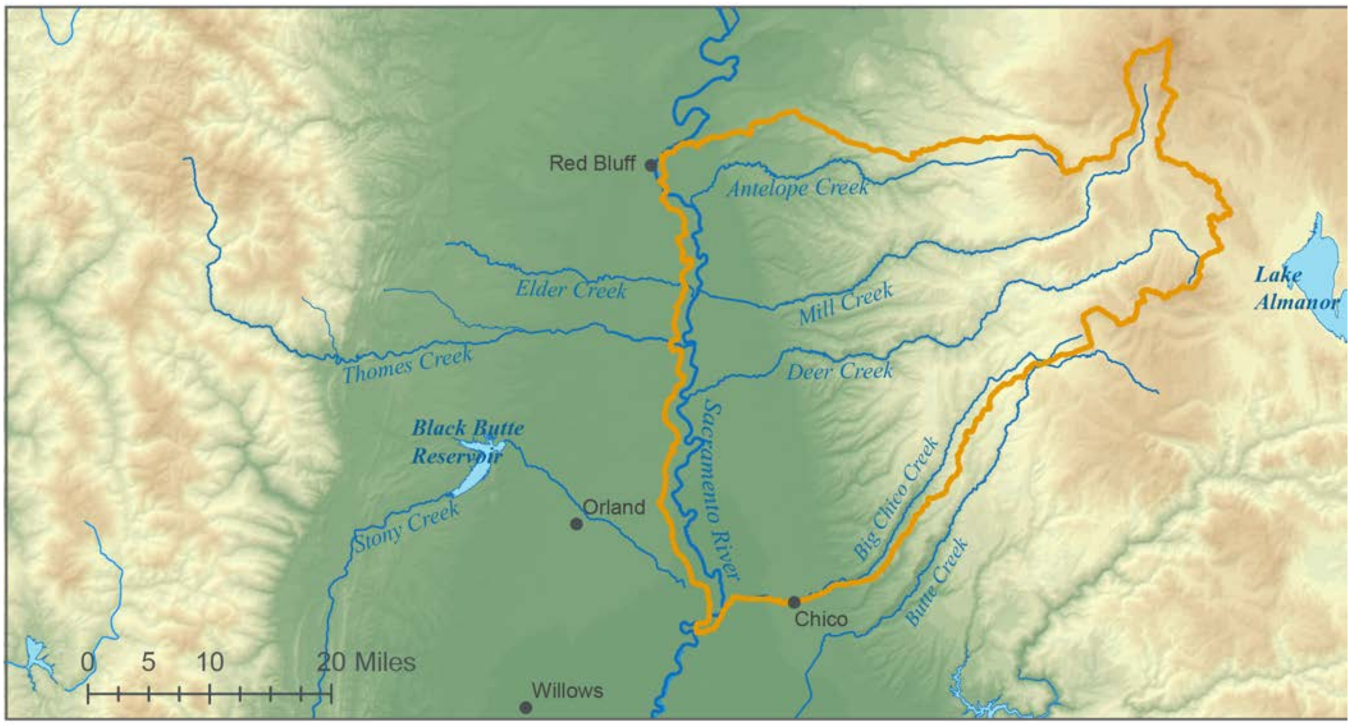
Deer, Mill, and Antelope Creeks[32]

Background

Deer, Mill, and Antelope creeks are east-side tributaries of the Sacramento River below Shasta Dam (Figure A10). All three creeks are important spawning and holding[33] habitat for Central Valley spring-run Chinook salmon and Central Valley steelhead, both listed as threatened under the federal and California Endangered Species Acts (National Marine Fisheries Service and California Department of Fish and Wildlife 2014). None of the creeks have significant water storage, and the primary use from all three is agricultural irrigation. Although each creek has a relatively limited number of diversions, water use in all three can cause flows to drop sufficiently to make salmon and steelhead migration impossible.

FIGURE A10

Deer, Mill, and Antelope Creeks



SOURCE: PPIC. For a detailed list of sources, see Figure 1.

Institutional Framework and Environmental Challenges

Even before the latest drought, the State Water Board, the California Department of Fish and Wildlife (CDFW), and the National Marine Fisheries Service (NMFS) had focused on flows in the three creeks, both because of their high value salmon and steelhead habitat and because diversions had the potential to limit fish habitat. As a result, the agencies had reliable and relatively complete data regarding water withdrawals and streamflow, as well as a good understanding of the tributaries' hydrology (National Marine Fisheries Service 2014). Several conservation groups—most notably The Nature Conservancy (TNC)—were also active in protecting streamflows and fish

[32] This case study summarizes findings from a longer article by Vissers (2017) featured in *West-Northwest Journal of Environmental Law and Policy*.

[33] Holding habitat is needed for spring-run Chinook that enter the rivers in the spring and stay until fall for spawning.

habitat in the tributaries well before the onset of drought. The Department of Water Resources has also been active on Mill Creek to encourage conjunctive use.

