BUREAU OF RECLAMATION

Long-Term Operation – Biological Assessment

Chapter 10 – Longfin Smelt

Central Valley Project, California

Interior Region 10 – California-Great Basin

U.S. Department of the Interior November 2023

Mission Statements

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The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

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Chapter 10 Longfin Smelt

Longfin smelt *(Spirinchus thaleichthys)* in the San Francisco Bay/Sacramento–San Joaquin Delta Estuary (Bay-Delta) are pelagic (most frequently occurring in open water habitats) forage fish that exhibit a facultatively anadromous life history whereby migration to sea is not required to complete the lifecycle (Moyle 2002:236). Longfin smelt are generally adapted to cold- and cool-water habitats so elements of their facultatively anadromous life cycle within the San Francisco Estuary (SFE) are influenced by seasonal water temperature variation (e.g., Jeffries et al. 2016:1712; Yanagitsuru et al. 2021:Figure 1). The adults reproduce in low salinity to freshwater habitats beginning in early winter and extending into the spring as water temperature allows. The larvae rear during the spring in locations near where they were spawned. As water temperatures warm each spring into early summer, the young fish move seaward, and many individuals move into the Pacific Ocean during the summer months. It is speculated that some of these fish may spend extended periods of time at sea, but many individuals return to the estuary beginning in the fall and continuing into the early winter. These returning fish appear to be a combination of fish getting ready to spawn and younger individuals that are unlikely to do so.

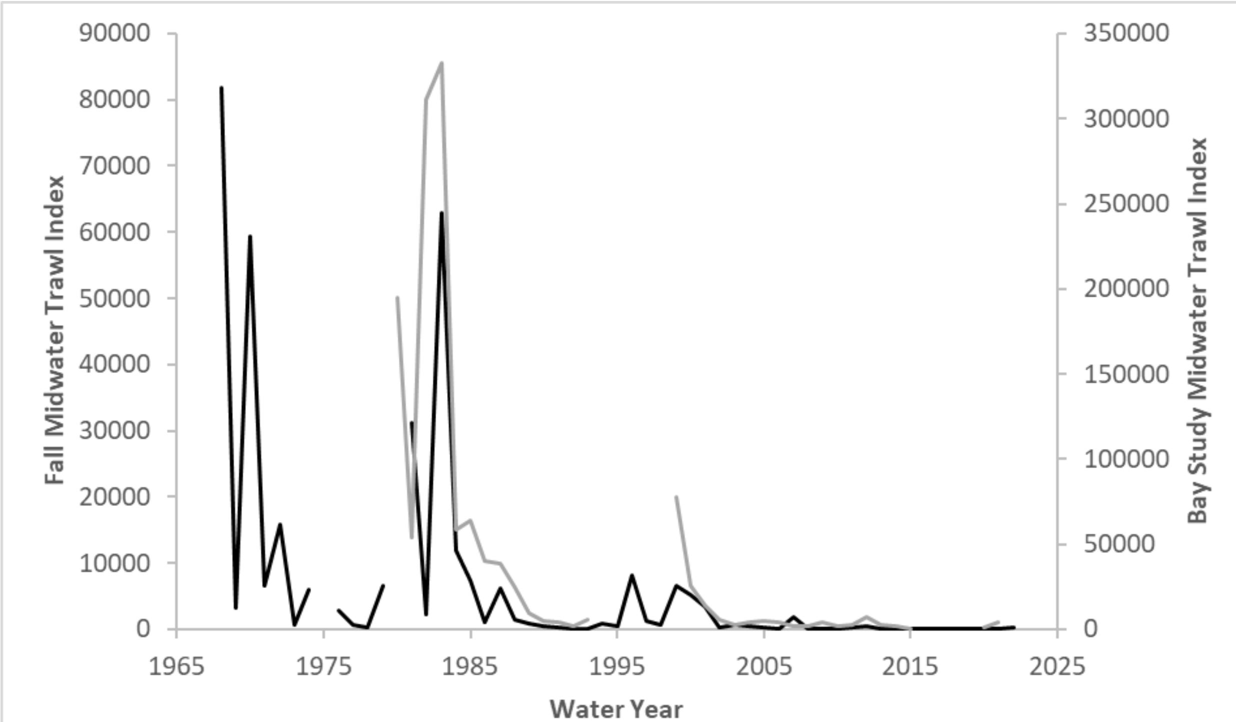
10.1 Status of Species

The longfin smelt Bay-Delta distinct population segment (DPS) was determined to be a distinct population segment that warranted listing as an endangered or threatened species under the Endangered Species Act on April 2, 2012, but the listing was precluded by higher priority listing actions. On October 7, 2022, U.S. Fish and Wildlife Service (USFWS) published a proposed rule that would find the longfin smelt, Bay-Delta DPS as an endangered species under the Endangered Species Act. This proposed rule's original comment period closed on December 6, 2022. On February 27, 2023, the USFWS reopened a 30-day comment period to allow for a public hearing held on March 14, 2023.

10.1.1 Distribution and Abundance

Survey efforts encompass abundance estimates of all life stages of the longfin smelt in the estuary (Figure 10-1). The data from these efforts indicate a recent and significant decline for longfin smelt throughout the estuary and across all life stages resulting in the conclusion that the current longfin smelt population size is small (U.S. Fish and Wildlife Service 2022).

Field surveys for documenting long-term abundance trends indicate longfin smelt numbers have substantially declined over time, with current relative abundance reflecting small fractions of the species' historical relative abundance and representing a decline of three to four orders of magnitude over the course of available historical abundance records. The general trend over time has been lower highs and lower lows in abundance for the DPS (U.S. Fish and Wildlife Service 2022). A summary of annual population growth rates derived from the monitoring data showed that, on average, abundance has declined from year to year, although some years with large growth rates contributed to variability (U.S. Fish and Wildlife Service 2022).



Source: California Department of Fish and Wildlife unpublished data.

Figure 10-1. Time Series of the Fall Midwater Trawl Survey (FMWT; black line; primary y-axis; Water Years 1959-2022) and Bay Study Midwater Trawl Survey (gray line; secondary y-axis; Water Years 1995-2021) Abundance Indices for longfin smelt (All Ages).

10.1.2 Life History and Habitat Requirements

The longfin smelt are 9–11 centimeters (cm) (3.5–4.3 inches (in)) in length with a relatively short lifespan of approximately two to three years. The longfin smelt, as a species, occurs in bays and estuaries from northern California north along the coast through Alaska. The Bay-Delta DPS of longfin smelt occupies the San Francisco Bay Estuary and areas of the Pacific Ocean out to the Farallon Islands. The tidally influenced San Francisco Bay Estuary includes the central and south San Francisco Bay, Suisun Bay, and San Pablo Bay, and the Sacramento–San Joaquin Delta (Delta). Longfin smelt are pelagic fish (fish most frequently occurring in open-water habitats) that exhibit a facultatively anadromous life history, meaning older juveniles and adults can migrate to the ocean, but are required to return to low salinity to fresh water for spawning and rearing (Grimaldo et al. 2017; Moyle 2002). Longfin smelt spawn only once in their lifetime but may have multiple spawning events during the spawning season (generally late fall to early spring) (U.S. Fish and Wildlife Service 2022). Reproduction occurs in low salinity to freshwater habitats beginning in late fall/early winter and extends into the spring as water temperature and low salinity conditions allow (U.S. Fish and Wildlife Service 2022).

Longfin smelt life history is highly dependent on the freshwater inflow, water temperature, and environmental conditions and resources of the San Francisco Bay estuary. The amount and duration of freshwater input from rivers and tributaries flowing into the estuary influences the location and extent of where the appropriate water temperature and saline conditions are present for the longfin smelt to carry out its life functions (U.S. Fish and Wildlife Service 2022). These freshwater flows can be natural, such as in wet years or dry years, or resulting from human-altered water management. Higher inflows into the Delta increases the size of the low salinity zone habitat that is available. Lower inflows into the Delta decreases the size of the low salinity zone habitat that is available. The needs of longfin smelt have been categorized by USFWS into three main resource needs and biological condition categories and include: (1) appropriate freshwater or low-saline water conditions; (2) appropriate water temperature conditions; and (3) adequate food resources and availability by life stage (2022). As longfin smelt is subject to both freshwater and saline water conditions, its habitat is extremely variable. These variable conditions along with other factors exert a strong influence on the condition of the longfin smelt's food resources.

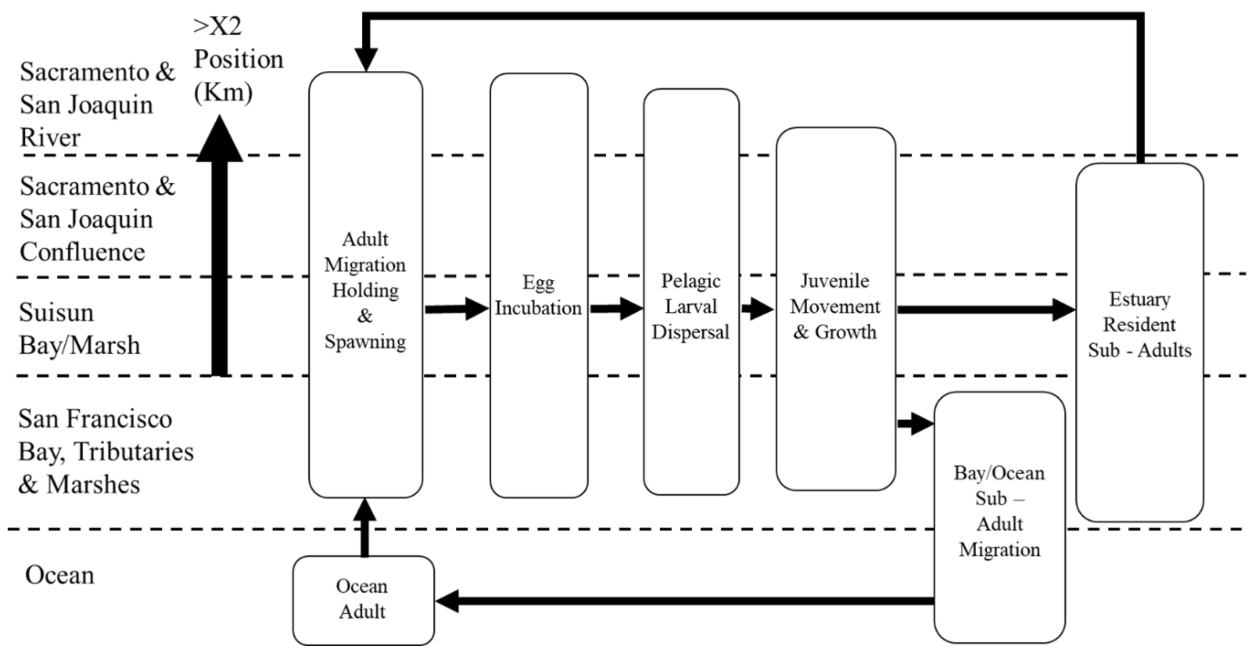
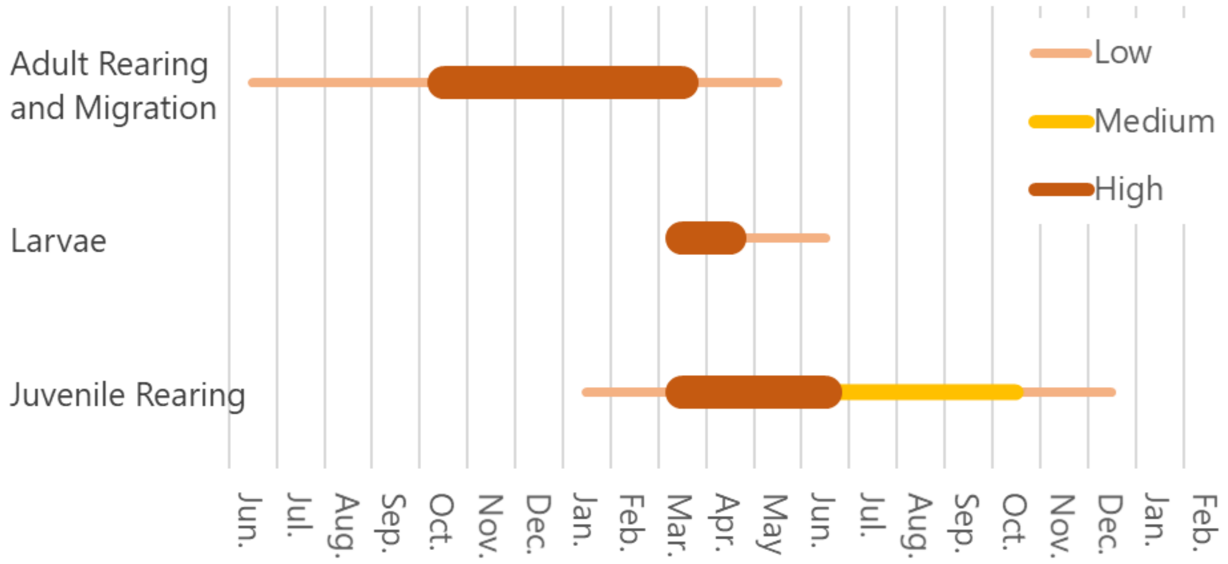


Figure 10-2. Simplified Geographic Life Stage Domains for Longfin Smelt.

In the San Francisco Estuary, longfin smelt larvae hatch between December and May, with rare observations outside this range (Baxter 1999:180). Peaks in abundance of recently hatched yolk-sac larvae occurred most commonly in February (during 8 of 10 years) and March otherwise (in 2 of 10 years; Baxter et al. 1999:183). Hatch timing is determined by when fish spawn and the temperature at which embryos incubate with incubation time decreasing with increasing water temperatures (see Figure 2-4). At 7°C (44.6°F), embryos hatch in 40 days (Dryfoos 1965:42). Sibley and Brocksmith (1995:38) reported an average incubation duration of 29 days at water temperatures ranging from 8 degrees Celsius (°C) to 9.5°C (46.4 to 49.1 degrees Fahrenheit [°F]). Similarly, Moulton (1970:50) noted that incubation time averaged 25 days at temperatures ranging between 9.6 and 10.6°C (49.3 to 51.1°F). Hobbs et al. (2013:49) incubated eggs at warmer temperatures than any of the studies mentioned above (12 ± 1 °C (53.6 ± 1.8°F) and found the shortest mean incubation duration (16 days). More recently, Yanagitsuru et al. 2021 found that incubation took an average of 23.7 days at 9°C (48.2°F), 19.3 days at 12°C (53.6°F), and 16.5 days at 15°C (59°F).

