FEATURE

Delta Smelt and Water Politics in California

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Illustration credit: Rene Reyes, US Bureau of Reclamation.

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The Delta Smelt *Hypomesus transpacificus* is a small translucent fish that lives in the heart of California's water distribution system. It is an endemic species that is on verge of extinction, largely because it is in direct competition with people for water. This article discusses the controversy surrounding this fish by describing (1) the biology of Delta Smelt; (2) California's complex water storage and distribution system; (3) the history of Delta Smelt, including conservation efforts; (4) the present controversies surrounding it; and (5) the future of Delta Smelt. The decline of Delta Smelt is a strong indicator that the ecosystem of the Sacramento–San Joaquin Delta has undergone large-scale changes that make it an unfavorable environment for native fishes. Reversing the trajectory of the Delta Smelt toward extinction will require major shifts in California water policy and water use as well as active management of the smelt's habitat and life history.

INTRODUCTION

The Delta Smelt *Hypomesus transpacificus* is a small translucent fish that is endemic to the Sacramento–San Joaquin Delta (Figure 1). The delta, once a vast tidal wetland, was reclaimed, largely for agriculture, between 1860 and 1930 and became the hub of California's water distribution system by the 1960s (Figure 2). Delta Smelt was an abundant pelagic fish, but its population began showing signs of distress in the mid-1980s. It was listed as threatened by state and federal governments in 1993 and by the early 2000s was in severe decline (Sommer et al. 2007). It was up-listed to California endangered status in 2010. As a listed species, it is provided protection that sometimes limits diversion of water for human use, especially for irrigated agriculture, making it one of the most reviled fish in the West. Resentment increased during the severe drought of 2012–2016. Presidential candidates, sitting members of the House and Senate, and a cast of political pundits routinely urged abandonment of all protection for Delta Smelt, typically citing the small size of the fish in relation to the outsized demand for water for farming in one of the most important agricultural regions in the United States. This conflict between an economically insignificant fish and powerful economic and political forces is a classic test of the will of the American people to protect helpless species through the federal Endangered Species Act (ESA) of 1973 and the California Endangered Species Act of 1970.

In this article, we summarize how this controversy has arisen by briefly describing (1) the biology of Delta Smelt; (2) California's complex water storage and distribution system; (3) the history of Delta Smelt, including conservation efforts; (4) the present controversy; and (5) the future of Delta Smelt. The information in this article largely comes from our recent review of Delta Smelt biology (Moyle et al. 2016) and the review of California water issues by Hanak et al. (2011).

BIOLOGY

The Delta Smelt (family Osmeridae) is one of a suite of fishes endemic to California's Central Valley, most of which are in decline (Moyle 2002; Moyle et al. 2012). The Delta Smelt has a distinctive life history. Most live just 1 year, although a few can survive to age 2 (Figure 3), and attain total lengths of 65–90 mm. Because of their diminutive size, they have relatively low fecundity (1,000–12,000 eggs, depending on female size), but they are serial spawners, which allows bet-hedging for optimal spring conditions (LaCava et al. 2015). Two basic life history strategies allow them to survive highly variable conditions. One is to remain in fresh tidal waters of the northern delta for their entire life cycle. The other is for larvae or small juveniles to be carried by river currents to rear through summer in historically productive brackish regions of the San Francisco Estuary, primarily Suisun Bay and Marsh. In fall, maturing fish move into the delta to spawn in freshwater (Bush 2016), presumably on sandy beaches and other substrates to which the embryos can stick. At present, both migratory and resident fish spawn mainly in the northern and western delta, where the Sacramento River has high influence.

Delta Smelt are weak swimmers, using a stroke-and-glide style of swimming. During landward migrations to freshwater, they move to the channel bottom or to the edge during ebb tide and back into the main stream during flood in order to move upstream by "surfing" the tides (Bennett and Burau 2015). Moderate turbidity seems to assist Delta Smelt both to see their prey, which consists of pelagic copepods, cladocerans, and mysid shrimp, and to remain invisible to predators.

Physiologically coolwater fish, Delta Smelt are usually found at temperatures of less than 25°C and prefer temperatures of around 20°C (Swanson and Cech 2000); this makes them vulnerable to increased temperatures resulting from habitat loss, water management, and global warming. They are euryhaline but occur mostly at salinities of 0–7 practical salinity units (Feyrer et al. 2007). They are often exposed to diverse contaminants, with poorly understood consequences.

The life history requirements of Delta Smelt have made them increasingly vulnerable to change. Their weak ability to swim against currents makes them easily entrained in water export pumping plants. Their reliance on zooplankton makes them subject to competition from invasive species that have depleted the pelagic food web, especially the overbite clam *Potamocorbula amurensis.* Their need for cool water impedes foraging in shallow-water food-rich habitats. Their specialized spawning habits make embryos and larvae vulnerable to alien fishes that prey on them. This combination has resulted in increasing population instability followed by steep declines. Today, Delta Smelt are infrequently captured in fish survey programs, even those that target them (Figure 4).