Deer, Mill, and Antelope Creeks share several common attributes: relatively few water suppliers or large irrigators, no significant surface storage, and critical habitat for listed species. The watersheds differ in other respects. Mill Creek has one main large water company (Los Molinas Water Company) and seven smaller water-right holders. The water users on Mill Creek have a history of cooperative efforts with regulatory agencies and conservation groups to protect streamflows. These efforts date back to 1990, when Los Molinas entered into an agreement to switch some of its surface water diversions to groundwater pumping at key times to leave more water instream for fish. TNC owns an environmental water right on Mill Creek, which affords it a seat at the table with the other water-right holders. The Mill Creek water users agreed to a Long-Term Cooperative Management Plan in 2007, which created a system for limiting diversions for fish flows through calls on the creek. In contrast, Antelope Creek and Deer Creek only have two significant water users each (Vissers 2017).

The Latest Drought

The centerpiece of the State Water Board's drought response on Deer, Mill, and Antelope Creeks was an emergency regulation adopted on May 21, 2014 (State Water Resources Control Board). Following two consecutive extremely dry years, there was a significant risk that irrigation diversions would dry up all three creeks, or at least reduce flows sufficiently to block fish passage and eliminate access to holding and spawning habitat. The regulation included three critical components: minimum flows and pulse flows for all three creeks, authorization for board staff to issue water rights curtailment orders if necessary to meet flow targets, and a provision that board staff would not issue curtailment orders if the water users within each watershed could reach voluntary agreements with the fishery regulatory agencies to protect stream flows.[34]

A related but separate action by CDFW and NMFS under the California Voluntary Drought Initiative provided additional incentives for water users to voluntarily reduce water withdrawals. The initiative provided that if a water user entered into a voluntary agreement, that agreement would be considered a mitigating factor if the water user inadvertently caused harm to (or take of) any ESA-listed species.

In Mill Creek, the existing arrangements softened the blow of the emergency regulation and paved the way for water-right holders to sign a voluntary flow agreement under the regulation, thereby avoiding a curtailment order. Although Antelope Creek did not have the same history of cooperative agreements, both of its water users signed voluntary agreements to maintain stream flows. They did so primarily because they were facing the threat of mandatory curtailment orders, and they preferred the ESA enforcement protection afforded under the California Voluntary Drought Initiative.

Deer Creek was a different story. The two primary water-right holders had a history of conflict, both with each other and with the regulatory agencies. Ultimately, one of them was not willing to sign a voluntary agreement, and the board issued a curtailment order. Both water-right holders complied with the curtailment order. The user who refused to sign chose to preserve the option of suing the State Water Board over any ESA enforcement protection afforded by the voluntary agreements.

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[34] The emergency regulation was significant from a legal perspective because it authorized curtailment of appropriative water rights in favor of protection of instream, environmental uses of water. The board relied on several legal authorities to justify this decision: Governor Brown's 2014 declaration of a drought emergency; California Water Code Section 1058.5, which authorizes the board to issue emergency regulations during severe droughts; the board's own finding of the existence of a severe drought; its determination that water withdrawals that impaired minimum flows needed for salmon and steelhead would constitute unreasonable uses of water under Article X, Section 2 of the California Constitution; and its authority to limit water rights if needed to protect public trust resources. See 23 California Code of Regulations §877.

In 2015 the emergency regulation was renewed by the State Water Board with subsequent re-adoption of the emergency regulation provisions. In contrast to 2014, an insufficient number of water-right holders in the watershed signed the voluntary agreements resulting in two curtailment orders for Antelope Creek.

Lessons

On the ground, the State Water Board's emergency regulation, the voluntary agreements on Mill and Antelope Creeks, and the Deer Creek curtailment order provided for adequate minimum flows for fish passage and holding habitat, and avoided catastrophic dewatering of the three creeks. Although there were a few issues with compliance, the creeks generally benefitted from the required flows. All three creeks received base flows and pulse flows from March 15 through June 15 for fish migration, lower base flows for juvenile salmon after that, and base flows for fish passage during the winter months. Both base flows and pulse flows were higher than levels achieved under previous voluntary measures in the watersheds.

The flows did result in successful fish migration and spawning. For example, CDFW estimated that 268 spring-run Chinook entered Deer Creek from February through June 2015. CDFW data showed that between October 26 and December 15, 971 fall-run Chinook salmon and 56 fall-entry steelhead were recorded passing Ward Dam on Mill Creek, and that 89 additional salmon entered Mill Creek and spawned downstream of Ward Dam. In short, the evidence suggests that the State Water Board's actions avoided catastrophic dewatering of the creeks and protected the fishes' critical habitat, despite the unprecedented lack of water.

The primary weakness of the board's actions relates to the overall role of these three creeks in the Sacramento River system. Salmon fared poorly throughout the Sacramento River basin during the drought. There is insufficient information to determine if the actions that resulted in better flows in Deer, Mill, and Antelope creeks improved survivorship, particularly because juveniles must move through the Sacramento River and Delta to reach the sea. Therefore, it is not clear how much improved flows in the three tributaries contributed to protection of salmon and steelhead populations. As a result, some water users on the tributaries believe they were unduly burdened, with few demonstrative benefits for overall fish populations.