Longfin smelt maturation begins in the fall with mature fish observed as late as May of the following year (Tempel and Burns 2021, slide 3). Longfin smelt are sexually dimorphic, where males darken in color and the base of their anal fin hardens and elongates, presumably for sweeping fine sediments from spawning sites (Wang 1986:6–10). Most longfin smelt at the onset of maturation are > 90 millimeters (mm) fork length (FL) (Baxter pers. comm.). Fecundity increases exponentially as a function of female size, and ranges from about 1,900 eggs in a 73 mm female to over 16,000 in a 132 mm female (California Department of Fish and Game 2009a:11, Figure 3). Studies of longfin smelt fecundity for the Lake Washington and Harrison Lake populations also yielded similar results, with fecundity tending to be a function of both size and feeding success (Dryfoos 1965:120; Chigbu and Sibley 1994:7–8).

The spatial distribution of larvae (< 20 mm length) within the San Francisco Bay-Delta has not been fully resolved due to lack of adequate coverage by monitoring programs (Grimaldo et al. 2017:1777, Figure 5; Grimaldo et al. 2020:10, Figure 6). The majority of larvae are affiliated with the estuary's major low-salinity zone generated by the mixing of freshwater inflow from the Delta with the brackish waters of the estuary (see Section 2.3). However, larvae can also be found in freshwater tributaries to the Bay when their inflows are high enough and temperatures low enough to support egg survival and hatching (Lewis et al. 2019:3). The spatial distribution of these larvae reflects the year-to-year variation in the geographic location of the low-salinity zone (Dege and Brown 2004:57, Figure 3; Grimaldo et al. 2020:10, Figure 6). Within the low-salinity zone and adjacent waters, larvae have been commonly collected in both littoral (nearshore) and pelagic (offshore) habitats. Upon hatching, the larvae may swim toward the water surface which may facilitate relatively rapid seaward transport (California Department of Fish and Game 2009a, p. 8). However, it is not clear that such a behavior also facilitates retention in the low-salinity zone, especially when Delta outflow is high (Kimmerer et al. 2014:910, Figure 5). Modeling by Gross et al. (2022) found early-stage longfin smelt larvae would be rapidly transported seaward and suggests larval longfin smelt undergo from a passive to directional behavior transition which may include tidal vertical migration and depth seeking behavior to retain position in the low salinity zone (LSZ). Using a 3-dimensional hydrodynamic modeling framework, Kimmerer et al. (2014:910–11, Figures 5 and 6) applied the relatively modest swimming capabilities of copepods to show how well simple behaviors could help planktonic animals avoid being washed out to sea and keep them loosely associated within particular salinity ranges. Copepods are considerably smaller than larval fishes, and if they are able to influence their own location in the estuary, it may be hypothesized that longfin smelt larvae may possess this capacity as well (Bennett et al. 2002:1502). The recent findings of larval densities in tidal marsh channels and other edge habitats in densities comparable to offshore waters provides another potential low salinity zone retention mechanism since tidal currents are slower over shallow shoals and associated marsh channels (Bever et al. 2016:15, Figure 8b).



This is a generalized figure of timing; please see Appendix C, *Species Spatial and Temporal Domains*, for specific timing of life stages.

Figure 10-3. Temporal Life Stage Domains for Longfin Smelt.

Aggregated survey data have been used to show that juveniles (>20 mm in length) have been detected at one time or another throughout the estuary and into some tributaries to the Delta above tidal influence (Merz et al. 2013:132, Figure 2). However, the spatial distribution of juveniles shows a distinct seaward migration as water temperatures warm in the late spring and early summer (Rosenfield and Baxter 2007:1590; Tobias and Baxter 2022, in press). Juveniles have been collected most frequently from deep water habitats as opposed to shoals (Rosenfield and Baxter 2007:1586). In Lake Washington, age-0 and age-1 longfin smelt favor deep water during daylight and move closer to the surface at night (Quinn et al. 2012:342), likely moving in relation to their major source of food, mysid shrimp (Chigbu et al. 1998:180). It is possible that the Bay-Delta DPS does so as well, but this has not been evaluated for post-larval fish. Selection for deep water and a general shift to marine habitat were hypothesized to be behavioral responses to seasonally increasing water temperatures (Tobias and Baxter 2022, in press and not peer reviewed). Phillis et al. (2021, entire) utilized boosted regression trees and concluded that the strongest predictors of juvenile longfin smelt catch in the 20-mm Survey were bottom salinity, Secchi depth, Julian Day, water temperature, surface salinity, and the 7-day average position of X2. The same study predicted larval habitat availability during March through July under low and high spawner abundance in dry, moderate, and wet years (see Figure 2-7). These authors also predicted that, in dry years, habitat distributions shifted to Suisun Bay and north San Pablo Bay. Whereas in moderate flow years, their analysis predicted that higher freshwater flows resulted in lower salinity into areas of San Pablo Bay, and habitat suitability was predicted to increase in the South San Francisco Bay. In wet years, they predicted high suitability habitat is available in Suisun Bay, San Pablo Bay, and some of the South San Francisco Bay. Based on otter trawl survey data, juvenile longfin smelt rapidly adapt to and inhabit increased salinities because about half the juveniles captured by the larval net came from the salinity range 8 to 24 ppt (Baxter et al.

1999:189–190), well seaward of X2. This increase in salinity distribution represents both seasonal increases in upper estuary salinity as outflow declines and downstream movement of some individuals (Baxter et al. 1999:191). By their first summer of life, juvenile longfin smelt inhabit salinities up to and including marine water (i.e., 32–33 practical salinity units) (Baxter et al. 1999:191; Rosenfield and Baxter 2007:1590; Kimmerer et al. 2009:385). By May of most years, young-of-the-year longfin smelt begin to reach 40 mm FL (Rosenfield and Baxter 2007:1581). At this size, and regardless of outflow, these approximately 40 mm young of the year are typically distributed throughout the estuary (Baxter et al. 1999:189; Merz et al. 2013:136–139). Longfin smelt are found from low salinity (and occasionally freshwater) on the upstream end of the Bay-Delta DPS range, to marine conditions on the downstream end.

Distributions of older age-0 and age-1 fish have only been described coarsely into densities across shoal and channel (≥7m depth) habitats. For both age groups, density was almost always higher in the deeper channel habitats, and significantly higher from the first fall through the second spring of life, and between the second fall and second winter of life (Rosenfield and Baxter 2007:1586). In any given month, Bay Study data indicate that some fraction of the longfin smelt population remain in the Bay, but an unknown fraction may be found in the ocean (Rosenfield and Baxter 2007:1590; Merz et al. 2013:142). Longfin smelt have been detected in the nearshore ocean outside San Francisco Bay (Garwood 2017; City of San Francisco and CH2M Hill 1984 and 1985, entire). In addition, Feyrer et al. (2015) found a statistical association between the North Pacific Gyre Oscillation (an index of) and age-0 longfin smelt catch in the Bay Study. For this correlation to have any mechanistic basis, longfin smelt would need to be present in the ocean. These observations all support the hypothesis that at least partial anadromy is a life history strategy used by longfin smelt, which is consistent with the pattern observed in other populations range-wide (Rosenfield and Baxter 2007:1590). Recent longfin smelt otolith analyses have supported the conclusion; Lewis et al. (2019:63) used isotope ratios in otoliths and indicated that longfin smelt may exhibit at least four unique life history strategies. Another perspective is that the fish may be displaying a single life history strategy within a continuum, spawning in waters that are fresh to slightly brackish and then consistently transitioning into waters too saline to be discerned using strontium. The important indication is that component life stages of longfin smelt display variable spatiotemporal distribution as part of its life history strategy (Figure 2-7: Predicted juvenile habitat availability under various scenarios based on boosted regression tree models; source: Phillis et al. 2021, unpublished data)

10.1.3 Limiting Factors, Threats, and Stressors

The *2022 Special Status Assessment for Longfin Smelt* identified seven main threats to the species. Those threats are reduced freshwater flows, food limitation, elevated water temperature, loss of suitable spawning habitat, predation, contaminants, and entrainment. Longfin smelt larvae diets are dominated by a copepod, *Eurytemora affinis*, and increasingly larger prey as they grow. The invasion of the estuary by the overbite clam has led to the decline in *Eurytemora affinis.* Longfin smelt have specific water temperature thresholds for different life stages and parts of the bay exceed the various life stage requirements in certain seasons. The loss of suitable spawning habitat is due to a reduction in the size of the low salinity zone. This threat is directly related to the reduction in freshwater flows. Predation is a threat that is not completely understood; the early life stages are assumed to be more vulnerable to predation, and decreased food availability results in greater foraging requirements and therefore increased vulnerability to predators.

Contaminants can enter the bay through various sources (agricultural and municipal) with unknown risks and impacts to this species. Entrainment of longfin smelt can occur from various exports and agricultural diversion in the Delta.

The Proposed Action impacts freshwater flows, food limitation, entrainment, and amount of suitable spawning habitat through the influence over the inflows into the Delta, outflows associated with the pumping plants and food subsidy actions.

In the absence of a Management Analysis and Synthesis Team conceptual model specific to longfin smelt, U.S. Department of the Interior Bureau of Reclamation (Reclamation) drew from the stressors identified in the 2022 Species Status Assessment (U.S. Fish and Wildlife Service 2022) to identify the potential stressors on longfin smelt.

- **Adults**
    - *Entrainment:* Subadult longfin smelt habitation in the San Francisco Estuary is limited to when water temperatures are below 22°C (Baxter et al. 2010:68) and, based on field surveys of ripe and post-spawning females (Wang et al. 1986:9; Tempel and Burns 2021:slide 12), successful spawning may require water temperatures below 14°C.
    - *Habitat Loss:* The only fairly well demonstrated aspect of longfin smelt spawning behavior is that the fish appear to find spawning locations in and near the low-salinity zone (Grimaldo et al. 2020:10, Figure 6) and other smaller low salinity habitats in Bay Area tributaries (Lewis et al. 2019:3).
    - *Food Availability:* As described under Life History, approximately 90% of juvenile and, when they return to the estuary, adult longfin smelt diets are comprised of predominantly mysids and, to a lesser extent, amphipods (Burdi pers. comm.; California Department of Fish and Wildlife unpub Diet Study Data). Feyrer et al. (2003) showed that longfin smelt are primarily mysid feeders. *Neomysis mercedis*, which was once a dominant contributor to the low-salinity zone food web, has dropped in numbers by over tenfold. *N. mercedi*s has been largely replaced by *Hyperacnthomysis longirostris* (non-native mysid) (Avila and Hartman 2020). Overall mysid abundance declined after invasion of the overbite clam in Suisun Bay (Winder and Jassby 2011). The decline is believed to be due to the clams filtering out phytoplankton (Kimmerer 2002), but there is a negative relationship between *N.* mercedis abundance and increasing position of X2 before 1987 and a positive relationship with increasing position of X2 from 1988-1999 (Kimmerer 2002:Figure 7).
    - *Predation:* Predation on longfin smelt has only been documented in the Delta, and predation rates in marine coastal regions and marine-brackish regions of the San Francisco Estuary are unknown. Furthermore, gut content analyses often don't reveal life stage of the prey, so it is difficult to determine the impact on adult longfin smelt. Brandl et al. (2021) detected longfin smelt in 20% of the stomachs and gut contents of Sacramento pikeminnow, and in less than 1% of striped bass in the Delta region. Sacramento pikeminnow appear to be the dominant predator for longfin smelt in the Delta (Mahardja et al. 2021). The predation rate of striped

bass in the marine to brackish regions of adult longfin smelt distribution is unknown, but striped bass is only an occasional predator of longfin smelt in the regions of the Delta (Grossman et al. 2016; Brandl et al. 2021).

    - *Toxins:* Field-based toxicity is difficult to determine, as impacted fish are not recovered in order to be examined (i.e., fish either die from direct exposure and resulting disease, or are eaten). Risk of exposure and effect, as determined by comparison to other species (e.g., Delta smelt and inland silverside) potentially include direct effects on development, growth and reproduction; impacts resulting from impairments to bioenergetic demands, impaired locomotion, reducing feeding success and leading to increased susceptibility to predation, disease, and entrainment (Brander et al. 2012:2854; Brander et al. 2016; Connon et al. 2009:12; Hasenbein et al. 2014:696; Jeffries et al. 2015a:17407; Jeffries et al. 2015b:55; Cole et al. 2016:219; DeCourten and Brander 2017:2). In general, actions that eliminate, reduce, or dilute these contaminants in waters of the Central Valley are expected to benefit longfin smelt and other fishes in the Estuary.

- **Juveniles**
    - *Entrainment:* Longfin smelt juveniles and sub-adults may be entrained and experience high mortality at water diversions. Water diversions modify hydrodynamics in ways that may transport juvenile longfin smelt to sub-optimal habitats within the Delta. Indirect mortality may occur because water diversions affect habitat quantity and quality. Also, water diversions may impact the abundance and distribution of longfin smelt prey, predators, and competitors.
    - *Reduced Freshwater Flow:* In high outflow years, longfin smelt are believed to benefit from a suite of mechanisms that can extend the spawning season and increase the cumulative survival of juveniles. Conversely, during low outflow years, fewer of these benefits are accrued and survival is reduced. For these reasons, the interannual variation in Delta outflow and to lesser extent, flows in Bay Area tributaries (which can also be represented by correlates like X2) mechanistically represent a primary population need from December through May or June each year. The strong relationship of the juvenile longfin smelt abundance index with outflow may be more important for juveniles rather than earlier life stages (i.e., hatching larvae), as Kimmerer and Gross (2022) revealed the index was positively related to outflow after March but outflow was unrelated in the year of hatching.
    - *Water Temperature:* Subadult longfin smelt habitation in the San Francisco Estuary is limited to when water temperatures are below 22°C (Baxter et al. 2010:68), and, based on field surveys of ripe and post-spawning females (Wang et al. 1986:9; Tempel and Burns 2021:slide 12), successful spawning may require water temperatures below 14°C, while larvae and young juveniles show a preference for temperatures below 12°C and 20°C, respectively, for successful rearing--particularly in food-limiting environments like the San Francisco Estuary, where bioenergetic metabolic demands for caloric intake increase with increasing water temperatures.