CALIFORNIA WATER

California has been called the "hydraulic society" because of its dependence on infrastructure to move water from places of high abundance to places of low abundance (Hundley 2001). Most precipitation falls in the northern state and at high elevations, especially the Sierra Nevada, during cool winter months, while demand is highest in the Central Valley and Southern California during hot, dry summers. Agriculture accounts for approximately 62% of net developed water use (Hanak et al. 2011). Urban and industrial use is about 16%, allowing huge cities like Los Angeles to develop in areas that are desert. This leaves only 22% of developed water available for environmental uses, such as streamflows and wetlands. Moving all this water around requires more than 1,400 large dams and many smaller ones, as well as thousands of kilometers of aqueducts. About half the developed water moves through the delta, drawn south by two huge pumping plants in the south delta, those of the federal Central Valley Project (CVP) and the State Water Project (SWP; Figure 1). The CVP, operated since 1951, was originally designed to deliver water from the

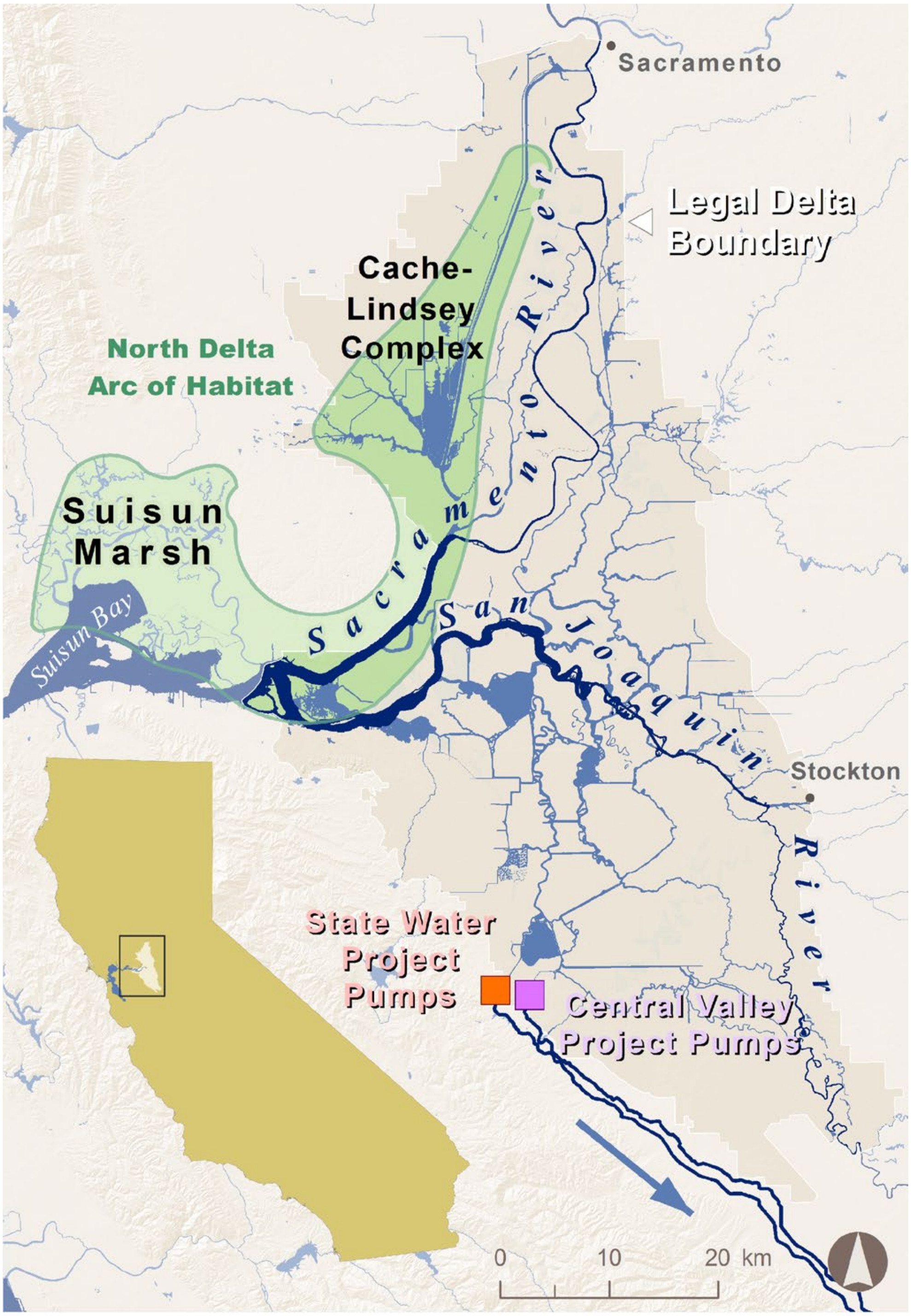

Figure 1. The Sacramento–San Joaquin Delta showing features mentioned in the text. The North Delta Arc of Habitat is the primary location of Delta Smelt habitat today. The San Joaquin River in the delta is largely without freshwater inflow from the historic river, but the large channel is still present because it is used for shipping and is strongly tidal; it is poor smelt habitat. The State Water Project and Central Valley Project pumps send large volumes of freshwater to farms and urban areas, mostly south of the delta but also including San Francisco Bay Area cities.