Several key lessons emerge that could guide improvements for managing freshwater ecosystems statewide:

- **Accounting.** Deer, Mill, and Antelope Creeks' importance as salmon and steelhead habitat meant that the regulatory agencies and water managers had ample data and a good grasp of the biology and hydrology of the three tributaries before the onset of drought. Consequently, they could decide with a high degree of certainty what actions were needed to meet the flow targets. The collection and analysis of the necessary data in advance of the drought greatly facilitated drought response.
- **Planning.** Protecting stream flows had been a focus in these three watersheds well before the drought. Particularly in Mill Creek, the plans and strategies adopted before the drought began eased implementation of the emergency regulation during the drought. The effectiveness of flow protection measures on Deer, Mill, and Antelope Creeks may be limited by stresses on salmon and steelhead elsewhere in the system, however. Flows in these tributaries need to be protected, because these tributaries represent particularly important habitat for remnant wild runs of salmon and steelhead. But those efforts must be folded into better overall management of the Sacramento River system.
- **Flow allocation and management.** On Mill Creek, the fishery regulatory agencies, water users, and environmental stakeholders implemented at least two significant voluntary agreements to protect flow. The first was TNC's purchase of water rights. The second was Los Molinas Water Company's conjunctive management strategy to switch some of its surface water diversions to groundwater pumping to augment stream flows. These strategies minimized the additional water use reductions during the drought and laid

the foundation for cooperative implementation of further water use reductions as needed. These preexisting arrangements paved the way for reduced conflict, provided additional assurances for water users to soften the blow of the emergency regulation, and served as a model for water-right holders to pursue voluntary flow agreements in lieu of curtailments. In addition, the State Water Board’s emergency regulations for the three tributaries demonstrate that it can protect the environment when it chooses to use those powers. The regulations elevated flows for fish over appropriative water rights, based on emergency powers triggered by the drought, the public trust doctrine, and Article X, Section 2 of the California Constitution. The threat of potential curtailment orders and ESA enforcement also motivated some water users to enter into voluntary agreements to protect vital fish habitat.

The Russian River[35]

Background

The Russian River is a major coastal river in northern California, It originates in Mendocino County and flows through Sonoma County before entering the Pacific Ocean (Figure A11). Its watershed covers approximately 1,485 square miles. The Russian River and its numerous tributaries are habitat for Chinook salmon, coho salmon, lampreys, and steelhead as well as a diverse freshwater fish fauna (e.g., Russian River tule perch). Historically, major runs of salmon and steelhead spawned in the Russian, with cool water tributaries playing a major role as juvenile rearing habitat. Stream channelization, road construction, and water diversions have all taken a toll on anadromous fish runs. Under the federal Endangered Species Act, the runs of steelhead and Chinook are listed as threatened, and coho are listed as endangered (US Army Corps of Engineers 2008).

FIGURE A11

The Russian River watershed

SOURCE: PPIC. For a detailed list of sources, see Figure 1.

[35] This case study summarizes findings from a longer article by Ugai (2017) featured in *West Northwest Journal of Environmental Law and Policy*.

Institutional Framework and Environmental Challenges

The Sonoma County Water Agency operates two reservoirs in the Russian River system, Lake Mendocino and Lake Sonoma. In recent years, wine growers have become the most economically significant water users in the basin, which currently is home to more than 60,000 acres of vineyards (*Light v. State Water Resources Control Board 2014)*. In the years before the latest drought, some conflicts arose between the water needs of vineyards and the flow needs of salmon. The principal source of conflict was surface water diversions and groundwater pumping to water grape vines to protect them from spring frost damage. This practice would sometimes dewater key tributaries, because many vineyards would pump water for this purpose at the same time.

In 2011, the State Water Board issued regulations that prohibited surface water diversions and groundwater pumping except in compliance with a water demand management plan. The regulations were based on the board's finding that, although frost protection was a beneficial use, water withdrawals that harmed salmonids was unreasonable under Article X, section 2 of the California Constitution. Water users challenged this regulation in court, but the California Court of Appeal upheld the regulation in 2014 in *Light v. State Water Resources Control Board*.

The Latest Drought

During the drought, regulatory efforts focused on four key tributaries to the Russian River identified as high priority for salmon and steelhead. Green Valley, Mill, Dutch Bill, and Mark West Creeks were all at high risk of dewatering and having high temperatures. These actions took two phases: encouragement of landowners to enter into voluntary agreements to limit surface water diversions beginning in April 2014, and an emergency rule to reduce both surface water diversions and groundwater pumping issued in July 2015.