- *Habitat Loss:* A strong positive relationship between longfin smelt young-of-year class size and freshwater flow through the Estuary has been documented repeatedly (Stevens and Miller 1983; Jassby et al. 1995; Meng and Matern 2001; Kimmerer 2002; Rosenfield and Baxter 2007; California Department of Fish and Game 2009). The relationship may be due to improved conditions for oviposition, incubation, or larvae (Tables 2, 3). Baxter (1999) and Dege and Brown (2004) found little correlation between freshwater inflow and larval abundance, which hints that freshwater flow impacts larval survival to the juvenile life stage more than it influences spawning habitat availability or hatching success, however these analyses are likely biased due to shifts in longfin smelt distribution outside of survey areas. Nobriga and Rosenfield (2016) found freshwater flow had a positive association with recruits per spawner. Grimaldo et al. (2020) found during high-flow years, there was a seaward shift in distribution of larval longfin smelt.

- *Food Availability:* As described under Life History, approximately 90% of juvenile longfin smelt diets are comprised of predominantly mysids and, to a lesser extent, amphipods (Burdi pers. comm.; California Department of Fish and Wildlife unpublished Diet Study Data). Feyrer et al. (2003) showed that longfin smelt are primarily mysid feeders. *Neomysis mercedis*, which was once a dominant contributor to the low-salinity zone food web, has dropped in numbers by over tenfold. *N. mercedi*s has been largely replaced by *Hyperacnthomysis longirostris* (non-native mysid) (Avila and Hartman 2020). Overall mysid abundance declined after invasion of the overbite clam in Suisun Bay (Winder and Jassby 2011). The decline is believed to be due to the clams filtering out phytoplankton (Kimmerer 2002), but there is a negative relationship between *N. mercedi*s and increasing position of X2 before 1987 and a positive relationship with increasing position of X2 from 1988-1999 (Kimmerer 2002:Figure 7).

- *Predation:* Increases in predation on juvenile and sub-adult longfin smelt are unlikely to be responsible for the most recent decline in the longfin smelt population. Brandl et al. (2021) detected longfin smelt in 20% of the stomachs and gut contents of Sacramento pikeminnow, and in less than 1% of striped bass in the Delta region. Sacramento pikeminnow appear to be the dominant predator in the Delta, which is a native species in decline (Mahardja et al. 2021). There remains a degree of uncertainty about historic populations being affected by the introduction of striped bass into the estuary, often referred to as the phantom predator hypothesis (Nobriga and Smith 2020). In a study by Rogers et al. (2022), top-down effects of predation on estuarine fishes (including longfin smelt) appeared to be strongest in brackish regions, and bottom-up effects were strongest in freshwater regions. Based on timing of arrival in the Estuary and subsequent longfin smelt population response, Moyle (2002) suggested that Mississippi silverside (*Menidia audens*) might have had a major impact on longfin smelt population dynamics. Mississippi silversides can be piscivorous; however, they prefer shallow water habitats where juvenile and sub-adult longfin smelt are rare. Thus, their impact as predators of juvenile and sub-adult longfin smelt is probably slight.

- *Toxins:* The impact of anthropogenic chemical inputs on longfin smelt habitat use, survival, and reproduction is almost completely unstudied; however, chemical toxins are a leading suspect in the general decline of pelagic species in the San Francisco Estuary (Sommer et al. 2007). Foott and Stone (2007) found high rates of hepatocyte vacuolation (25-75%) in small samples of longfin smelt juveniles caught in 2006 and 2007, but the cause and meaning of this phenomenon cannot be determined without comparisons between known healthy longfin smelt and those known to be exposed to toxins. The hepatocyte vacuolation did not appear to have a major health impact on the longfin smelt juveniles studied (Foott and Stone 2007). Urban stormwater and agricultural runoff may be contaminated with pesticides, herbicides, oil, grease, heavy metals, polycyclic aromatic hydrocarbons, and other organics and nutrients that potentially have direct lethal and sub-lethal physiological and behavioral effects on juveniles and destroy the aquatic life necessary for growth and survival. Bifenthrin, a primary insecticide used in urban and agricultural applications, generally increases during the rainy season due to runoff (Mauduit et al. 2023; Ruby 2013; Weston et al. 2019). The timing of runoff typically aligns with longfin smelt spawning, November through April. In a lab study by Mauduit et al. (2023), the researchers observed effects of bifenthrin on behavior that ultimately affected yolk sac volume and hatchling size. There remains considerable uncertainty associated with determining the impacts of operations on the toxicity and contaminants stressor, particular for impacts in the Delta. Schoellhamer et al. (2007) demonstrated that contaminants associated with suspended sediments were higher in shallow environments in comparison to the main channels. There have been documented cases of acute toxicity in the main channels of the San Francisco Estuary, as evident in Werner et al. (2010). Juvenile longfin smelt may ingest and accumulate toxins over the course of their lives with potentially negative consequences.

- **Eggs and Larvae**
  - *Entrainment (only larvae):* When water is removed from emigration corridors, longfin smelt larvae may be diverted as well. Because eggs are demersal, water diversions are unlikely to affect egg development directly. Longfin smelt larvae that become entrained in diversions almost certainly die – these fish are not successfully screened from most current diversions and would probably not survive “salvage” operations even if they were screened effectively. Indirect mortality may occur because water diversions affect habitat quantity and quality. Furthermore, water diversions modify hydrodynamics in ways that may transport larval longfin smelt to sub-optimal habitats within the Delta. Spawning locations have been estimated using field observations of gravid females and yolk-sac larvae (Grimaldo et al. 2017; Lewis et al. 2019), and through particle-tracking modeling (Gross et al. 2022) to suggest spawning extends farther seaward than previously estimated (Moyle 2002). Based on these studies, longfin smelt appear to spawn in the low-salinity zone where brackish and freshwaters meet (Grimaldo et al. 2017:11), in tidal wetlands of South San Francisco Bay (Lewis et al. 2020:3), and in San Pablo and lower South Bay during wet years (Grimaldo et al. 2020:10). Longfin smelt migrate from areas of high salinity to either brackish or

fresh water for spawning from winter to the spring, and spawn by the spring (Rosenfield 2010:4; Lewis et al. 2019:5). Since longfin smelt spawn farther seaward than previously thought, entrainment from the State Water Project (SWP) and Central Valley Project (CVP) pumps do not appear to have a substantial effect on the population (Gross et al. 2022:189). Kimmerer and Gross (2022) indicate that larval abundance is not related to outflow effects, and that the relationship of longfin smelt with freshwater flow may be more important after March/ early larval development.

- *Food Availability:* As described under Life History, approximately 90% of juvenile longfin smelt diets are comprised of predominantly mysids and, to a lesser extent, amphipods (Burdi pers. comm.; California Department of Fish and Wildlife unpub Diet Study Data). *Neomysis mercedis*, which was once a dominant contributor to the low-salinity zone food web, has dropped in numbers by over tenfold. *N. mercedi*s has been largely replaced by *Hyperacnthomysis longirostris* (non-native mysid) (Avila and Hartman 2020). Overall mysid abundance declined after invasion of the overbite clam in Suisun Bay (Winder and Jassby 2011). The decline is believed to be due to the clams filtering out phytoplankton (Kimmerer 2002), but there is a negative relationship with increasing position of X2 before 1987 and a positive relationship with X2 from 1988-1999 (Kimmerer 2002:Figure 7). Feyrer et al. (2003) showed that longfin smelt are primarily mysid feeders.
- *Reduced Freshwater Flow:* Recent studies on longfin smelt early development in culture indicate the optimal salinity for growth and survival of yolk-sac larvae occurs in moderately brackish conditions, 5 to 10 ppt (Yanagitsuru et al. 2022). Findings by Kimmerer and Gross (2022) suggest that outflow effects are more important after March.
- *Water Temperature:* Successful spawning may require water temperatures below 14°C, while larvae and young juveniles show a preference for temperatures below 12°C and 20°C, respectively, for successful rearing--particularly in food-limiting environments like the San Francisco Estuary, where bioenergetic metabolic demands for caloric intake increase with increasing water temperatures (Wang et al. 1986; Tempel and Burns 2021). Recent studies in the captive culture program at UC Davis help bolster the previous studies, demonstrating that water temperatures of 15°C can be detrimental to developing yolk-sac larvae, and that cooler water temperatures between 9°C and 12°C improve survival during these early life stages (Yanagitsuru et al. 2021). Generally speaking, temperature correlates positively with growth rate up to a threshold and beyond that threshold, temperature and egg mortality would be positively correlated. Given the northern distribution of this species and for most of the family Osmeridae, it is unlikely that longfin smelt encounter critically low temperatures in the San Francisco Estuary. Indeed, because the San Francisco Estuary population is at the southern edge of the species' range, it is possible that eggs and larvae in this population are stressed by warm temperatures.

- *Habitat Loss:* A strong positive relationship between longfin smelt young-of-year class size and freshwater flow through the Estuary has been documented repeatedly (Stevens and Miller 1983; Jassby et al. 1995; Meng and Matern 2001; Kimmerer 2002; Rosenfield and Baxter 2007; California Department of Fish and Game 2009). The relationship may be due to improved conditions for oviposition, incubation, or larvae. Baxter (1999) and Dege and Brown (2004) found little correlation between freshwater inflow and larval abundance, which hints that freshwater flow impacts larval survival to the juvenile life stage more than it influences spawning habitat availability or hatching success. However, these analyses are likely biased due to shifts in longfin smelt distribution outside of survey areas. Nobriga and Rosenfield (2016) found freshwater flow had a positive association with recruits per spawner. Grimaldo et al. (2020) found during high-flow years, there was a seaward shift in distribution of larval longfin smelt.

- *Predation:* The early life stages of fish are often subject to high rates of predation that play important roles in modulating abundance and amplifying the consequences of food limitation (Ahrens et al. 2012:46, Figure 2, and throughout; Pangle et al. 2012:5–6). Thus, changes in vulnerability to predation of eggs, larvae, and small juvenile longfin smelt are a plausible hypothesis for why survival is higher in wetter years than drier years. If predation rates covary with the freshwater flow influence on longfin smelt recruits produced per spawner, they are likely modulated through several other mechanisms like turbidity, water temperature, access to zooplankton prey, or outcomes of differences in wet versus dry year hydrodynamics (Figure 2-8). Predation-related longfin smelt mortality during the egg stage is not well documented. Since little is known about egg deposition locations, microhabitats, or incubation periods, the lack of information regarding egg predation rates is not surprising. New species are constantly being introduced to the San Francisco Estuary (Moyle 2002), and little information regarding the impact of predation on egg and larval longfin smelt is available. The positive relationship between freshwater flow in the Estuary and young-of-year (juvenile) class size of longfin smelt may arise, at least in part, because high freshwater flow rates increase the volume of LFS rearing habitat with relatively high-turbidity and thereby reduce exposure of LFS to visually oriented predators. Similarly, low fresh water flow rates appear to result in an eastward shift of the longfin smelt larval distribution (Dege and Brown 2004; California Department of Fish and Game 2009); this places a greater portion of the larval longfin smelt population in the Delta, an area with high populations of introduced predatory fish species.

- *Toxins:* At this time, there are few studies of the effect of water chemistry on the development, growth, or survival of longfin smelt eggs or larvae. Mauduit et al. (2023) reported bifenthrin, an insecticide used in agriculture, affects fitness-determinant traits of early life stages of longfin smelt. Studies of other fish species suggest that the potential for widespread effects of toxic compounds (including sublethal impacts) on both longfin smelt eggs and larvae may be important (Figure 3; Tables 2, 3). For example, Viant et al. (2006) found significant developmental abnormalities and mortality in Central Valley Chinook salmon eggs or alevins exposed separately to three different types of pesticides (larvae were more sensitive to these compounds than eggs). In general, actions that eliminate reduce, or dilute these contaminants in waters of the Central Valley are expected to benefit longfin smelt and other fishes in the Estuary.

10.1.4 Management Actions

10.1.4.1 Recovery Plan Activities Related to the Central Valley Project and State Water Project

In 1996, USFWS issued a "*Recovery Plan for the Sacramento-San Joaquin Delta Native Fishes*" which includes the longfin smelt. The recovery plan identified recovery objectives and criteria for the recovery of the species. Given that this recovery plan is more than 25 years old, some of the understanding may reflect the science at the time and may need to be updated.

The following recovery objectives, identified in the 1996 Recovery Plan, are associated with Reclamation's operation of the CVP. The current status of these objectives are included.

- *Increase Delta inflows to improve the quality and availability of habitat within the Delta (Priority 3):* This ongoing activity is part of operations and addressed in this consultation.
- *Provide transport inflows and outflows for larval and juvenile dispersal from the Sacramento River (Priority 1):* This ongoing activity is part of operations and addressed in this consultation.
    - *Provide transport inflows and outflows for larval and juvenile dispersal from the San Joaquin River (Priority 1):* This ongoing activity is concurrent but separate from this consultation.
    - *Place the 2 parts per thousand isohaline at Roe Island (Priority 1):* Attempts to generally increase size of the Low Salinity Zone are included in this consultation.
    - *Place the 2 parts per thousand isohaline at Chipps Island (Priority 1):* Attempts to generally increase size of the Low Salinity Zone are included in this consultation.
    - *Place the 2 parts per thousand isohaline at the confluence of the Sacramento-San Joaquin River at Collinsville (Priority 1):* Attempts to generally increase size of the Low Salinity Zone are included in this consultation.
- *Provide flows and restrict pumping (Priority 1):* This ongoing activity is part of operations and addressed in this consultation.