Sacramento River, especially water stored in Shasta Reservoir, to farms in the San Joaquin Valley. The SWP, operated since 1966, delivers water from the Feather River, stored in Oroville Reservoir, to Southern California and San Francisco Bay area cities as well as San Joaquin farmers. While these two projects are part of a larger network of canals and dams (Hanak et al. 2011), we focus on the CVP and SWP pumps ("the pumps") because their tandem operation most affects Delta Smelt.

In response to the availability of CVP and SWP water, irrigated acreage greatly expanded, especially in the desert areas of the west side of the southern Central Valley. The projects also allowed urban areas to keep growing and high-tech

Figure 2. (Top left) Delta Smelt; photo credit: M. Young. (Top right) Barker Slough in the north delta, spawning and early rearing habitat for Delta Smelt; photo credit: P. Moyle. (Bottom left) A delta marina, showing levees that protect large tracts of farmland; photo credit: P. Moyle. (Bottom right) Harvey O. Banks Pumping Plant of the State Water Project, in the south delta. The open water in the distance is a forebay, used to improve ease of pumping. Photo credit: California Department of Water Resources.

industries to develop (e.g., Silicon Valley) in coastal central California and Southern California. The volume of water moving through the pumps (exports) increased steadily from the 1950s, with some dips because of drought (Figure 5). For the past 10 years, exports from the pumps have been highly variable, mostly due to the extended drought. Any water that is not exported from or consumed by farms and municipalities upstream or within the delta becomes delta outflow, to San Francisco Bay. This highly simplified version of project water management does not reflect that:

- More than half the water potentially flowing into the delta is diverted upstream of it and is therefore not counted in export totals.
- Most delta outflow in summer is water released from dams to ensure that delta farmers have freshwater with which to irrigate their crops.
- Delta outflow is used to create a freshwater barrier to prevent the pumps from exporting brackish water.
- Freshwater is used to dilute salty agricultural return water that will be diverted from the San Joaquin River to the pumps.
- When outflows are weak and pumping is strong, net flow can be reversed or directed across the delta towards the pumps, confusing and entraining migratory fish such as juvenile salmon and Delta Smelt.

HISTORY OF DELTA SMELT

There are few early records of Delta Smelt, although their remains are found in Native American archaeological sites (Gobalet et al. 2004). Early fish biologists regarded Delta Smelt as a population of Pond Smelt *Hypomesus olidus*, thought to be common in estuaries and lakes around the Pacific rim, from California to Japan. McAllister (1963) split up Pond Smelt into a number of species but named Delta Smelt "*H. transpacificus*" because he continued to lump it with populations in Japan (now Wagasaki *H. nipponensis*). Genetic and morphological studies later revealed that Delta Smelt is a separate species most closely related to Surf Smelt *H. pretiosus,* a common marine smelt off the California coast (Stanley et al. 1995; Trenham et al. 1998).

The first systematic surveys of fish in the delta, in the 1940s, revealed Delta Smelt to be common and widely distributed in the upper estuary (Erkkila et al. 1950; Ganssle 1966). When regular pelagic fish surveys began in the 1960s, Delta Smelt was among the most numerous fish caught, leading to the first life history study (Moyle et al. 1992). However, in the 1980s, the smelt population declined concurrently with a series of ecosystem-wide changes:

- Extended drought, reducing freshwater inflows (1987–1992);
- Increased exports by the south delta pumps, especially during April when larval smelt were vulnerable to entrainment;
- Invasion by the overbite clam, which became highly abundant in brackish water in the late 1980s, greatly reducing availability of zooplankton;
- Invasion by the Mississippi Silverside *Menidia audens*, an abundant egg and larval predator;
- Increases in the diversity and abundance of contaminants, such as pesticides, ammonium, and pharmaceuticals; and
- Large increases in distribution and abundance of aquatic weeds, especially Brazilian waterweed *Egeria densa* and water hyacinth *Eichornia crassipes*.