- **April 2014.** The California Department of Fish and Wildlife (CDFW) and the National Marine Fisheries Service (NMFS) entered into a voluntary drought initiative focused on four priority watersheds, including the main stem of the Russian River. The initiative sought to enlist landowners in efforts to restore flows during the drought, in exchange for modest regulatory assurances under the state and federal Endangered Species Acts—specifically, a commitment by both agencies that they would consider a landowner's participation in the initiative in enforcement decisions if an inadvertent species take should occur due to the landowner's actions (National Marine Fisheries Service and California Department of Fish and Wildlife 2014).
- **May 2015.** CDFW had reached agreements with 19 residential landowners in the basin (similar in structure to what was seen on the Deer, Mill, and Antelope Creeks), who had agreed to conserve water and to provide CDFW access to their property for purposes of monitoring and rescuing fish. The most notable benefits of these voluntary efforts, however, came from short term flow augmentation agreements, including the following (see Ugai 2017):
  - In early April 2015, a number of juvenile coho were trapped in an isolated pool on Porter Creek. Voluntary releases from storage by a Gallo winery allowed the fish to migrate downstream to the main stem.
  - In August 2015, approximately 2,000 juvenile coho and 1,400 juvenile steelhead were in danger of being trapped in Dutch Bill Creek. Agencies connected the water tank of a small local water agency (the Camp Meeker Recreation and Park District) to the creek using 450 feet of flexible pipe. A small release from Camp Meeker's tank (0.10 cubic feet per second) was enough to allow the fish to survive through the summer.
  - Voluntary releases from storage by several parties on Green Valley Creek helped connect isolated pools.
  - In 2015 and 2016, Jackson Family Wines made voluntary releases from storage and donated $20,000 to buy equipment to make those releases possible.

- **June 2015.** Despite these efforts, by late spring and early summer the situation for Russian River salmon was near catastrophic. Summer flows in the four priority tributaries were 90 percent lower than in 2010, and as many as 30,000 juvenile coho were at risk of stranding and death. At the behest of CDFW in collaboration with NMFS, on June 17, 2015 the State Water Board adopted a drought emergency regulation entitled "Emergency Actions due to Insufficient Flows for Specific Fisheries in Tributaries to the Russian River" (Emergency Regulation).

The Emergency Regulation included two components: a Conservation Order and an Information Order. The Conservation Order applied only to non-agricultural water use in the four priority basins. It imposed water use restrictions that largely tracked those the board had already applied to municipal users earlier in the drought, including prohibiting watering of ornamental turf (lawns) and washing cars with water sourced from the four watersheds.

The Information Order was needed because the board did not have complete data regarding water users in the basin, and would need that data "to inform future actions" if the Conservation Order was not adequate. The Information Order required all landowners and water suppliers to submit a variety of data regarding their diversions of surface water and pumping of groundwater, including the location of the diversion or well, the uses of the water, amounts used, any storage capacity, and pumping rates.

The State Water Board did not issue any curtailment orders to protect fish (as it had for Sacramento tributaries—see the Deer, Mill, and Antelope case study), in part because there were a broader number of water users in the Russian tributaries and but also because there was a lack of flow recommendations from fish agencies. Many users pumped groundwater that is not within the board's permitting authority.

Lessons

The voluntary flow augmentation actions that CDFW and other agencies took with local landowners and regional authorities (such as the Gold Ridge resource conservation district) were the most successful part of the state's effort in this watershed. In several instances, a small amount of extra water allowed older juvenile fish to migrate downstream and young juvenile fish to rear and survive over summer. Collectively, these efforts may have saved thousands of juvenile salmon and steelhead, although insufficient monitoring was conducted to verify this. The subsequent fate of these fish is unknown.

The consequences of the Conservation Order are still unclear. The amount of water conserved is unknown, and compliance with the order may have been spotty. Due to the small amount of water involved, there probably would have been no way to accurately measure the change in flows from any water that was saved. The Conservation Order also failed to impose any requirements on agricultural uses of water. This led to loud and public complaints among other landowners. Enforcement of the order also proved difficult, because of the rural nature of the landscape and because it is difficult to monitor water use by private landowners. Lax enforcement also generated hard feelings on the part of those landowners who cut their water use. Finally, a lack of data about water use and the interaction between water use and streamflow make it impossible to determine the impact of conservation efforts on streamflow or fish.

The Information Order did allow the State Water Board to collect important data about water use in the basin—data that would have been a valuable asset in making water management decisions during the worst stretches of the drought. The data collection effort started late in the drought and took time, however, in part because of difficulties landowners had filling out the web-based form that the board developed for the purpose and a reluctance by some landowners to provide the requested information. It was not until January 2016 that the board achieved a 90 percent response rate on the survey. The data came in too late to inform drought response decision making.

The State Water Board's response was also hampered by the nature of water use in the four tributaries. Many water users there rely on small wells, which are outside the board's permitting authority. In addition, the large number of water users would make regulatory action more difficult than in the Sacramento tributaries, where the board was able to focus on a smaller number of large water users. (See the Deer, Mill, and Antelope Creek case study). Time will tell the severity of the consequences of the recent drought, but initial signs are not positive. Surveys in 2014 of several key spawning creeks found 97 percent fewer juvenile coho than a similar survey in 2013.[36]

Several key lessons emerge that could guide improvements for managing freshwater ecosystems statewide:

- **Accounting.** Drought response in the Russian River basin underscores the importance of good data about water use and streamflow. Agencies lacked basic data about water use, including the locations of wells and diversions, the amount of water withdrawn or pumped, and the extent and purpose of water use. They also lacked information about watershed hydrologic processes, particularly the interaction between groundwater withdrawals and streamflow. This lack of information hampered the agencies' decision making, as well as assessment of the effectiveness of the actions they did take. However, the Sonoma County Water Agency does monitor fish populations in the river and its tributaries, so the impacts of decisions on fish could be studied.
- **Planning.** The most effective agency responses in the Russian River basin were not the State Water Board's formal orders, but rather a series of improvised efforts by CDFW working with water users and resource conservation districts to voluntarily augment flow where and when it was critically needed. These efforts required creativity, a willingness of water users to take actions to protect fish, an effective presence on the ground, and knowledge of where additional water would most benefit fish. Together, these factors enabled CDFW to accomplish a great deal with a small amount of water. All of these agreements and other potential agreements would have been more effective, however, if negotiated as part of pre-drought planning.
- **Flow allocation and management.** The State Water Board's basis for its emergency order in the priority tributaries was its power to prohibit unreasonable uses of water, as well as its finding that water use that harms salmon may be unreasonable. The board had previously used this authority as the basis for its earlier frost protection regulations in the basin, a rationale upheld by the California Court of Appeal in the *Light* litigation. It also deployed this authority more directly and effectively in the Deer, Mill, and Antelope creek watersheds during the drought.

Managed Wetlands

Background

The wetlands of California's Central Valley provide important habitat for resident and migratory waterbirds. These wetlands are especially important in the fall, winter, and spring, when millions of ducks, geese, cranes, and shorebirds use them as stopping points on their journey along the Pacific Flyway (Garone 2011). Historically, the Central Valley wetlands would have flooded and dried throughout the year. In periods of drought, the amount of habitat would decline. When the droughts broke, however, the rivers of the Sierra Nevada would flood the valley, transforming it into a vast inland sea that supported abundant bird populations (Garone 2011). The construction of upstream dams resulted in the capture of most of the floodwaters, and land development drained most natural wetlands. Today, Central Valley birds rely on a network of managed wetlands—intentionally flooded areas in federal refuges, state wildlife areas, and on private lands (Garone 2011) (Figure A12). They also use flooded

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[36] From a 2015 op-ed by Thomas Howard and Chuck Bohnam.

farmlands that act as surrogate wetlands, the most notable of which are rice farms that are flooded in the fall and winter to break down rice straw (Strum et al. 2013, Petrie et al. 2016). The amount and quality of the habitat provided by managed wetlands and flooded agricultural fields are highly regulated and dependent on the delivery of water.

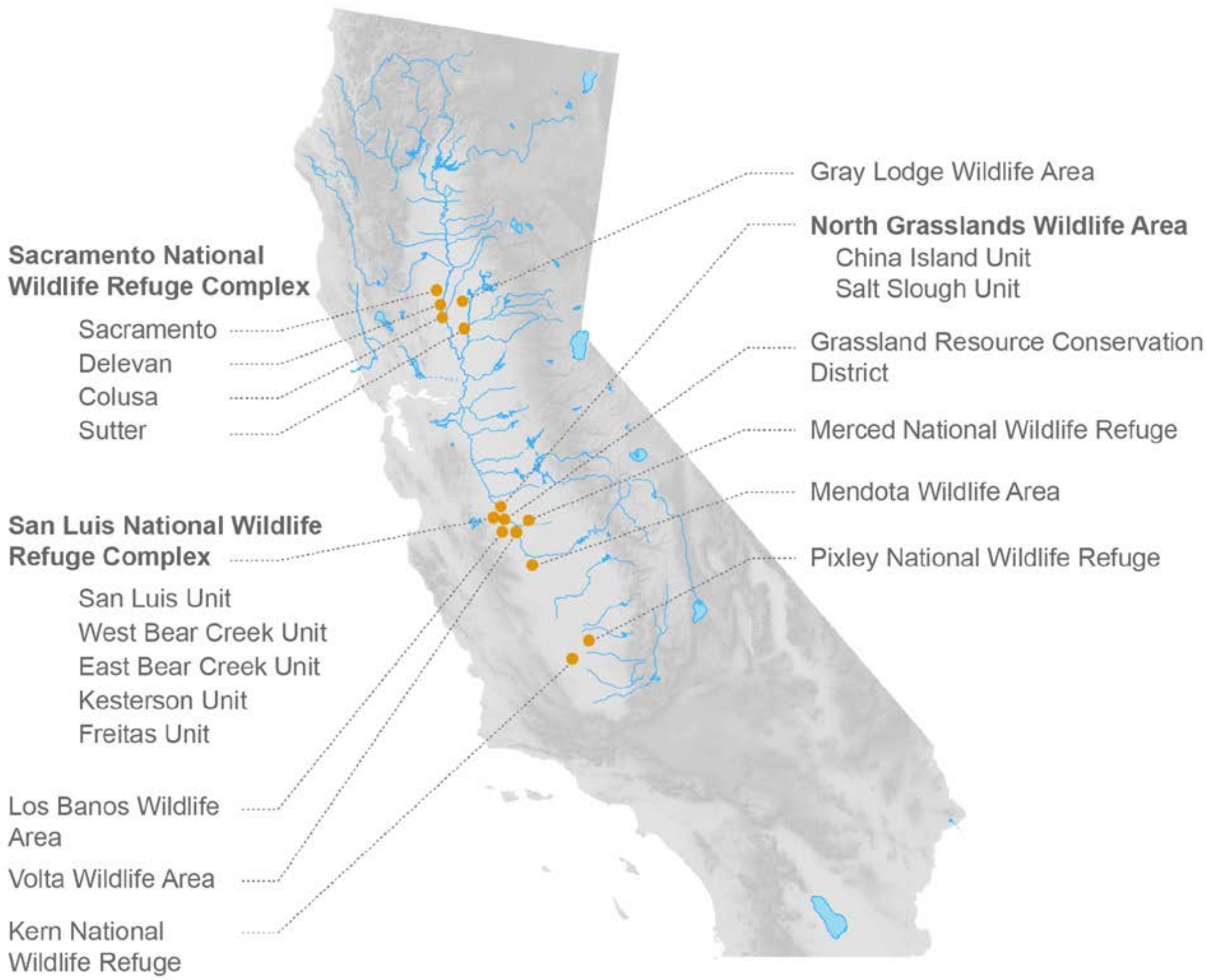
Institutional Framework and Environmental Challenges