- *Change operations of facilities to reduce losses and facilitate fish movement within the Delta (Priority 3):* This ongoing activity is part of operations and addressed in this consultation.

    - *Reduce predation with the State's Clifton Court Forebay and within other CVP and SWP diversions (Priority 2):* This ongoing activity is part of operations and addressed in this consultation.

    - *Screen diversions at the CCWD Rock Slough Intake (Priority 2):* This ongoing activity is concurrent but separate from this consultation.

    - *Restrict diversions by the CCWD when eggs, larvae or juveniles are present using generalized "windows" or recent-time monitoring (Priority 3):* This ongoing activity is concurrent but separate from this consultation.

    - *Close Delta Cross Channel gates when juveniles are present using generalized "windows" (discrete time interval, for example January through April) or recent-time monitoring (Priority 2):* This ongoing activity is part of operations and addressed in this consultation.

    - *Evaluate reduction of fish movement into Georgiana Slough through use of hydroacoustic barrier or deflector (Priority 2):* This ongoing activity is concurrent but separate from this consultation.

    - *Meet water quality and flow standard for public water projects (Priority 2):* This ongoing activity is part of operations and addressed in this consultation.

    - *Monitor for location and numbers of fish throughout the Delta so that recovery objectives may be implemented, and decisions made on success of implementation (Priority 2):* This ongoing activity is part of operations and addressed in this consultation.

    - *Develop screening criteria for adults, juveniles and larvae (Priority 2):* Completed.

    - *Monitor the location of the 2 parts per thousand isohaline and relate to Delta 14-day running mean outflow and California Department of Fish and Wildlife (CDFW) surveys that determine longfin smelt abundance (Priority 2):* This ongoing activity is part of operations and addressed in this consultation.

10.1.4.2 Other Recovery Plan Activities

The following recovery objectives, identified in the 1996 Recovery Plan and are not associated with the operation of the CVP.

- *Develop additional habitat and vegetation zones with the Delta (Priority 2)*

- *Develop additional habitat and vegetation zones with Suisun Marsh and Suisun Bay (Priority 2)*

- *Restore additional shallow-water spawning habitat in upstream freshwater areas (Priority 2)*
- *Restore additional shallow-water spawning habitat in tidal areas (Priority 2)*
- *Conduct toxicological investigations to determine susceptibility of fish to various metals and pesticides (Priority 3)*
- *Study effects of introduced species (Priority 3)*
- *When considering projects, mitigate for all functions and values so that no net loss of shallow-water (less than 3 meter deep) habitat occurs (Priority 1)*
- *Control existing harmful introduced species (Priority 3)*

10.1.5 Monitoring

- CDFW's Fall Midwater Trawl (FMWT) have been sampled since 1967.
- CDFW's San Francisco Bay Midwater Trawl (1980–Present).
- CDFW's San Francisco Bay Otter Trawl (1980–Present).
- UC Davis's Suisun Marsh Otter Trawl (1979–Present).
- USFWS's Chipps Island Trawl survey (1976–Present).
- Fish Salvage at the SWP Skinner Delta Fish Protective Facility (1979–Present).
- USFWS's Delta Beach Seine Survey (1976–Present).
- CDFW's Summer Townet Survey (1959–Present).
- CDFW's Striped bass egg and larval survey (1968–1995).
- CDFW's 20mm survey (1995–Present). This survey runs in the spring to catch larval and juvenile longfin smelt.
- U.S. Army Corps of Engineers' Napa River Survey (2001–Present). This survey catches delta smelt in the Napa River.
- CDFW's Spring Kodiak Trawl (2002–Present).
- North Bay Aqueduct Larval Fish Survey (1996–Present).
- Smelt Larval Survey (2009–Present) Samples for early-stage longfin smelt larvae biweekly January–March.
- Bay Study (1980–Present) samples monthly year-round and targets juveniles to small-sized adult fish (20–250 mm).
- Suisun Marsh Survey (1980–Present).
- Longfin Smelt Distribution in the Coastal Pacific Ocean (2021–Present).

10.2 Effects Analysis

The following sections summarize potential effects of the Proposed Action to longfin smelt by life stage and stressors from *"Species Status Assessment for the San Francisco Bay-Delta Distinct Population Segment of the Longfin Smelt*" (SSA) developed by the USFWS (2022). Appendix B, *Water Operations and Ecosystem Analyses*, shows how the seasonal operation of the CVP and SWP change river flows, water temperatures, and water quality parameters in different locations and under different hydrologic conditions. Appendix C summarizes when fish may be present in different locations based on historical monitoring in the Central Valley. Appendix D, *Seasonal Operations Deconstruction*, analyzes potential stressors for the seasonal operation of the CVP and SWP. Deconstruction of the seasonal operation systematically evaluated how each stressor identified by the longfin smelt SSA may or may not change from the Proposed Action of CVP and SWP operations to store, release, divert, route, or blend water. Appendix G, *Specific Facility and Water Operations Deconstruction*, analyzes potential stressors due to facility specific operations, and Appendices H through R analyze conservation measures to minimize or compensate for adverse effects. Stressors not linked to the operation of the CVP and SWP were identified as "not anticipated to change". Stressors that the Proposed Action may change to an extent insignificant or discountable were documented. Insignificant effects relate to the size of the impact and should never reach the scale where take occurs. Based on best judgment, a person would not be able to meaningfully measure, detect, or evaluate insignificant effects. Discountable effects are those extremely unlikely to occur. Based on best judgment, a person would not be able to expect discountable effects to occur.

Stressors exacerbated by the Proposed Action that may result in effects on listed species were documented and, when appropriate, proposed conservation measures identified.

10.2.1 Juveniles Rearing and Migration

Juveniles are rearing in the LSZ before their migration out to the ocean. This rearing period typically begins around March 1 but can occur as early as early January. As water temperatures warm in the late spring and early summer juveniles move seaward (Rosenfield and Baxter 2007). Some individuals remain in the SF Bay Estuary year-round (Merz et al. 2013).

Stressors that may change at a level that is insignificant or discountable include:

- The Proposed Action may increase the *Water Temperature* stressor. CVP and SWP storage and diversion decreases Delta inflow. Delta water temperature is negatively correlated with Delta inflow in the spring (Bashevkin and Mahardja 2022) and reservoir operations may influence water temperature to a minimal extent in the lower reaches of the Sacramento River (Daniels and Danner 2020). However, in the Bay-Delta water temperature is mainly driven by timing of snowmelt (Knowles and Cayan 2002), air temperature and meteorology (Vroom et al. 2017; Daniels and Danner 2020). The historical water temperatures do not exceed 68°F at Prisoner's Point (juvenile cellular stress response; Jeffries et al. 2016) in the early spring. There is uncertainty about whether the decreased inflow from reservoir operations would lead to increased Delta water temperatures; however, the correlations include wet years with flood operations.

The volume of water required to provide sufficient thermal mass to deviate from ambient air temperatures is substantially larger than releases outside of flood operations.

- The Proposed Action may increase the *Toxicity* stressor. CVP and SWP storage and diversion of water decreases Delta inflow, limiting the potential for dilution of contaminants. In the Delta, the potential for dilution of contaminants depends on sampling location (Stillway et al. 2021). Contaminants are likely local and have little response to CVP and SWP flows (Werner et al. 2010). CVP and SWP operations are not a proximate cause of contaminants mobilized from the watershed, agricultural lands, and urban effluent (Guo et al. 2010).
- The Proposed Action many increase the *predation* stressor. During the juvenile rearing and migration period, the Proposed Action will store and divert water and reduce Delta inflows and outflow. Certain locations in the Delta (e.g., Clifton Court Forebay, the scour hole at Head of Old River, Delta fish collection facilities, the Delta Cross Channel gates) are considered predator hotspots and during operations of those that are CVP/SWP facilities, longfin smelt will be exposed to predation. Studies have been conducted as far back as the 1980s on the abundance of predatory fish inhabiting Clifton Court Forebay (Kano 1990; Gingras and McGee 1997) and more recent studies have predicted high predation hazard for scour holes like the Head of Old River site (Michel et al. 2020). Predation is widespread and exacerbated by disruption of habitat from land use and invasive aquatic vegetation, climate change, and altered predator dynamics from well-established invasive piscivorous non-native fish such as striped bass, largemouth bass and Mississippi silversides. Predation rates are a function of correlated variables such as predator presence, prey vulnerability, and environmental conditions (Grossman et al. 2013; Grossman 2016). Reduced turbidity from the Proposed Action can also increase predation risk (Ferrari et al. 2013, Schreier et al. 2016). Higher temperatures increase metabolic demands of fish which may cause longfin smelt to increase time spent foraging and exposure to predators. Effects of the Proposed Action on water temperature and food visibility that may interact with the predation stressor were analyzed in those sections. Indirect effects of predation are described further in Appendix J, *Winter and Spring Pulses and Delta Outflow—Smelt, Chinook Salmon, and Steelhead Migration and Survival*, Appendix K, *Summer and Fall Delta Outflow and Habitat*, and Appendix I, *Old and Middle River Flow Management*. Any residual effects of predation associated with the Proposed Action are considered insignificant.

Described below are stressors exacerbated by the Proposed Action, potentially resulting in incidental take. Also described below are conservation measures included as part of the Proposed Action to avoid or compensate for adverse effects.

10.2.1.1 Entrainment

The proposed diversion of water may increase the entrainment risk stressor. During the juvenile rearing and migration period, Proposed Action will export water from the Delta and lead to the storage and diversion of water which will reduce Delta inflows and outflows. Old and Middle River (OMR) flows towards the central and south Delta will also increase. Entrainment is discussed in two ways: (1) fish encountering CVP and SWP facilities where they may be pulled into diversions or the export facilities as they follow net flows (Grimaldo et al. 2009); and (2) fish routed/advected through water ways in the Delta where they may experience decreased survival. Grimaldo et al. (2009) found OMR flow was the only variable that explained interannual salvage abundance for age-0 longfin smelt. Salvage of age-0 fish peaked in April – May (Grimaldo et al. 2009).

Multiple topic-specific appendices address aspects of adult migration through the Delta.

- Appendix G includes sections for Tracy Fish Collection Facility and Skinner Fish Delta Fish Protective Facility
- Appendix I presents analysis of Old and Middle River Management and Delta Cross Channel Closure conservation measures

The Proposed Action involves several actions intended to minimize the entrainment of juvenile longfin smelt. These actions included decreased exports to allow for more positive OMR during specific time frames, in response to abiotic conditions and fish observations.

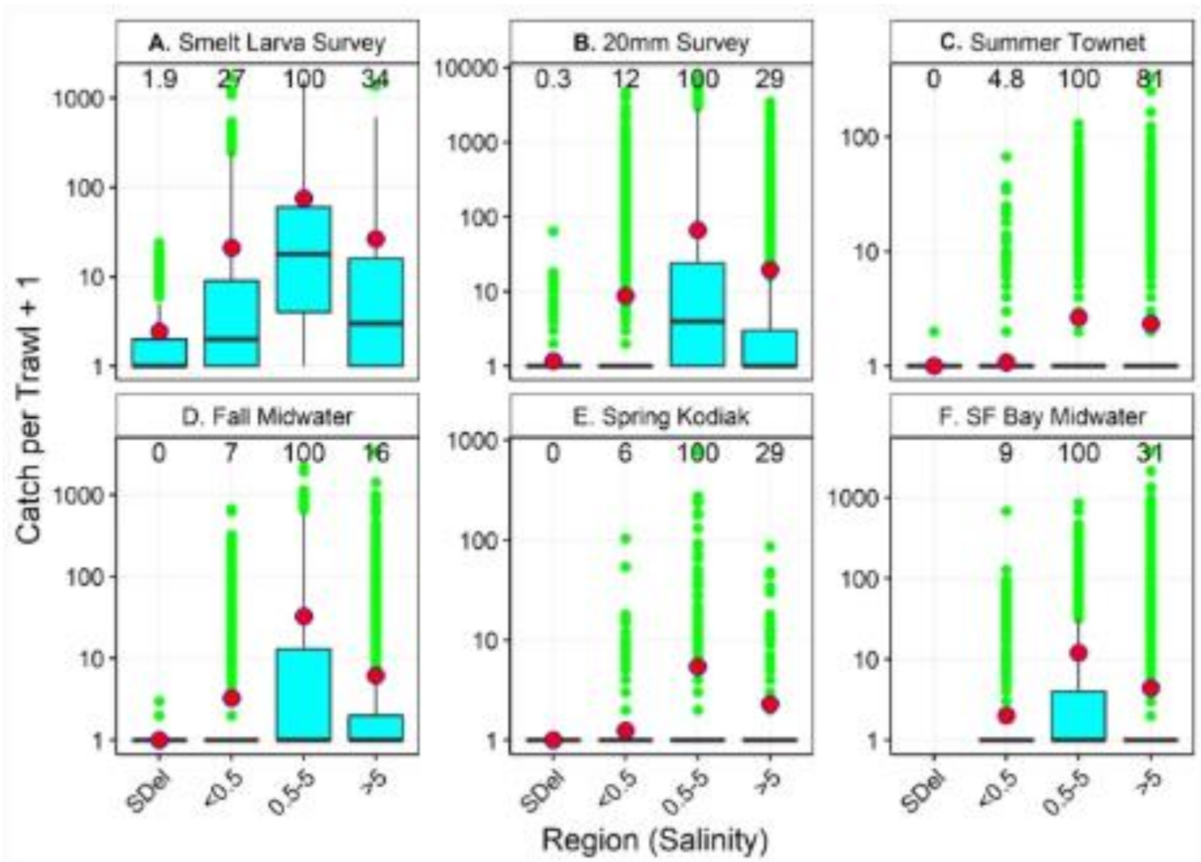
The increase in entrainment stressor is expected to be **lethal**. Entrainment can result in direct mortality by removal through the Delta fish collection facilities or indirect mortality by routing fish into areas of poor survival. When fish are entrained into the south Delta, they are exposed to greater predation risk since the invasive aquatic macrophyte, *Egeria densa*, dominates the littoral zone in the south Delta (Durand et al. 2016) and provides habitat for the invasive largemouth bass (Brown and Michniuk 2007) which prey on other fish species.