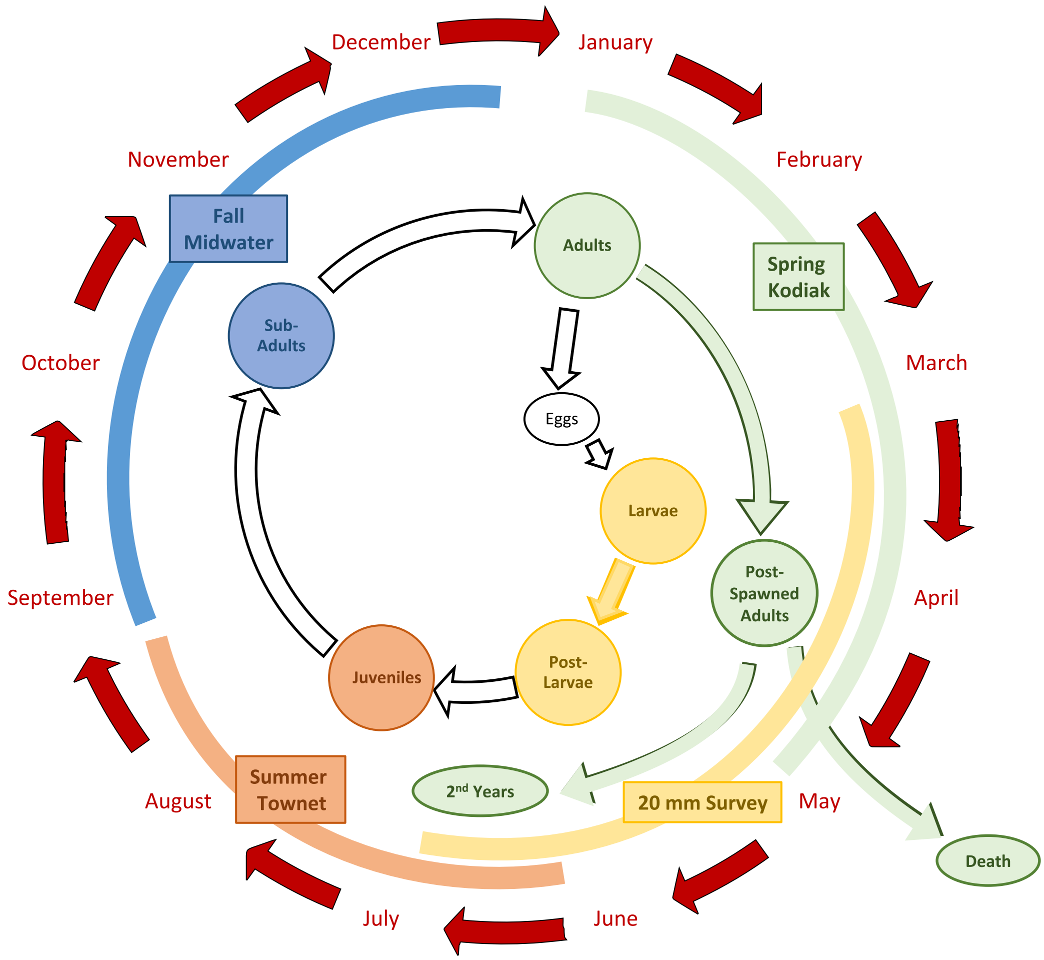

Figure 3. Delta Smelt life history, in relation to four key surveys and calendar year. Most smelt live just 1 year and different sampling methods are required for each life history stage. Larvae and postlarvae are sampled in the 20 mm Survey (yellow), juveniles by the Summer Townet Survey (orange), subadults by the Fall Midwater Trawl Survey (blue), and adult spawners and postspawners by the Spring Kodiak Trawl Survey (green). A few smelt live 2 years and may spawn twice. From Moyle et al. (2016).

The overall result was a major shift in the delta ecosystem to conditions less favorable to pelagic species, including mysid shrimp, Delta Smelt, Longfin Smelt *Spirinchus thaleichthys*, and juvenile Striped Bass *Morone saxatilis* (Sommer et al. 2007).

CONTROVERSIES

Causes of Decline

When Delta Smelt was listed under state and federal endangered species acts, reduced freshwater outflow to the estuary was identified as the primary cause of decline, followed by entrainment in small agricultural diversions within the delta and the pumps in the south delta (Moyle et al. 1996). However, it was also noted that other effects were likely contributing to the decline, including reduced food abundance due to competition from overbite clam and other introduced species and increased concentrations of contaminants. The focus on outflow and exports was contentious because adult Delta Smelt abundance was not clearly correlated with outflow, while the number of smelt entrained in South Delta pumps was strongly positively correlated with their abundance. Given the plethora of alternative hypotheses for population decline, the sociopolitical environment, the economic cost of reduced water for agriculture, and the lack of direct evidence for an outflow or export effect on abundance, the recovery plan, which essentially recommended improved flows for smelt, was largely ignored.

Prior to publication of the recovery plan, state and federal agencies responsible for management of the delta entered into an agreement, the Bay-Delta Accord (1994), which established flow criteria for salinity management in the delta. This led to a well-funded science program investigating smelt biology and alternative hypotheses for the decline. The research produced several hundred peer-reviewed publications (Moyle et al. 2016); it has been integral to understanding drivers of Delta Smelt abundance. The focus on research also meant, conveniently, that costly changes to water deliveries could be delayed while relatively inexpensive research and monitoring were in progress. Some actions were taken in response to recommendations by state and federal agencies, including reduced flows towards the south delta pumps and some tidal habitat restoration. However, although water operations became more sensitive to reducing smelt entrainment, and while much was learned about smelt and their habitat requirements, these programs failed to provide a simple fix for Delta Smelt that could lead to recovery.