Most managed wetlands in the Central Valley depend on surface water deliveries. The water supply for many of these wetlands was formalized in the 1992 Central Valley Project Improvement Act (CVPIA). This agreement authorizes an annual contracted delivery of approximately half a million acre-feet of mostly Central Valley Project (CVP) water to federal, state, and private wetlands. In drought years, the CVPIA gives USBR flexibility to reduce water deliveries to these wetlands.

During drought years, water for waterbird habitat on flooded cropland and private wetlands is also limited, both because less water is delivered to farms and because farm managers may choose to fallow their land to sell the water for use elsewhere in California.

FIGURE A12

The Central Valley federal refuges, state wildlife areas, and privately managed wetlands



SOURCE: California Department of Fish and Wildlife.

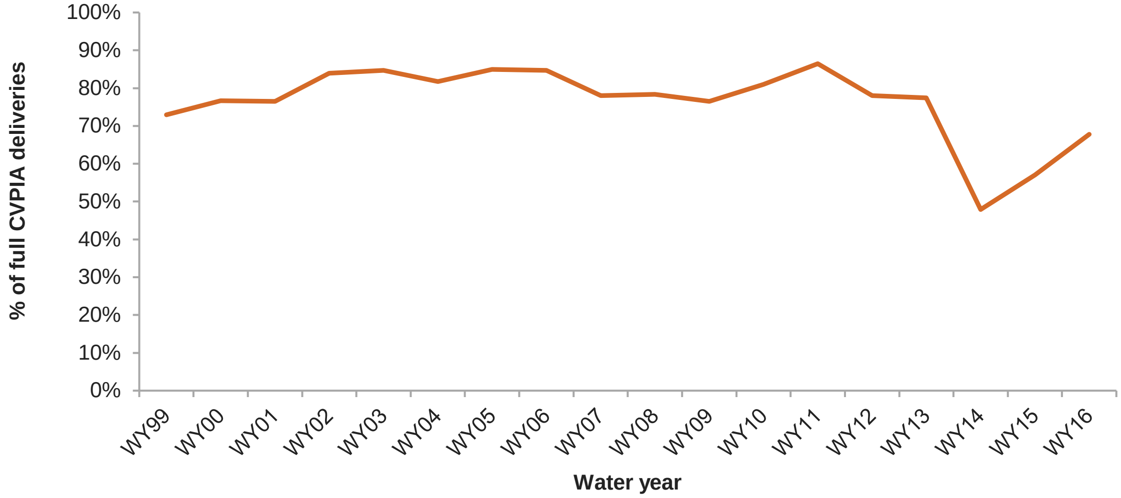
NOTE: These wetlands receive water from the Central Valley Project Improvement Act.

Latest Drought

During the 2012–16 drought, water deliveries to the refuges were reduced as much as 48 percent of the full CVPIA wetland water supply (Figure A13). The proportion of these reductions matched that of water allocations to other CVP senior water-right holders.[37] The impact of these reductions varied across the refuges. Some refuges experienced only modest reductions in their water deliveries; others received almost no water. They were also variable by season, with almost no water available for spring and summer irrigation on the refuges.

FIGURE A13

CVPIA water allocations delivered to Central Valley wildlife refuges between 1999 and 2016



SOURCES: Data assembled from Bureau of Reclamation reports (https://www.usbr.gov/mp/cvpia/docs_reports/) and personal communications with Refuge Water Supply Program staff in May 2017.

NOTES: Water year is the period between March–February, such that water year 1999 spans from March 1999 to February 2000. Full CVPIA delivery is the combined Level 2 and Incremental Level 4 water requirements (totaling 555,515 acre feet) for optimum habitat development and management at 19 federal, state, and private management wetlands identified in Section 3406(d) of the Central Valley Project Improvement Act.