Although the Proposed Action may increase the entrainment risk stressor, entrainment of juvenile longfin smelt exists in the **environmental baseline** (without the Proposed Action). The SSA summarizes the major modifications to the physical, biological, and hydrological alterations that have occurred to the Bay-Delta from its historic conditions. In addition, tidal conditions can facilitate downstream transport or entrainment depending on the flood and ebb of tides during the fortnightly spring-neap cycle (Arthur et al. 1996). Entrainment of longfin smelt also is influenced by non-CVP and non-SWP diversions in the Delta. Most of the 370 water diversions operating in Suisun Marsh are unscreened (Herren and Kawasaki 2001).

In the Delta, Reclamation’s past operation of the Delta Cross Channel Gates and Reclamation and DWR’s past operation of export facilities influenced the flow of water in the Delta. Reclamation and DWR have operated the CVP and SWP to reduce the risk of entrainment under Biological Opinions issued by the USFWS and NMFS in 2004/2005, 2008/2009, and 2019. Under those Biological Opinions, Reclamation and DWR have: (1) closed the Delta Cross Channel Gates; (2) controlled the net negative flows toward the export pumps in Old and Middle rivers to reduce the likelihood that fish would be diverted from the San Joaquin or Sacramento River into the southern or central Delta; and (3) improved fish screening and salvage operations to reduce mortality from entrainment and salvage. SWP facilities in the Delta have also operated consistent with an incidental take permit that addresses longfin smelt issued under the California Endangered Species Act by CDFW on March 31, 2020.

The **proportion** of the population affected by the Proposed Action varies annually, depends on hydrology, and export rates and is likely **low**. Reclamation considered historic salvage and literature on entrainment to estimate the proportion of the population affected by an increase in the entrainment risk stressor.

Analysis of catch per trawl data from various environmental monitoring surveys in the upper estuary by Kimmerer and Gross (2022) found mean juvenile catch in the south Delta was 0.3% of the mean catch in the LSZ when using the 20mm survey data (Figure 10-4). Fish present in the South Delta are at greater risk of being entrained.



Source: Kimmerer and Gross 2022, Figure 3.
Boxplots showing catch per trawl of longfin smelt for each of six sampling programs in the upper estuary (panels A–F). The four boxes in each panel show differences among four regions: the south Delta near the diversion intakes (“SDel”), and three regions defined by salinity ranges but excluding the south Delta. Boxes show quartiles, whiskers extend to the furthest point within 1.5 times the interquartile range from the boxes, and points are outliers. Circles give means, and numbers at the top of each panel give the percent of each mean to the highest mean in the panel, rounded to one decimal place if < 0.5. The south Delta was not sampled by the San Francisco Bar Study (F). Data are from all years when the program operated; confining the data to the years when the Smelt Larva Survey was operating, 2009–2020, gave essentially the same result.

Figure 10-4. Catch per Trawl Survey for Longfin Smelt in the Upper Estuary for Various Salinities and the South Delta.

Table 10-1. Historic Juvenile Longfin Smelt Salvage (< 84 mm FL) from State Water Project and Central Valley Project Facilities, and Water Year Type based on the Sacramento Valley Index.

Year	Juvenile Salvage (<84)	Water Year Type	Larval and Juvenile Protection Conditions
1993	17	W	-
1994	350	C	-
1995	4	W	-
1996	6	W	-
1997	40	W	-
1998	12	W	-
1999	26	AN	-
2000	80	AN	-
2001	210	D	-
2002	1233	D	-
2003	158	BN	-
2004	29	D	-
2005	6	W	-
2006	0	W	-
2007	12	C	-
2008	159	C	-
2009	20	BN	-
2010	9	AN	Yes
2011	0	W	No
2012	517	D	Yes
2013	175	C	Yes
2014	10	C	Yes
2015	35	C	Yes
2016	3	D	Yes
2017	0	W	No
2018	1	BN	Yes
2019	2	W	No
2020	261	D	-
2021	250	C	-
2022	898	C	-

The Longfin Smelt Salvage OMR Relationship Analysis, Appendix I, Attachment X, *[Attachment Title]*, provides context for juvenile salvage during the spring (April - May). The analysis uses a recreation of the regression used by Grimaldo et al. (2009) to examine the relationship between the number of juvenile longfin smelt salvaged and Old and Middle River flows (m^3/s).

Overall, predicted salvage varied among water year types (WYT); salvage was the highest for the Wet and Above Normal WYT and lowest for the Critical WYT. Mean salvage under the Proposed Action phases ranged from 3,706 to 1,110.

Grimaldo et al. (2009) found that the Old and Middle River flow explained interannual salvage abundance for longfin smelt. As OMR flows became more negative, the mean number of fish salvaged increased. Net negative flows indicate that the flow is headed towards CVP and SWP facilities and fish are at least partially moving with the reverse flows.

Table 10-2. April–May Predicted Mean Longfin Smelt Salvage by Water Year Type.

WYT	EXP1	EXP3	NAA	Alt2woTUCPwoVA	Alt2woTUCPDeltaVA	Alt2woTUCPAllVA
Wet	28	37	1359	3706	2764	2697
Above Normal	89	117	1335	3757	1829	1779
Below Normal	152	172	1451	2647	1901	1763
Dry	218	247	1464	2091	1578	1403
Critical	304	286	905	1110	1170	1126

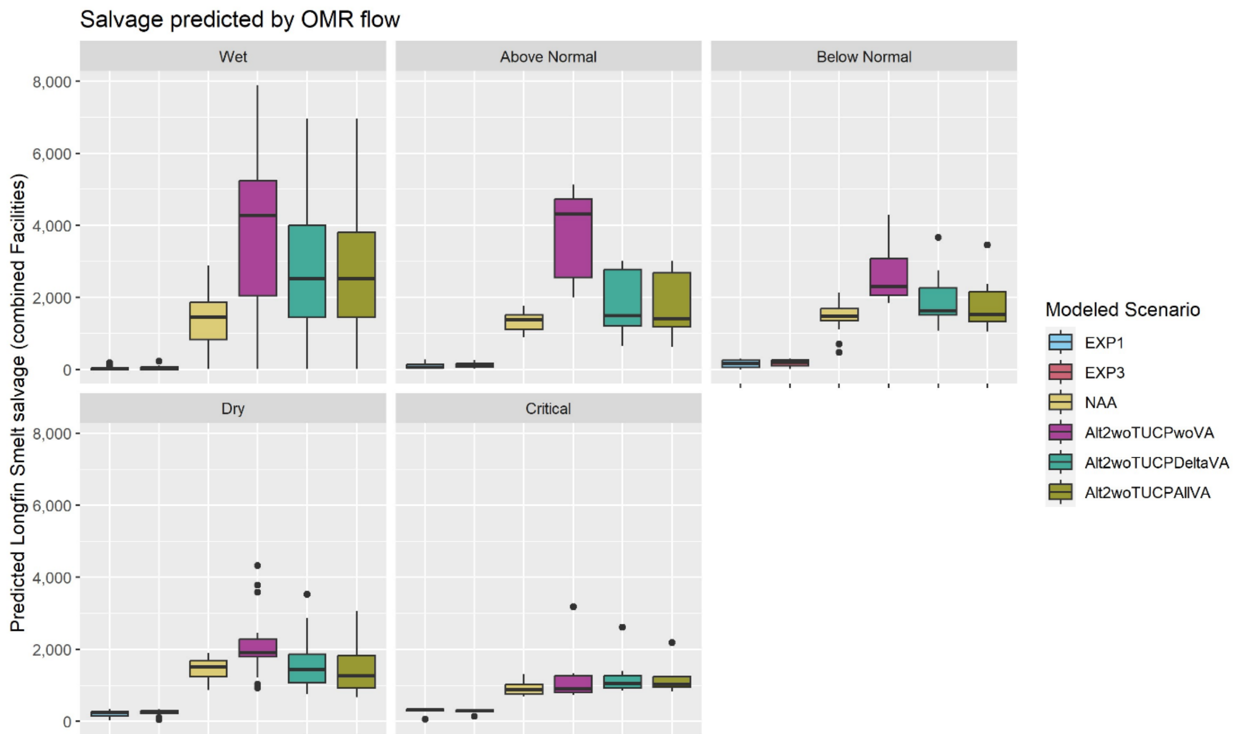


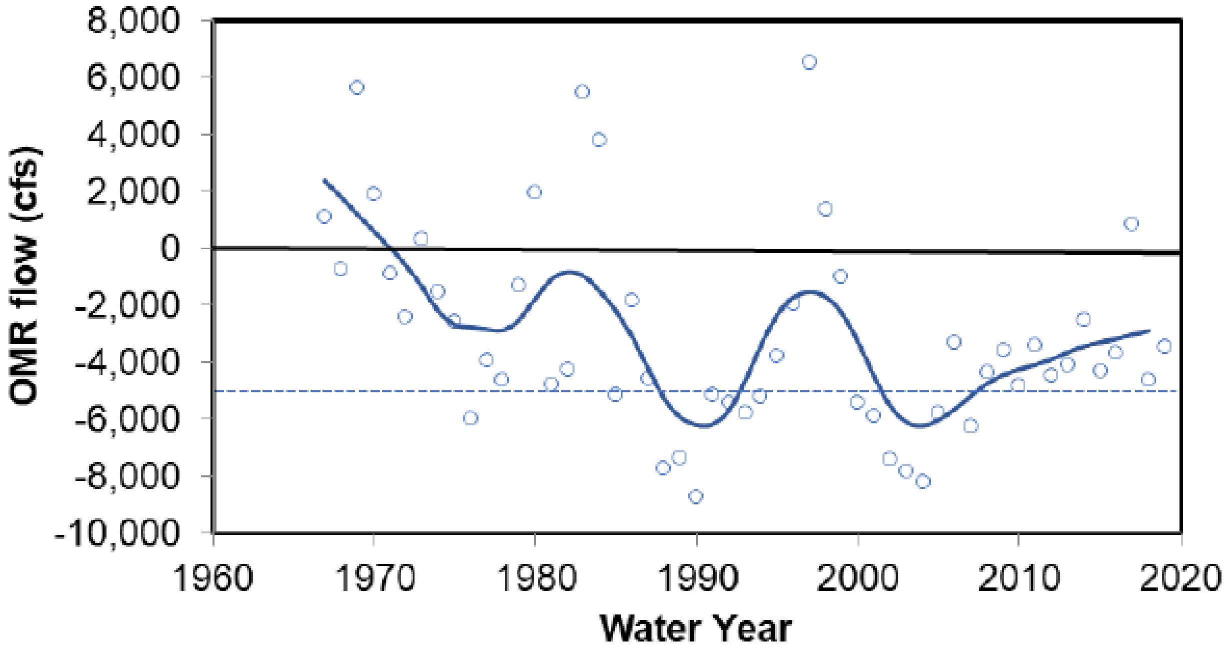
Figure displays data given in Table 10-2.

Figure 10-5. Total Salvage at SWP and CVP Facilities Combined, Predicted from Old and Middle River Flows.

Volumetric influence, flow into junctions, zone of influence (ZOI), and particle tracking modeling results may be applicable for longfin smelt depending on location. Modeling analysis results are presented in Chapter 5, *Winter-Run Chinook Salmon.*

The **frequency** of the stressor is directly linked to hydrology, dependent on Reclamation's actions and is and is likely **medium**.

Net negative OMR flow increases entrainment risk. CDFW (2020) analyzed mean monthly from December to March OMR flows for 1967 through 2019. In 42 out of 52 (~81%) years negative OMR flow was net negative and 16 out of 52 (~31%) years had a negative OMR flow of -5000 cubic feet per second (cfs) or greater (Figure 10-6)



Source: California Department of Fish and Wildlife 2020, Figure 6.
Dashed line at -5,000 cfs for reference. Loess smoother line shown but not used in an analysis.

Figure 10-6. Mean Monthly Winter (Dec-Mar) Old and Middle River (OMR) Flows for 1967 through 2019

While changes to operations are targeted towards reducing entrainment of Delta smelt, they may also benefit longfin smelt (California Department of Fish and Game 2009). Analysis of historical secchi depth and Dayflow data between water year (WY) 2010 and 2019 found in 7 out of 9 years (~78%) larval and juvenile protection conditions (QWEST was negative after March 15th and secchi depth in the south Delta is less than 1m) were met.

The **weight of evidence** for the entrainment stressor includes multiple analyses and modeling using historical monitoring data, which is species and location specific.

- Kimmerer and Gross (2022) used historical survey data (1959–2021) that are quantitative, species specific and location specific. The analysis is published in a peer reviewed journal. The data was used to examine the distribution of longfin smelt at different life stages across different salinity ranges and to develop an estimate of larval longfin smelt loss due to entrainment. The authors noted loss of larval longfin smelt to diversions was highly variable with large error bars, and that surveys do not fully cover the range of larval longfin smelt.
- Volumetric influence modeling is quantitative, not species-specific, and not location specific. This analysis is not published and is a simplified representation of the Bay-Delta (proportion of Sacramento inflow exported).

- Particle tracking modeling (PTM) is quantitative, not species-specific, and location-specific. The methodology has been used in multiple peer-reviewed publications (see Kimmerer and Nobriga 2008 above), PTM is a widely accepted method to estimate particle movement and can be evaluated with covariates.
- Zone of influence modeling is quantitative, not species-specific (but not expected to be, environmental variable), and not location specific. This analysis is not published but is a widely accepted method for evaluating spatial extent of varying levels of exports within the Bay-Delta.
- Juvenile and larval protection conditions used historical data water quality data that are quantitative, not species specific and is location specific. The analysis is not published. The data was used to evaluate when first flush conditions would have occurred historically.