In 2016, the annual Summer Townet Survey index for Delta Smelt was 0.0 for the second year in a row (down from

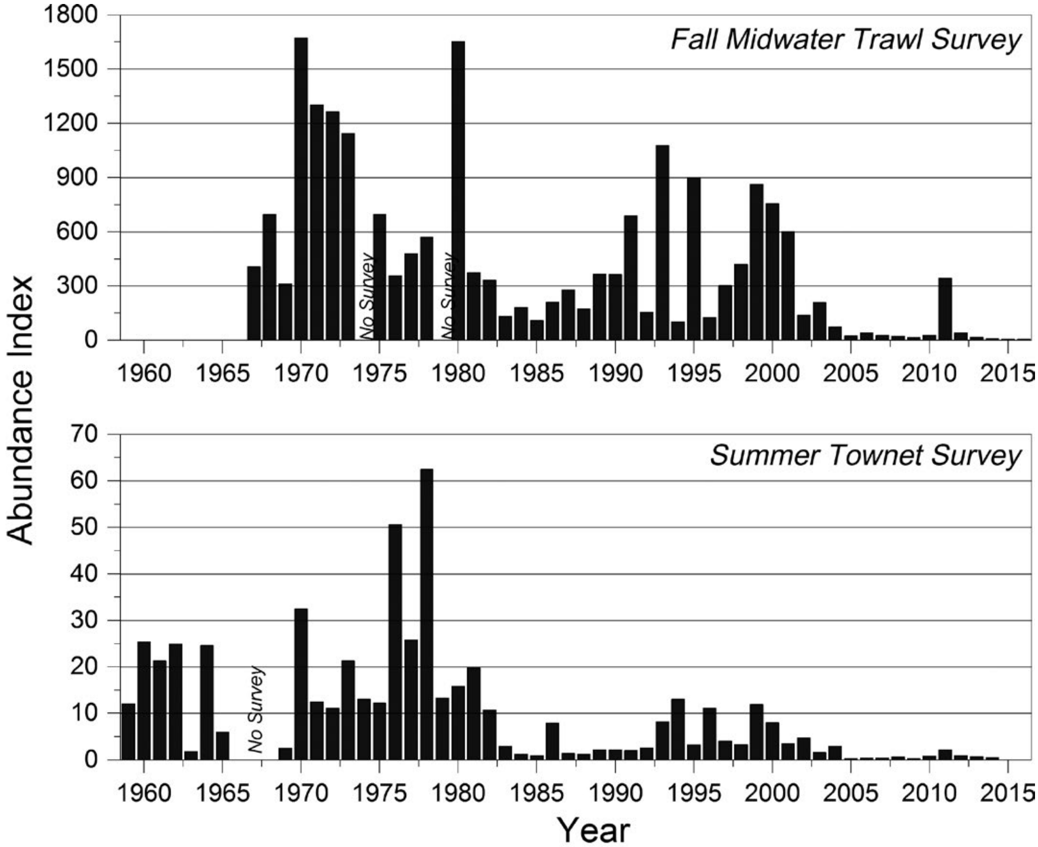

Figure 4. Indices of Delta Smelt abundance in the two longest-running fish sampling programs in the delta. The Summer Townet Survey samples juvenile smelt while the Fall Midwater Trawl Survey samples subadult smelt, mostly prespawning individuals.

a high of greater than than 60 in 1978), causing the California Natural Resources Agency to propose a set of actions to help recover the species, called the Delta Smelt Resiliency Strategy. The strategy includes a set of emergency measures intended to forestall extinction of the smelt. In addition to proposing actions to control aquatic weeds, supplement pelagic food webs through managed wetlands, add sediment to increase turbidity, manage predators, and create spawning habitat, the strategy proposes an additional 250,000 acre-feet (1 acre-foot = 1,233.48 m^3) of water be purchased for outflow augmentation in 2017 and 2018. It is unclear whether this relatively small amount of water relative to Sacramento River flows will be sufficient to move Delta Smelt into Suisun Bay or to stimulate food production for them.

Delta Outflows

Freshwater flows through the Delta have been polemicized as "wasting water to the sea" to protect smelt instead of providing water for farmers (Cloern et al. 2017). Stakeholders most commonly invoke this sentiment when water exports from the delta are reduced for environmental purposes, including when significant numbers of Delta Smelt are detected in the vicinity of or are entrained at the pumps (USFWS 2016). Pumping may also be reduced to protect out-migrating smolts of listed anadromous species such as spring-run and winter-run Chinook Salmon *Oncorhynchus tshawytscha* (NMFS 2016). However, the single greatest factor restricting volume of water exported is not the presence of vulnerable fish near the pumps. Rather, it is the presence of elevated salinity in the delta, which occurs when export rates are high relative to freshwater inflows. Environmental flows are generally maintained to protect water quality (that is, reduce salinity) both for export and for farms in the western delta (Lund et al. 2010) by maintaining a freshwater wedge to the west of the pumps, buffering them from salinity intrusion. In short, pump operation requires much more water than can be effectively exported in order to keep salt water at bay. For example, during 2011–2016, salinity management required a third more water than was exported (NMFS 2016; USFWS 2016). In contrast, pumping restrictions specifically aimed at Delta Smelt accounted for approximately 1% additional water. Furthermore, protections for Delta Smelt did not cause mandatory reductions on any day in 2014 or 2015. However, voluntary reductions of exports in 2015 and 2016 totaled about 324,000 acre-feet, which amounted to about one-sixth of all exported water during 2015 (J. Rosenfield and G. Reis, The Bay Institute, personal communication). In total, from 2011 through 2016, flows used to protect all ESA-listed species, including Delta Smelt, accounted for a little more than 6.5% of delta outflow. In other words, outflows for fish comprised a relatively small contribution to the challenges faced by San Joaquin farmers, even during drought.