In addition, lower deliveries of project water to farmers reduced the amount of rice that was planted in the Central Valley. Rice acreage fell from an average of 567,000 acres in 2010–13 to 434,000 acres in 2014 (–24 percent), 423,000 acres in 2015 (–25 percent), and then rose back to 564,000 acres in 2016, a year of improved precipitation in northern California (US Department of Agriculture, National Agricultural Statistics Service, California Acreage Reports, accessed May 4, 2017). Restricted water deliveries also reduced the acreage of these fields that was flooded after harvest to break down rice straw. Winter flooded rice is estimated to have been reduced by as much as 247,000 acres during the drought (Petrie et al. 2016).

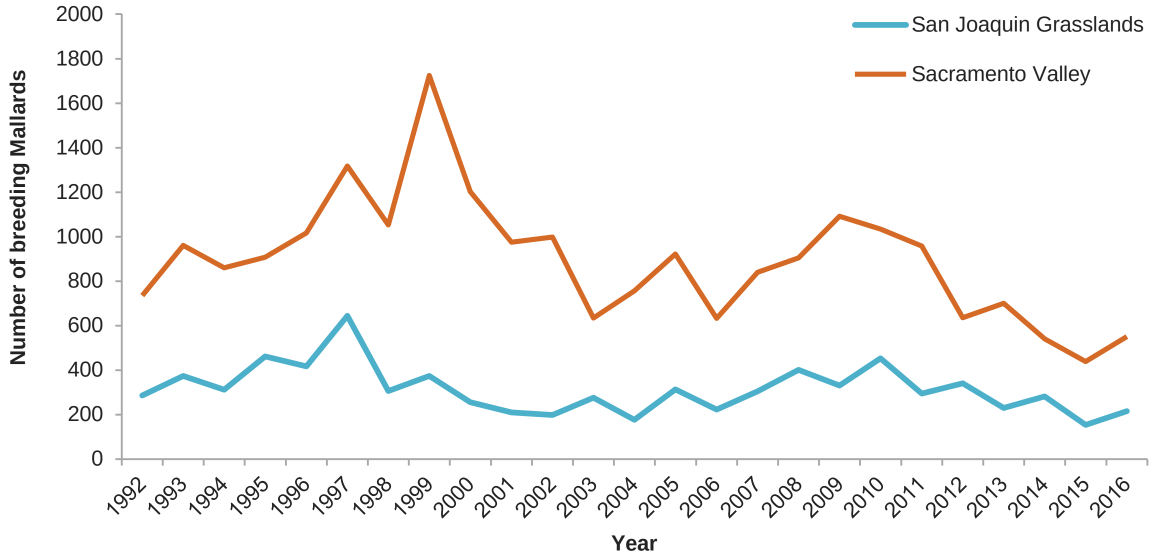
While quantitative analyses of the drought’s effects on waterbirds population levels are lacking, qualitative observations suggest that in the Central Valley they were relatively resilient. The apparent persistence of Central Valley waterbirds speaks to the existing legal framework for managing refuge water, a strong spirit of collaboration, and some fortuitous late winter rainfall at the height of the drought.

[37] The Sacramento River Water Rights Settlement Contractors and the Exchange Contractors in the San Joaquin Valley held pre-project water rights. Their contracts grant them preferential rights to available CVP supplies in recognition of their senior water rights.

There was a modest decrease in the number of breeding Mallards detected on the Department of Fish and Wildlife brood pond surveys (Figure A14). The decline was most pronounced in the Sacramento Valley, where the number of breeding pairs detected declined from 2013 to 2015.

FIGURE A14

During the drought, the number of breeding mallards declined, especially in the Sacramento Valley



SOURCE: Unpublished data from the California Department of Fish and Wildlife Breeding Waterfowl Population Surveys.

For wintering waterfowl and shorebirds, several vulnerabilities were associated with the reduced flooding. One concern was that crowding of large flocks of birds into the few remaining wetlands would lead to disease outbreaks (Rosen 1972). The other was that food resources would be exhausted before the end of the winter (Petrie et al. 2016). In January and February 2014, at the height of the drought, substantial rain fell throughout the Central Valley. Although these rains did little to increase reservoir levels, they did flood many of the seasonal wetlands and some agricultural fields, providing a late season reprieve for the Central Valley's waterbirds.

The drought also spurred political challenges for waterbird management. Water scarcity created the conditions that fostered conflict-based narratives. These narratives included disputes between agricultural and environmental uses, as well as between environmental interests, as water managers and regulators sometimes had to decide whether to allocate scarce supplies to instream flows that support fish and other riverine species, or to ricelands that also support waterbirds and other wetland species. Although some of these conflict narratives received significant attention, in many cases the on-the-ground experience of water for refuges was one of cooperation and collaboration.

Lessons

The waterbirds' persistence through the drought was facilitated by cooperation among a diverse group of stakeholders, who worked together to ensure that the limited available water was put to the best possible use. Although in most years, CVPIA wetlands are operated relatively independently of one another, during the drought there was a concerted effort to increase communication and coordination among refuges. This included weekly meetings of refuge managers to discuss regional bird movements and the amount of available habitat. Sharing this information allowed managers to make water management decisions with near real-time information. During the most severe months, some refuge staff were meeting as many as three times a week.