Conservation measures in the Proposed Action that minimize or compensate for effects of the operation of the CVP and SWP on this stressor include:

- January 1 and Start of OMR Management
- Larval and Juvenile Longfin Smelt Protection Action
- Minimum Instream Flows
- Spring Delta Outflow

Conservation measures in the Proposed Action for other species, life stages and/or stressors that may exacerbate this stressor include:

- Fall and Winter Base Flows for Shasta Reservoir Refill
- Reduced Wilkins Slough Minimum Flows
- Drought Actions

10.2.1.2 Freshwater Flow

The proposed diversion of water may increase the freshwater flow stressor. During the juvenile rearing and migration period, the Proposed Action will store and divert water from the Delta, decrease flows and change the size and position of the LSZ.

The size of the LSZ is largest when X2 is below 50 kilometers (km) in San Pablo Bay and second largest between 60 and 75 km, when the LSZ is in Suisun Bay (Kimmerer et al. 2013). The size of the LSZ is smallest when X2 is located near the Carquinez Strait (X2 ~ 50-60 km) and in at the confluence of the Sacramento and San Joaquin rivers (X2 ~ 80-85 km).

Young of the year longfin smelt tend to aggregate in the LSZ (Dege and Brown 2004), though they generally move into more marine waters during the summer months (Rosenfield and Baxter 2007). In the summer, there is low proportion of juvenile longfin smelt population in the freshwater portion of the estuary (Merz et al. 2013), as reflected by the limited detection of longfin smelt in fish surveys during these warmer months (Tobias and Baxter 2021). Longfin smelt may benefit when the LSZ coincides with the increased shallow water and marsh habitats in Suisun Bay, by allowing early-stage longfin smelt to maintain horizontal position and access food resources in higher quality habitat (Hobbs et al. 2006; Grimaldo et al. 2017). Increased freshwater flow also increases turbidity which can benefit longfin smelt by making them less visible to predators (Ferrari et al. 2014) and improve foraging efficiency (Hasenbein et al. 2013). Longfin smelt abundance is positively correlated with freshwater flow and the average position of X2 (Jassby et al. 1995; Kimmerer 2002; Kimmerer et al. 2009; Thomson et al. 2010; U.S. Fish and Wildlife Service 2022). The mechanism behind X2/freshwater flow and longfin smelt abundance may not only be related to salinity but could also be related to more dynamic aspects such as retention by estuarine circulation or transport to rearing areas (Kimmerer et al. 2013). Appendix J and Appendix K present analysis.

An increase to the freshwater flow stressor would cause the size and location of the LSZ to decrease and be further landward, decrease turbidity, and alter hydrodynamic processes that may benefit longfin smelt which is expected to be **sublethal to lethal**. Reduction of LSZ results in less suitable habitat for longfin smelt. Suitable rearing habitat would be further landward and subject to increased entrainment risk. Decreased flows may also decrease turbidity which may increase predation risk and decrease feeding efficacy. Additionally, with decreased flows, retention and transport processes may be disrupted, resulting in lower survival of larval fish.

Although the Proposed Action may increase the freshwater flow stressor, the freshwater flow stressor for juvenile longfin smelt exists in the **environmental baseline** (without the Proposed Action). Non-project exports can affect flow and the size and position of the LSZ (Hutton et al. 2017).

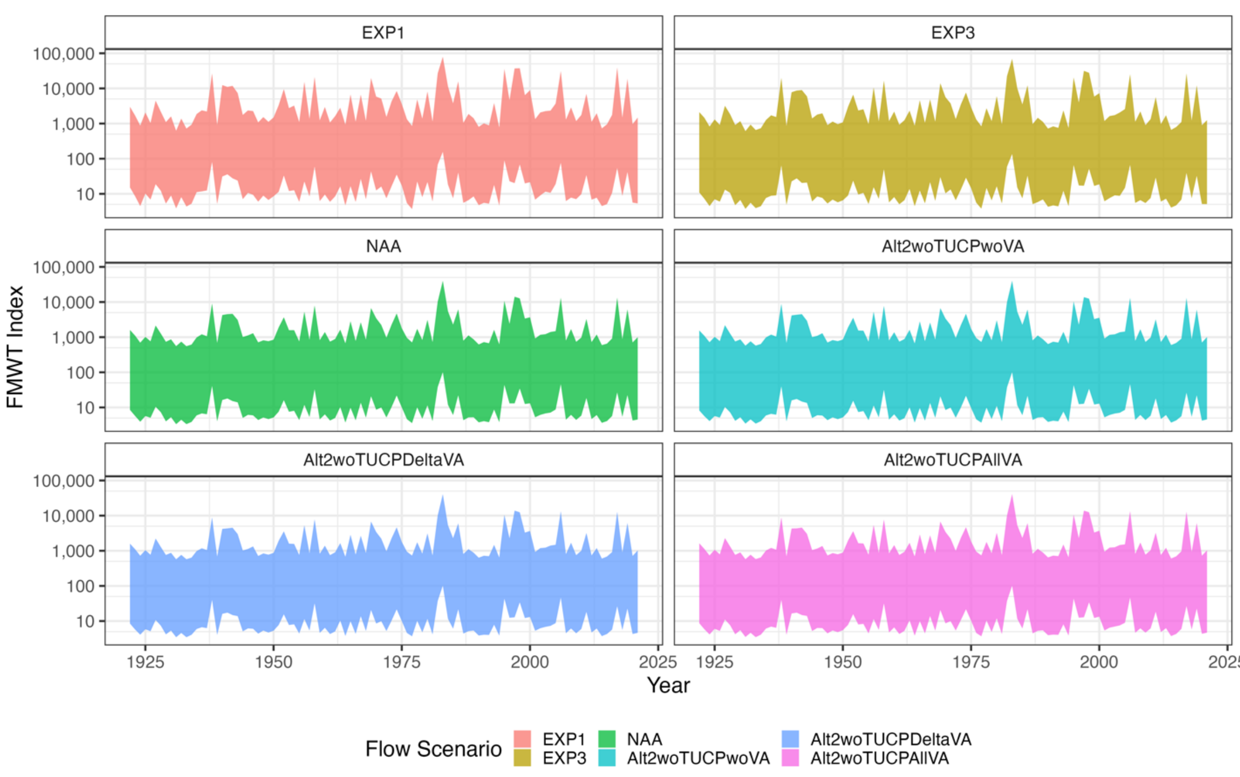
In the Delta, Reclamation's past operation of the Delta Cross Channel Gates and Reclamation and DWR's past operation of export facilities influenced the flow of water in the Delta. Reclamation and DWR have operated the CVP and SWP to reduce the risk of entrainment under Biological Opinions issued by the USFWS and NMFS in 2004/2005, 2008/2009, and 2019. SWP facilities have also operated under a 2020 ITP issued by the CDFW. Under those Biological Opinions, Reclamation and DWR have: (1) closed the Delta Cross Channel Gates; (2) controlled the net negative flows toward the export pumps in Old and Middle rivers to reduce the likelihood that fish would be diverted from the San Joaquin or Sacramento River into the southern or central Delta; and (3) improved fish screening and salvage operations to reduce mortality from entrainment and salvage. SWP facilities in the Delta have also operated consistent with an incidental take permit that addresses longfin smelt issued under CESA by CDFW on March 31, 2020.

The current Proposed Action involves several actions intended to minimize the freshwater flow stressor of juvenile longfin smelt. These actions included decreased exports from OMR during specific time frames, in response to abiotic conditions.

The **proportion** of the population affected by the Proposed Action is likely **low**. Reclamation considered literature and model data on freshwater flow to estimate the proportion of the population affected by an increase in the freshwater flow stressor.

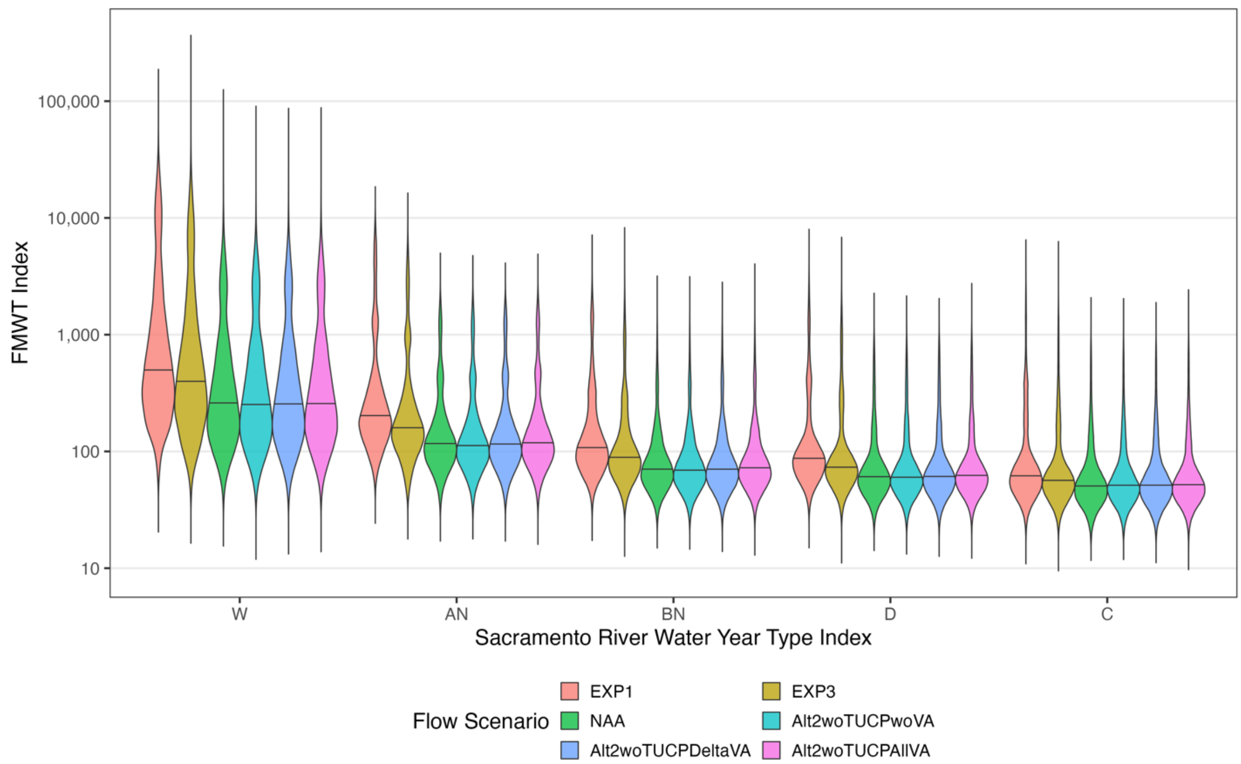
Analysis of catch per trawl data from various environmental monitoring surveys in the upper estuary by Kimmerer and Gross (2022) found mean juvenile catch was the highest LSZ when using the 20mm survey data (Figure 10-4).

The potential effect of operations on longfin smelt abundance is described in Appendix J, Attachment X, *[Attachment Title]*. A statistical modeling approach was developed relating the longfin smelt FMWT abundance index to: (1) Delta outflow; (2) the FMWT abundance index two years earlier (as a representation of parental stock size), and; (3) ecological regime (i.e., 1967–1987, pre-*Potamocorbula amurensis* invasion; 1988–2002, post-*P. amurensis* invasion; and 2003–2022, Pelagic Organism Decline). The mean annual FMWT index ranged from a high of approximately 716 to a low of approximately 78 across Proposed Action phases and water year types. Mean annual index values were highest for the wet water year type, across all Proposed Action phases, ranging from approximately 701-716. Mean annual index values decreased across water year types, going from wet to critical. For each water year type, the index values were similar across Proposed Action phases, with the Proposed Action Without TUCP Systemwide VA consistently highest ranging from ~ 79-716. The ranges across the Proposed Action phases within each water year type decreased from the wet water year type (range: ~16) to the critical water year type (range: ~ 1).



The 95th Bayesian credible intervals for the posterior predictive distributions are shown, based on the parental stock model and the 100 year time series of CalSim 3 Delta Outflow values for each scenario.

Figure 10-7. Longfin Smelt Index by Alternative Scenario.



Posterior predictive distributions for the FMWT index of Longfin Smelt abundance are shown aggregated by water year type for each scenario. The horizontal line in the distribution for each scenario represents the median predicted value.

Figure 10-8. Longfin Smelt Index by Water Year Type.

The **frequency** when habitat impacts species is **likely medium** to **large** and dependent position of X2 during the summer and fall seasons. In the summer 13 out of 26 years (50%), the median position of X2 was greater than 80 km. In the fall, 22 out of 27 years (~81%), the median position of X2 was greater than 80 km.

Source: California Data Exchange Center.

Figure 10-9. Boxplots of X2 Position (km) by Year and Season, 1996–2022.

The **weight of evidence** for the entrainment stressor includes modeling and historical monitoring data, which is species and location specific.

- Kimmerer and Gross (2022) used historical survey data (1959 - 2021) that are quantitative, species specific and location specific. The analysis is published in a peer reviewed journal. The data was used to examine the distribution of longfin smelt at different life stages across different salinity ranges and to develop an estimate of larval longfin smelt loss due to entrainment. The authors noted loss of larval longfin smelt to diversions was highly variable with large error bars, and that surveys do not fully cover the range of larval longfin smelt.
- The longfin smelt outflow model analysis used historical survey data (1967 – 2022) that are quantitative and species specific. The model is a statistical analysis that takes a Bayesian approach to examine log-linear regression models relating outflow, parental stock size, and ecological regimes to the FMWT abundance index.