Nevertheless, the Delta Smelt has remained a convenient "scape fish" for water shortages in the southern Central Valley. Curtailment of exports resulted in significant public media attention for farmers allegedly losing valuable crops and precious jobs to protect smelt, while some politicians even denied that the drought was real or claimed that it was man-made. In reality, since 2010, when Delta Smelt were up-listed to endangered status under the California ESA, few concrete actions,

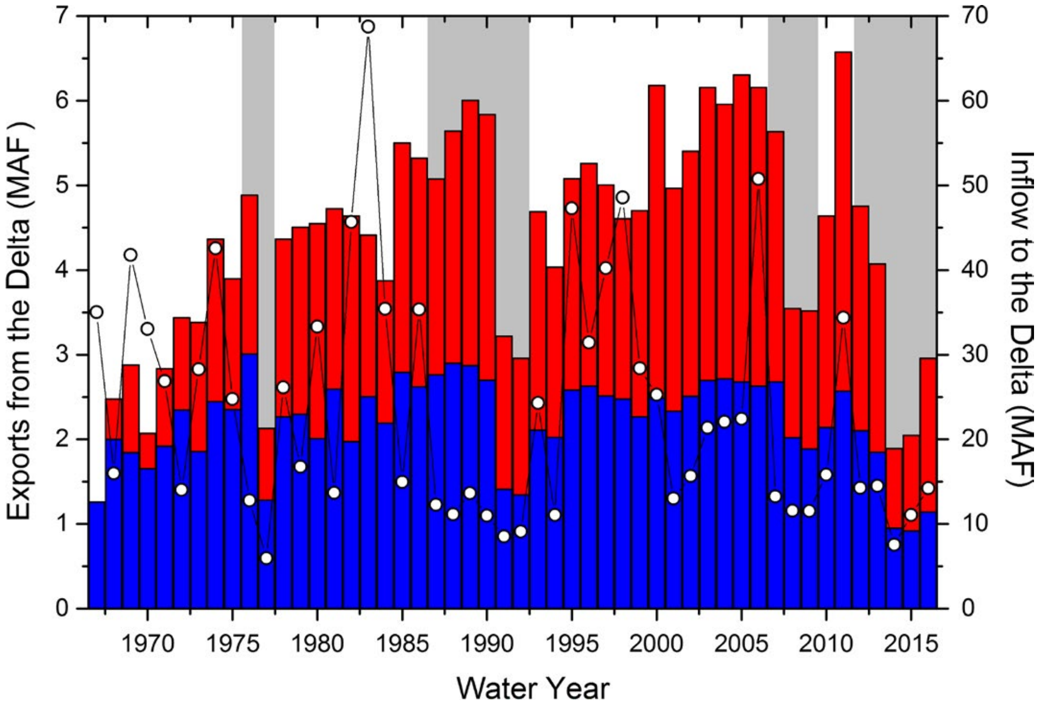

Figure 5. Total annual export (left axis) of water from the south delta by the pumps of the State Water Project (red) and federal Central Valley Project (blue) in million acre-feet. Gray bars show periods of drought, when pumping was reduced primarily because of low inflows. Total annual inflows of water to the delta in million acre-feet (right axis) are the open circles. Data from DAYFLOW (www.water.ca.gov/dayflow).

such as reducing exports or increasing inflows, have been taken to support smelt. While the Delta Smelt Resilience Strategy (CNRA 2016) proposes buying back freshwater to augment outflow, it does not recommend decreasing exports to protect smelt, in part because of the controversy. Overall, it is rare that pumping is curtailed exclusively to protect smelt, despite the political narrative that is spun.

Political narratives that attempt to pit fish against farmers disregard the importance of outflows to in-delta farmers for salinity protection for water export; for maintaining public health standards; for fisheries for Chinook Salmon, steelhead *O. mykiss*, and other species; for ecosystem support for a diverse native biota; and for other ecosystem services that impact human well-being (Cloern et al. 2017). Also obscured is the fact that water demand in California far exceeds supply under antiquated water policies based upon historical precedents (Hanak et al. 2011). Despite shortages of surface water in many areas, California's farm economy weathered the 2012–2016 drought remarkably well. Growth in high-revenue crops such as almonds and pistachios largely replaced financial losses in other crops, in part through aggressive groundwater exploitation (Howitt et al. 2015). Although reduced water deliveries inhibited expansion, California's farm economy overall remains quite healthy in contrast to the delta ecosystem. In particular, estuarine-dependent native fishes and fisheries have not been thriving.