Another area of collaboration was among the diverse environmental stakeholders. Early on, there was concern that providing water to refuges would conflict with the water needs of other water-dependent wildlife, especially fish and giant garter snakes (which live in wetlands, irrigation ditches, and drainage canals). These stakeholders quickly communicated regarding the timing and amount of water necessary, and through that process discovered that any conflicts were easily navigated and were not a significant impediment to making decisions about how to allocate water to different sectors of the environment.

Adaptive decision making was often limited by the availability of relevant data on the number and distribution of waterbirds, the amount of available habitat, and water supplies. Two major sources of data for managing waterfowl populations are the U.S. Fish and Wildlife Service mid-winter waterfowl surveys and the spring Breeding Waterfowl Population Surveys conducted by the California Department of Fish and Wildlife. The utility of these sources during the drought was limited because they are designed to serve as single measures for the entire year, so they provided relatively little information for making adjustments to water deliveries during the year. To generate more timely information about the distribution and abundance of waterbirds during the drought, managers looked to their local biologists, NGOs, and citizen scientists (e.g., online reporting of bird observation on eBird) to provide more timely information.

It was also challenging to track the amount and distribution of flooded habitat. Although individual refuges were able to measure the areas they flooded, understanding the large mosaic of private wetlands and flooded agricultural fields was a significant challenge. In response to this need for more timely information on the extent and location of flooded habitat, an automated tracking system for surface water has been developed (Reiter et al. 2015). This system uses Landsat data to generate regularly updated maps of surface water that land managers can use to inform decisions about where and when to create flooded habitat.

Wildlife managers responded to reduced surface water supplies in a number of different ways, but also faced a constraints regarding how they could use limited water. Some refuges had the ability to maintain habitat in the absence of surface water deliveries by pumping groundwater. Late-season announcements about water deliveries meant that some refuge managers did not water their lands even though they ultimately received enough water to improve habitat quality by doing so. Managers would also have benefitted from the ability to trade their surface water allocations with other refuges or possibly even other water users, to improve the allocation of scarce water across the entire Central Valley system. Incentive programs run by environmental stakeholders and federal programs did prove valuable in expanding habitat on farmers' fields. For example, reverse auctions were held to compensate farmers for temporarily flooding strategic lands when water was available.[38]

Several key lessons emerge that could guide improvements for managing freshwater ecosystems statewide:

- **Accounting.** The drought illustrated that California does not currently have an integrated system that can track and account for groundwater and surface water deliveries, the amount and quality of waterbird habitat, and changes in waterbird populations. Ideally, many of these data could be updated throughout the season in a manner that allows decisions to be updated throughout the year in response to changes in water availability. This drought spurred innovations involving the use of alternative data sources (including reporting by citizen scientists) and new tools to track the location of flooded habitat that can be employed

[38] The Nature Conservancy's BirdReturns is one such program, supported to date with philanthropic sources. Federal funds support a similar program run by the Natural Resources Conservation Service.

during future droughts. However, there are still significant opportunities for improvement in water accounting and ecological monitoring.

- **Planning.** The drought illustrated how dependent waterbird conservation has become on the agricultural matrix that surrounds the relatively small refuge system. As water restrictions went into place, several significant resource concerns beyond simply the limited refuge water supplies were identified such as the extent and location of fallowed agricultural fields (which are needed to maintain a buffer of flooded agricultural fields around each refuge).[39] Advanced planning that included the agricultural community could have helped addressed this challenge.
- **Flow allocation and management.** The establishment of an explicit water allotment for refuges under CVPIA has been beneficial for waterbird management. Even though deliveries are not always to levels prescribed under the act, water availability during dry years has likely improved.[40] But like farmers, refuge managers suffer from uncertainty about water availability during drought. Decisions about water deliveries were not made until late in the season, increasing uncertainty for all parties. Because these refuges did not know how much water they would receive until late in the growing season, some did not water their lands even though they ultimately received enough water to have done so. Having a water allocation process that puts a greater emphasis on anticipating and planning for drought would reduce this uncertainty and help with management decisions. Water transfers and expensive market acquisitions—which Reclamation relies on annually to meet its refuge water contract obligations—are also a challenge, both logistically and financially. There were unexpected challenges in securing refuge supplies through water transfers from outside of the refuge system. Transfers from north of the Delta to south of the Delta were hampered by south of Delta export pump restrictions. Even making water transfers between refuges can be difficult or prohibited by existing policies. Being able to manage water more flexibly, including being able to share water across refuges in a timely manner, would improve overall drought response for the refuge system. Increased flexibility could also be designed in such a way as to benefit other sectors of the environment (e.g., instream flows for fish) and other water users by making wetland water available if short term rainfall events can make up for surface water deliveries to wetlands.

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[39] Additionally, DWR’s policy of prohibiting cover crops to be grown on agricultural land fallowed to make water available for transfers limited the habitat value that these lands provided for nesting waterfowl during the spring and summer.
[40] Central Valley Project Improvement Act Refuge Water Supply Program (2009) evaluation estimated that average water deliveries to the refuges increased by about 21,000 acre-feet (up from 422,000 acre-feet) after the enactment of the CVPIA, and that reliability of these deliveries improved (p. 29).

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