Conservation measures in the Proposed Action that minimize or compensate for effects of the operation of the CVP and SWP on this stressor include:

- Minimum Instream Flow
- Winter and Spring Delta Outflow

Conservation measures in the Proposed Action for other species, life stages and/or stressors that may exacerbate this stressor include:

- Fall and Winter Base Flows for Shasta Reservoir Refill
- Reduced Wilkins Slough Minimum Flows
- Drought Actions

10.2.1.3 Food Availability

The food availability stressor may increase. During the juvenile rearing and migration period the storage and diversion of water will reduce Delta inflows and outflows. Abundances of historically important longfin smelt zooplankton prey taxa in the LSZ, including *Eurytemora affinis* and *Neomysis mercedis*, generally exhibit a positive correlation with Delta outflow (Kimmerer 2002). Larval longfin smelt (< 18 mm) prey primarily on calanoid copepods such as *Eurytemora affinis* and transition to feeding on larger mysids as they grow (> 25 mm) (Barros et al. 2022). Lojkovic-Burris et al. (2022) found longfin smelt fed on calanoid copepod prey when mysids were not readily available. Appendix J analyzes the effect of Spring Delta Outflow on food resources for native fishes. Appendix P, *Delta Habitat*, analyzes zooplankton abundance near different types of habitats.

The increase in food availability and quality stressor is **sublethal** to **lethal**. Higher food abundances in theory result in faster growth rates (Beck et al. 2003), leading to healthier and larger fish which presumably are less vulnerable to predation. Food limitation can also weaken longfin smelt, leading to such extremes as starvation, and alter behavior resulting in increased predation risk (Vehanen 2003; Borcherding and Magnhagen 2008). Food limitation can interact negatively with other stressors such as high water temperatures and contaminants (Bennett et al. 1995; Le et al. 2020; Lopes et al. 2022) resulting in higher mortality.

Although the Proposed Action may increase the food availability stressor, changes in food availability for juvenile longfin smelt rearing and migration exist in the **environmental baseline** (without the Proposed Action). The SSA summarizes the major modifications to the physical, biological, and hydrological alterations that have occurred to the Bay-Delta from its historic conditions. Those alterations were driven by “five human activities that have changed ecological functions and habitats in many riverine and estuarine systems with increasingly dense human populations: diking, draining, dredging, diverting, and discharging.” That has resulted in “an 80-fold decrease in the ratio of wetland to open water area in the Delta . . . [and] a substantial reconfiguration of the bays, sloughs, and channels, while large-scale water diversions, and discharge of contaminants have altered water quantity and quality. In addition, a wide variety of non-native plants and animals have been introduced and have become established in the [Delta] (Cohen and Carlton 1998; Light et al. 2005; Winder et al. 2011).” This has contributed to a decline in longfin smelt food sources including mysids and calanoid copepods. *Eurytemora affinis* and other zooplankton have experienced long term declines since the introduction of the overbite clam (Winder and Jassby 2011; Kimmerer 2002b), experienced seasonal shifts in peak abundance (Merz et al. 2016) and have been replaced by non-native species (Winder and Jassby 2011).

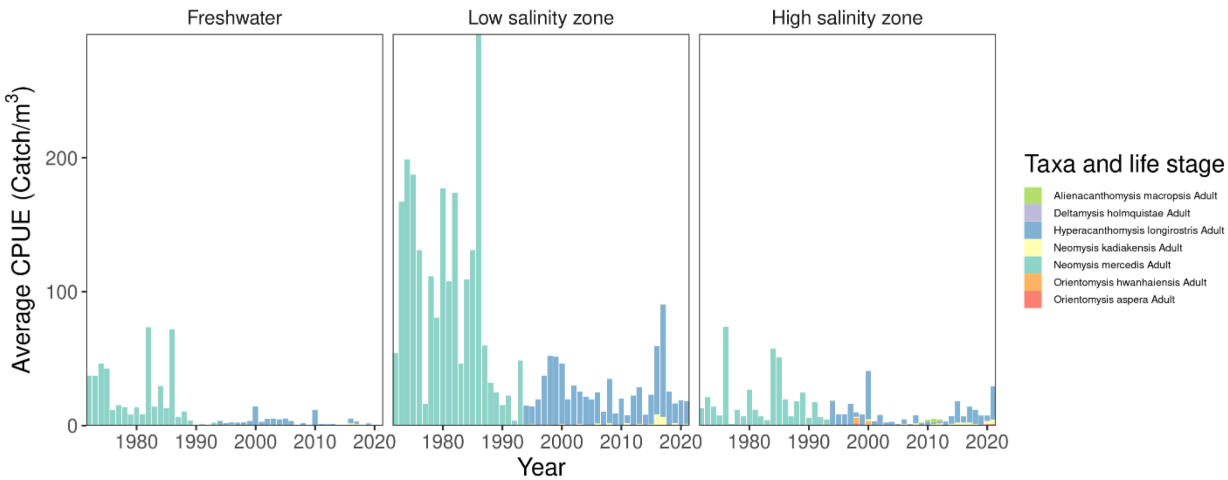
Operations at upstream CVP dams, SWP dams, and other dams, export operations at the CVP and SWP export facilities, and diversions by various water users have contributed to Delta inflows and outflows. CVP and SWP export facilities have operated under Biological Opinions issued by the USFWS and NMFS in 2004/2005, 2008/2009, and 2019. SWP facilities in the Delta have also operated consistent with an incidental take permit that addresses longfin smelt issued under CESA by CDFW on March 31, 2020.

Tidal restoration projects in the Delta may reduce the food availability stressor. Reclamation and DWR have completed consultation on Tidal Habitat Restoration projects in the Delta. The primary purpose of those projects is to protect, restore and enhance intertidal and associated subtidal habitat to benefit listed fishes, including longfin smelt, through increased food web production. To date, DWR has completed approximately 2,000 of 8,000 acres of tidal restoration in the Delta. In Chapter 2, *Environmental Baseline*, and Appendix E, *Exploratory Modeling*, Reclamation

The **proportion** of the population affected by the operation of the CVP is **medium**. Reclamation considered literature and environmental monitoring data on food availability to estimate the proportion of the population affected by an increase in the food availability stressor.

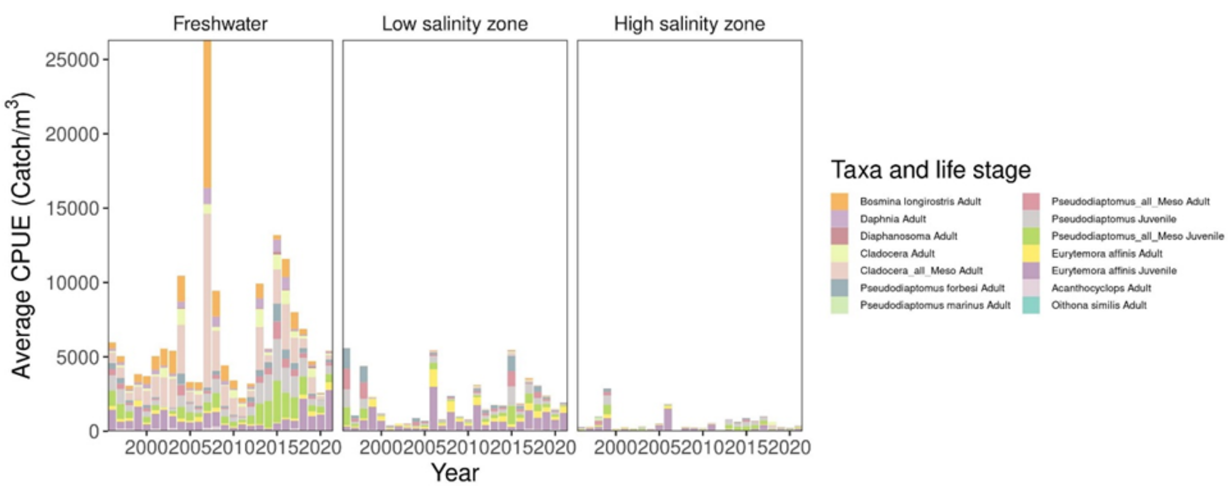
Analysis of catch per trawl data from various environmental monitoring surveys in the upper estuary by Kimmerer and Gross (2022) found mean juvenile catch was the highest LSZ when using the 20mm survey data (Figure 10-4).

Mysid (the primary food item for juvenile longfin smelt) density is highest in the LSZ. Juvenile longfin smelt also consume mesozooplankton such as *Eurtyemora affinis* but less frequently (Barros et al. 2022) or when mysids were not regionally available (Lojkovic-Burris et al. 2022). The density of mesozooplankton is lower in the LSZ than in freshwater.



Source: Zooplankton data synthesizer: Version 2.4.19000.

Figure 10-10. Average Mysid Density from Spring to Summer for Freshwater, Low Salinity Zone and High Salinity Zone.



Source: California Department of Water Resources Environmental Monitoring Program surveys. Selected prey species were from prey categories in Barros et al. (2022) and Lojkovic-Burris et al. (2022).

Figure 10-11. Average CPUE of Selected Longfin Smelt Mesozooplankton Prey from March to May, 1996–2021.

Models provide quantitative estimates of future conditions under the Proposed Action. Reclamation evaluated multiple lines of evidence, with different assumptions and complexity, to narrow the likely range of potential effects. A regression analysis supports the evaluation of this stressor.

The Zooplankton-Delta Outflow Analysis, Appendix J, Attachment X, *[Attachment Title]*, provides context for zooplankton density available for longfin smelt juveniles in the LSZ during the spring (March- May). The analysis is a regression of the relationship between historical zooplankton abundance (catch per unit effort, or CPUE) and Delta outflow (cfs), Figure 10-12. During spring months, cladocerans (except *Daphnia*), *Eurytemora affinis* (copepod) adults, harpacticoid copepods, other calanoid copepod adults (*Acartia* spp., unidentified calanoids, *Sinocalanus doerrii*, *Tortanus* spp., and Diaptomidae), and other calanoid copepod copepodites (*Acartia* spp., *Acartiella* spp., unidentified calanoids, *Eurytemora affinis*, *Sinocalanus doerrii*, *Tortanus* spp., and Diaptomidae) had a statistically significant positive relationship with Delta outflow. All the above taxa/groupings have been found in juvenile longfin smelt gut content studies (Barros et al. 2022; Lojkovic-Burris et al. 2022).

The CPUE under the Proposed Action phases varied among water year types; the wet WYT had the highest CPUE for each taxa/grouping, and the critical WYT had the lowest CPUE for each taxa/grouping.

The mechanism for why CPUE increases in the low salinity zone during higher outflow has not been clearly and definitively established. Kimmerer (2002) found lower trophic level taxa (zooplankton) responded inconsistently with flow across seasons and historical periods. Kimmerer also found that chlorophyll showed little response to flow, suggesting a bottom up, “agricultural model” explanation for increased CPUE with higher flows is unlikely. Another possible mechanism is that increased flows also increase subsidies of zooplankton from higher abundance freshwater regions into the LSZ (Hassrick et al. 2023; Kimmerer et al. 2019).