The Twin Tunnels

Additional controversy surrounds Governor Jerry Brown's proposal to dig two 48-km tunnels underneath the delta to deliver water from the Sacramento River directly to the pumps at an estimated cost of US$15.5 billion. The tunnel project, called California WaterFix (www.californiawaterfix.com) would protect California's water supply from catastrophic levee failure and salinity intrusion into the delta, which could shut down pumping for months. Such a shutdown would threaten California's agribusiness and leave millions of people with greatly reduced water supplies. As proposed, tunnel operations will not increase the amount of water being exported, although the current design has the physical capacity to do so. Delta Smelt would presumably be less vulnerable because tunnel intakes would be screened and located upstream of most Delta Smelt habitat, allowing fewer restrictions on pumping. Water not diverted through the tunnels would be used to create flow conditions that would benefit delta agriculture and the estuarine ecosystem.

Associated with WaterFix is EcoRestore, a plan to conduct large-scale habitat restoration as mitigation for freshwater exports via the twin tunnels and the pumps; it would be implemented mainly by returning diked farmland into tidal wetlands. The basis for restoration is the mandated "co-equal goals" of the Delta Stewardship Council (a product of the Bay-Delta Accord) that the environment must be treated as an equal partner in use of water that flows through the delta. Benefits of this restoration to Delta Smelt will not be large, unless the restoration projects are extensive, have ample connectivity, increase pelagic food supply, and have appropriate water quality. In fact, such restorations will most likely need to be supported by ecosystem flows that are not guaranteed by WaterFix. The environment, under this policy, is just another water stakeholder. Unfortunately, it starts from a very inferior position, having no secure rights, so ecosystem water becomes easy to sacrifice during times of water shortage (Hanak et al. 2011, 2015; Mount et al. 2015).

Not surprisingly, the twin-tunnels project is very controversial and has strong opposition from people and politicians in the delta region but support from those south of the delta. The tunnels are a new version of the proposed Peripheral Canal, which would have carried Sacramento River water around the delta rather than through it. The proposition to build the canal was soundly defeated by voters in 1982. However, a recent analysis indicated that fishes such as Delta Smelt would most likely have been better off if the canal had been built, provided it was operated to provide ecosystem benefits (Lund et al. 2010). The tunnels could presumably provide similar ecosystem benefits, if operated correctly. At the time of this writing, the future of the WaterFix program is uncertain, but alternatives generally involve reducing exports and increasing inflows to the delta, actions not popular with major water users. What is certain is that the status quo in delta water management will result in a delta that increasingly favors alien species and is hostile to native species that require a functioning estuary (Lund et al. 2010; Moyle et al. 2010).

Managing Mortality

Reducing mortality is an obvious way to increase spawning populations. But most sources of mortality, whether from predation, starvation, disease, or other factors, are hard to document and difficult to control. The largest source of such observable mortality is from salvage at the south delta pumps, where fish are captured, placed into tank trucks, and returned to the delta. These fish are recorded as "salvaged," although there is little evidence that smelt survive this process. The numbers of Delta Smelt salvaged at the fish facilities can exceed 300,000 in some years (e.g., 1981; www.wildlife.ca.gov/Conservation/Delta/Salvage-Monitoring). Kimmerer (2008) estimated population level effects of entrainment mortality range from 1% to 50% of the adult population; thus, in some years, this mortality can be extremely important. Several strategies have been developed to limit salvage, including minimizing the flows in the south delta that move smelt towards the pumps when fish are most vulnerable or when turbidity is high in the south delta, an indicator that Delta Smelt habitat is being entrained. The numbers of Delta Smelt in salvage in recent years has been low, at least in part due to this management strategy.

The U.S. Fish and Wildlife Service (USFWS) estimated the Delta Smelt population in 2016 to be between only 6,000 and 28,000 adults (https://ecos.fws.gov/ecp0/profile/speciesProfile?spcode=E070). Due to current extremely low numbers, USFWS has drastically reduced allocations of incidental take to the state and federal agencies managing the pumps as well as the long-term monitoring programs. The San Francisco Estuary has an extensive environmental monitoring program with several long-term (>40 years) monitoring surveys that are mandated for management of the estuary, including allocating freshwater outflows and incidental take. As the smelt population has continued to dwindle, take allocations have diminished to the point that long-term monitoring surveys may not provide sufficient data to guide management actions. Meanwhile, if salvage numbers remain low, freshwater exports may be allowed to increase due to the political and economic pressure to provide water for urban and agriculture needs, while monitoring studies may be cut back to reduce take of smelt, impacting scientific studies designed to provide environmental solutions.

A more precautionary approach would allow research and monitoring programs to be operated to maximize scientific benefits and reduce uncertainty in management actions. While monitoring and scientific studies can be modified to minimize incidental mortality, it must be acknowledged that complex problems in management and restoration cannot be resolved without robust science. As the population continues to collapse and other species approach jeopardy, more monitoring studies are going to be required, rather than less.

The loss of Delta Smelt take allocations could result in large economic losses to agriculture, the disruption of science to provide environmental solutions, and the loss of information to managers, creating hardships for many stakeholders in the extended delta community. However, there remains a great deal of uncertainty as to whether such extreme actions, or any others, will actually benefit Delta Smelt, given the high likelihood of its extinction in the wild (Moyle et al. 2016; Baumsteiger and Moyle 2017).

THE FUTURE OF THE DELTA AND DELTA SMELT

The Delta Smelt seems headed for extinction in the wild in the next 2–10 years, based on recent trends. This is a strong indicator that the delta ecosystem has undergone large-scale, probably irreversible, changes that make it an unfavorable environment for native fishes, of which Delta Smelt is a sentinel species (Moyle and Bennett 2008; Moyle et al. 2010). In the extinction queue immediately behind Delta Smelt are winter-run Chinook Salmon and Longfin Smelt, with several other listed or special concern species behind them. It is clear that large-scale changes in management of water and land are needed to keep these fish going, and we are skeptical that any major actions (e.g., WaterFix) can be taken before extinctions occur.

Given the relatively small amount of water used for smelt conservation, the extinction of Delta Smelt will not resolve California's water supply issues. After it and other vulnerable species have gone extinct, on-going problems will continue to prevail in the delta, including saltwater intrusion and inevitable restrictions upon export. Studies have shown that failure of one or more of the fragile levees surrounding delta islands could result in pulling large volumes of salt water into the delta (Moyle 2008; Hanak et al. 2011). The saline water would shut down exports for months and would require massive freshwater flows to flush the salt water out of the delta in order to resume export pumping. Even reduced outflows from drought can result in saltwater intrusion into the delta. With drought a frequent occurrence, California could be one or two levee failures away from catastrophe.

Unfortunately, conflicts of endangered species with human water demand are becoming worse rather than better under present circumstances. For example, a federal omnibus water bill that passed in December 2016 includes provisions that make it easier to shift water from endangered fishes to farmers south of the delta. The long-term prospects are also grim, given that global warming is likely to make most smelt habitat too warm for them to inhabit, new invasive species will further change the ecosystem, sea level rise will increase salinities, and major changes to delta topography will occur as levees collapse from floods and earthquakes (Moyle 2008; Brown et al. 2013; Hobbs et al. 2017).

In the meantime, how do we move forward in protecting Delta Smelt from total extinction?

Cultured Smelt

In 2007, the U.C. Davis Fish Conservation and Culture Laboratory was established to rear Delta Smelt through their entire life cycle. It has been extraordinarily successful but requires continuous input of wild fish to maintain genetic diversity. The captive population was established to provide fish for experimental studies and to be a hedge against extinction of the wild population. No captive-bred fish have been released into the wild, although there is now serious discussion of doing so (Hobbs et al. 2017). Given that life span in captivity is 2 years, if the Delta Smelt does go extinct in the wild, there will be a limited window of opportunity for reintroduction, assuming that environmental conditions are suitable and that the facility can produce sufficient fish for a reintroduction program.

However, relying upon the captive population for recovery of the species is problematic. The longer a reintroduction program is delayed, the more the captive smelt are likely to be on an evolutionary trajectory away from survival in the wild (Baumsteiger and Moyle 2017). We favor the immediate start of experiments, such as using eggs laid on mats by cultured fish and allowed to hatch in natural environments, perhaps in cages to protect the embryos and larvae from aquatic predators such as Mississippi Silverside (Hobbs et al. 2017). Successful rearing of these fish to adulthood and population resurrection requires a return to favorable environmental conditions associated with increased river inflows that will maintain cooler temperatures and support a food web that includes smelt. The slight increase in Delta Smelt population in 2011 (Figure 4), a wet year, provides some indication of the value of improved environmental conditions. The year 2017, one of the wettest years on record for California, may be the smelt's last hope for natural recovery, although there are no signs of response as of this writing (July 2017).

We recommend that the best approach to threading the needle of competing resource demands is to acknowledge the many potential threats to both water supply and native fishes and to find ways to moderate dependence upon the delta for water supply—in advance of crises of extinction, reduced supply or reduced export capacity. We favor directing resources to preserving species before they become extinct, rather than after. Thus, habitat conservation efforts should be directed to maximize positive interactions with environmental outflows. This can be best accomplished by focusing conservation efforts on the arc of habitat on the north side of the delta, from the Yolo Bypass through the Cache–Lindsey Slough complex, down the Sacramento River, to Suisun Marsh (Figure 1; Moyle et al. 2012). Suisun Marsh is a large tract of marsh habitat whose potential as a nursery area for juvenile fishes could be greatly enhanced (Moyle et al. 2014). The habitat in this arc is far from pristine, but it has the most potential for successful smelt-oriented restoration projects and for positive effects of increased flows from the Sacramento River and the Yolo Bypass. EcoRestore already has a number of independent restoration projects in this region and the Delta Smelt Resiliency Strategy calls for increased connectivity among these and other projects. The need now is thus to create larger, interconnected projects that will respond well to supportive, targeted environmental flows.

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