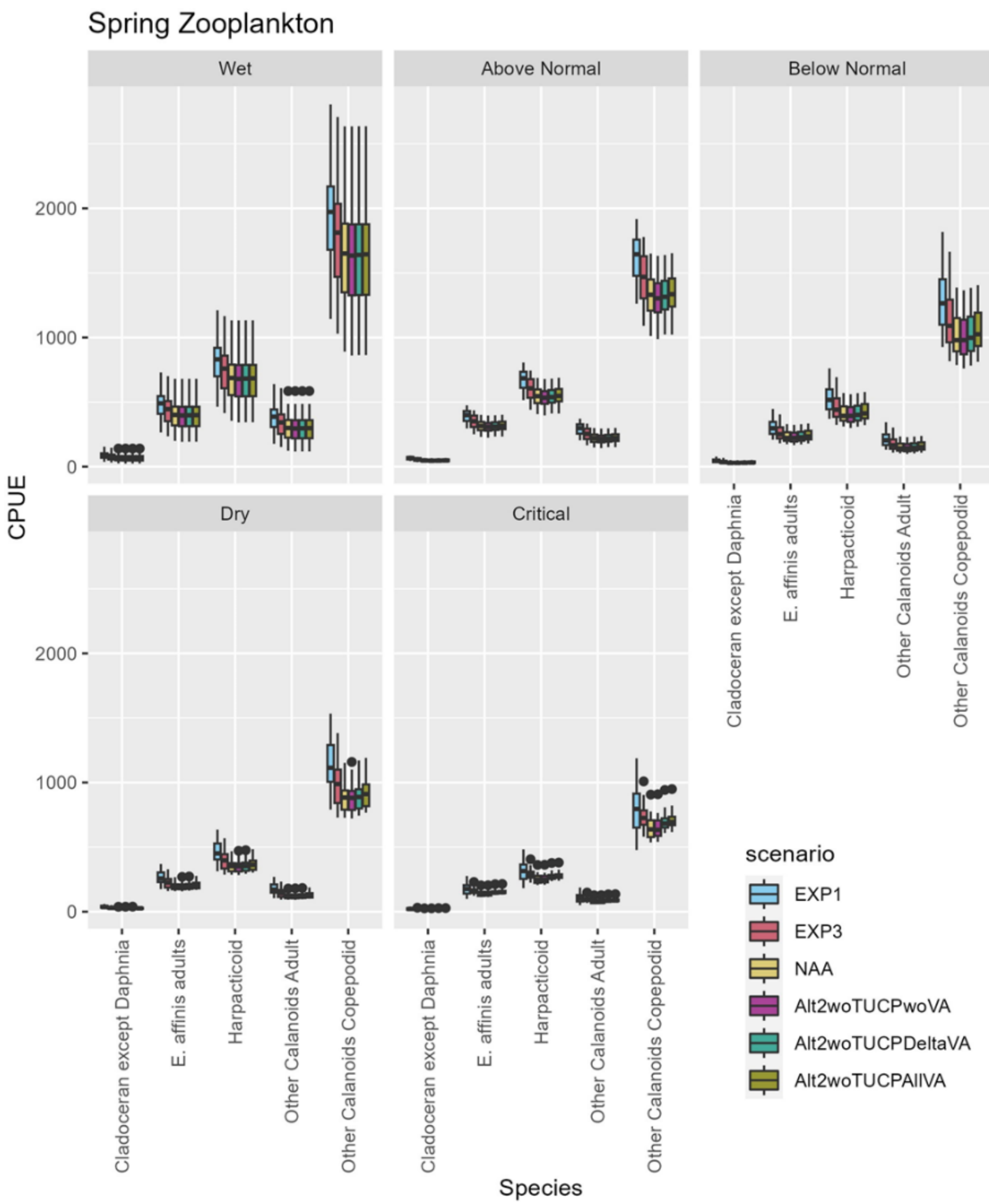
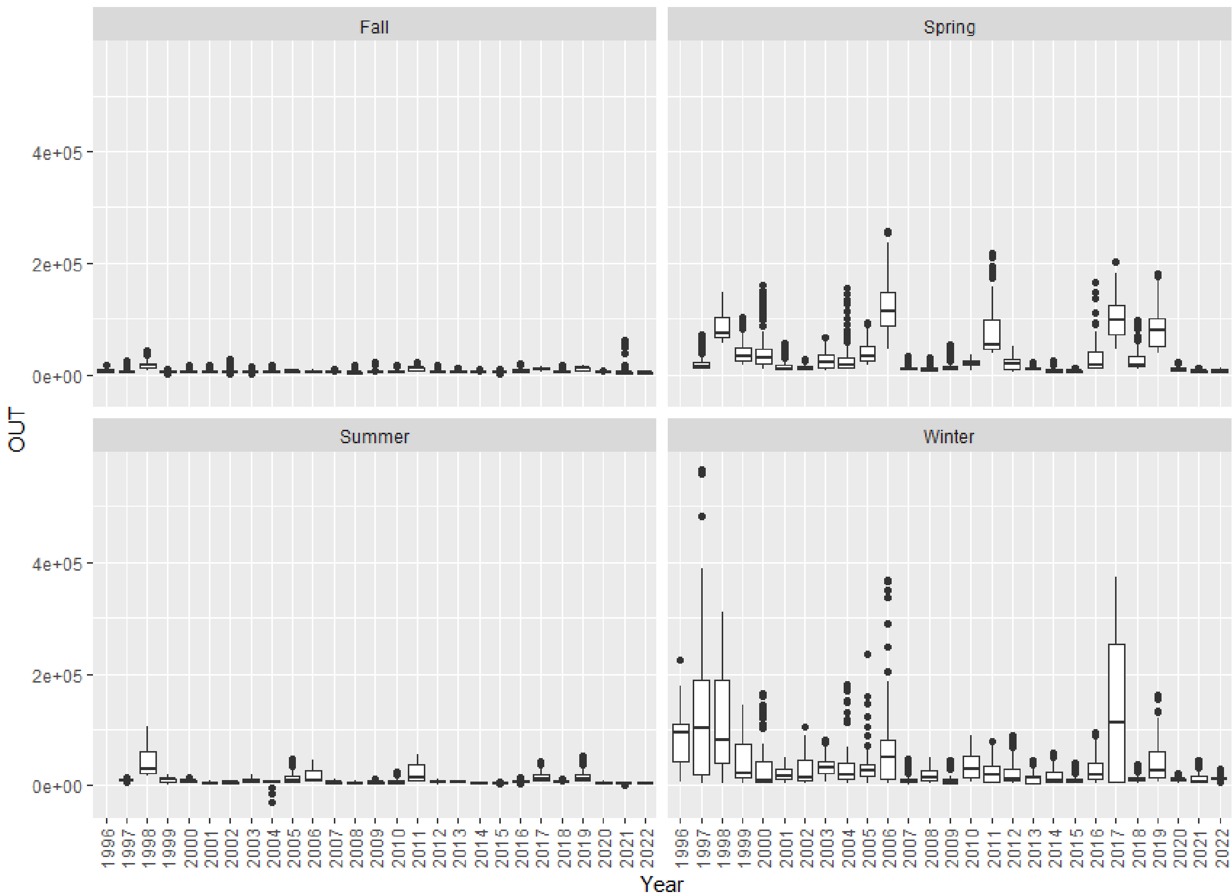


Figure 10-12. Boxplots of Significant Zooplankton Species CPUE by Scenario across Different Water Year Types for Spring.

The **frequency** of occurrence is annual, depends on the hydrology, and is **likely high**. In 21 out of 27 (~81%) years, spring outflow was low and in 21 out of 26 (~81%) years, summer outflow was low.



Source: California Data Exchange Center).

Figure 10-13. Boxplots for Outflow (cfs) at Chipps Island, 1996–2022.

The **weight of evidence** for the food limitation stressors includes data from monitoring surveys and studies in the Bay-Delta.

- Kimmerer and Gross (2022) used historical survey data (1959 - 2021) that are quantitative, species specific and location specific. The analysis is published in a peer reviewed journal. The data was used to examine the distribution of longfin smelt at different life stages across different salinity ranges and to develop an estimate of larval longfin smelt loss due to entrainment. The authors noted loss of larval longfin smelt to diversions was highly variable with large error bars, and that surveys do not fully cover the range of larval longfin smelt.

- The Zooplankton Flow Analysis Model is quantitative and location specific but not species specific. The model is a statistical analysis that incorporates historical biological data from long-term monitoring surveys for the low salinity zone. CPUE for multiple taxa groups was regressed against Delta outflow for each season. Statistically significant relationships were then applied to modelled conditions and operation scenarios.

Conservation measures in the Proposed Action that minimize or compensate for effects of the operation of the CVP and SWP on this stressor include:

- Minimum Instream Flow
- Spring Delta Outflow

Conservation measures in the Proposed Action for other species, life stages and/or stressors that may exacerbate this stressor include:

- Fall and Winter Base Flows for Shasta Reservoir Refill
- Reduced Wilkins Slough Minimum Flows
- Drought Actions

10.2.2 Adult Holding and Spawning

Longfin smelt are anadromous and semelparous, spend their adult life in bays, estuaries, and nearshore coastal areas, and migrating to the LSZ and freshwater tributaries to spawn between mid-fall to late spring, with peak spawning occurring from winter through spring, after which most adults die. During the summer, a small portion the population may be present in westward portions of Sacramento-San Joaquin Delta (Lewis et al. 2020; Rosenfield 2010).

Stressors that may change at a level that is insignificant or discountable include:

- The Proposed Action may increase the *water temperature* stressor. CVP and SWP storage and diversion decreases Delta inflow. Delta water temperature is positively correlated with Delta inflow in the winter and negatively correlated with Delta inflow in the spring (Bashevkin and Mahardja 2022) and reservoir operations may influence water temperature to a minimal extent in the lower reaches of the Sacramento River (Daniels and Danner 2020).

  The range of potential reservoir operations is unlikely to have a measurable effect on Delta water temperatures as Bay-Delta water temperature is mainly driven by timing of snowmelt (Knowles and Cayan 2002), air temperature and meteorology (Vroom et al. 2017, Daniels and Danner 2020). While there is uncertainty about whether the decreased inflow due to American River operations is a cause for changes in Delta water temperatures, historical water temperatures do not exceed 57.2°F at Prisoner's Point (adult spawning temperature, Wang et al. 1986) in the winter and does exceed 57.2°F in some years in the spring. The volume of water required to provide sufficient thermal mass to deviate from ambient air temperatures is substantially larger than releases outside of flood operations.

- The Proposed Action may increase the *toxicity* stressor. During the adult life stage, toxins may be mobilized through flooding of agricultural and urban areas; however, the seasonal operation of the CVP does not increase the flooding frequency. In the Delta, the potential for dilution of contaminants depends on sampling location (Stillway et al. 2021). Most contaminants are likely local and have little response to CVP and SWP flows (Werner et al. 2010), though some contaminants have a relatively long half-life (e.g., bifenthrin at 25-65 months) (Gan et al. 2005) and legacy contaminants such as mercury remain an issue. Overall, CVP and SWP operations are not a proximate cause of contaminants mobilized from the watershed, agricultural lands, and urban effluent (Guo et al. 2010).
- The Proposed Action may increase the *predation* stressor. During the adult migration and spawning period, the Proposed Action will store and divert water and reduce Delta inflows and outflow. Certain locations in the Delta (e.g., Clifton Court Forebay, the scour hole at Head of Old River, Delta fish collection facilities, the Delta Cross Channel gates) are considered predator hotspots and during operations of those that are CVP/SWP facilities, longfin smelt will be exposed to predation. Studies have been conducted as far back as the 1980s on the abundance of predatory fish inhabiting Clifton Court Forebay (Kano 1990; Gingras and McGee 1997) and more recent studies have predicted high predation hazard for scour holes like the Head of Old River site (Michel et al. 2020). Predation is widespread and exacerbated by disruption of habitat from land use and invasive aquatic vegetation, climate change, and altered predator dynamics from well-established invasive piscivorous non-native fish such as striped bass, largemouth bass and Mississippi silversides. Predation rates are a function of correlated variables such as predator presence, prey vulnerability, and environmental conditions (Grossman et al. 2013; Grossman 2016). Reduced turbidity from the Proposed Action can also increase predation risk (Ferrari et al. 2013, Schreier et al. 2016). Higher temperatures increase metabolic demands of fish which may cause longfin smelt to increase time spent foraging and exposure to predators. Effects of the Proposed Action on water temperature and food visibility that may interact with the predation stressor were analyzed in those sections. Indirect effects of predation are described further in Appendix J, Appendix K, and Appendix I. Any residual effects of predation associated with the Proposed Action is considered insignificant.

Described below are stressors exacerbated by the Proposed Action, potentially resulting in incidental take. Also described below are conservation measures included as part of the Proposed Action to avoid or compensate for adverse effects. Finally, the Proposed Action may also ameliorate certain stressors prevalent in the environmental baseline, and a description of these beneficial effects is provided below.

10.2.2.1 Entrainment

The proposed diversion of water may increase the entrainment risk stressor. During the adult migration and spawning period, the Proposed Action will export water from the Delta and lead to the storage and diversion of water, which will reduce Delta inflows and outflows. OMR flows towards the central and south Delta will also increase. Entrainment is discussed in two ways: (1) fish encountering CVP facilities where they may be pulled into diversions or the export facilities when adults move into freshwater regions for spawning; and (2) fish routed through specific migratory pathways in the Delta where they may experience decreased survival. Entrainment of adult longfin smelt was highest in winter (Grimaldo et al. 2009), when adults move to freshwater regions to spawn. It is predicted that the position of the LSZ within the estuary would relatively predict the extent of adult longfin smelt spawning and, therefore, risk of entrainment (U.S. Fish and Wildlife Service 2022). Entrainment of adult longfin smelt is largely explained by OMR flows at the interannual scale (Grimaldo et al. 2009). Entrainment at the export facilities may result in direct mortality (Kimmerer 2008) and can lead to consistently high rates of pre-screen losses of fish in Clifton Court Forebay (CCF) due to predation (Castillo et al. 2012). MacWilliams and Gross (2013) demonstrated wind velocity and export rates affected residence time in the forebay and therefore exposure to predation. When fish are entrained into the south Delta, they are exposed to greater predation risk since the invasive aquatic macrophyte, *Egeria densa*, dominates the littoral zone in the south Delta (Durand et al. 2016) and provides habitat for the invasive largemouth bass (Brown and Michniuk 2007) which prey on other fish species. Multiple topic-specific appendices address aspects of adult migration through the Delta.

- Appendix G includes sections for Tracy Fish Collection Facility and Skinner Fish Delta Fish Protective Facility
- Appendix I presents analysis of Old and Middle River Management and Delta Cross Channel Closures conservation measures

The Proposed Action involves several actions intended to reduce the entrainment of adult longfin smelt. These actions included decreased exports from OMR during specific time frames, in response to abiotic conditions and in direct response to the salvage of longfin smelt.

The increase in entrainment stressor is expected to be **lethal**. Entrainment can result in direct mortality by removal through the Delta fish collection facilities or indirect mortality by routing fish into areas of poor survival.

Although the Proposed Action may increase the entrainment risk stressor, entrainment of adult longfin smelt exists in the **environmental baseline** (without the Proposed Action). The SSA summarizes the major modifications to the physical, biological, and hydrological alterations that have occurred to the Bay-Delta from its historic conditions. In addition, tidal conditions can facilitate downstream transport or entrainment depending on the flood and ebb of tides during the fortnightly spring-neap cycle (Arthur et al. 1996). Entrainment of longfin smelt also is influenced by non-CVP and non-SWP diversions in the Delta. Most of the 370 water diversions operating in Suisun Marsh are unscreened (Herren and Kawasaki 2001).

In the Delta, Reclamation's past operation of the Delta Cross Channel Gates and Reclamation and DWR's past operation of export facilities influenced the flow of water in the Delta. Reclamation and DWR have operated the CVP and SWP to reduce the risk of entrainment under Biological Opinions issued by the USFWS and NMFS in 2004/2005, 2008/2009, and 2019. Under those Biological Opinions, Reclamation and DWR have: (1) closed the Delta Cross Channel Gates; (2) controlled the net negative flows toward the export pumps in Old and Middle rivers to reduce the likelihood that fish would be diverted from the San Joaquin or Sacramento River into the southern or central Delta; and (3) improved fish screening and salvage operations to reduce mortality from entrainment and salvage. SWP facilities in the Delta have also operated consistent with an incidental take permit that addresses longfin smelt issued under the California Endangered Species Act by CDFW on March 31, 2020.

The **proportion** of the population affected by the Proposed Action varies annually and depends on hydrology, and export rates. Reclamation considered historic salvage and literature on entrainment to estimate the proportion of the population affected by an increase in the entrainment risk stressor.

When adult longfin smelt are present in the south Delta, they are at greater risk of being entrained. Analysis of catch per trawl data from various environmental monitoring surveys in the upper estuary by Kimmerer and Gross (2022) found no adult catch in the south Delta using SKT data (Figure 10-4).

However, historical salvage records indicate adult longfin smelt are entrained in SWP and CWP facilities. Table 10-3 below shows that very few adult longfin smelt are entrained. Based on historical catch and salvage data records the proportion of the population affected is **low**.

Table 10-3. Historic Adult Longfin Smelt Salvage (> 84 mm FL) from State Water Project and Central Valley Project Facilities, and Water Year Type based on the Sacramento Valley Index.

Year	Adult Salvage (>84 mm FL)	Water Year Type	First Flush	Turbidity Bridge
1993	0	W	-	-
1994	1	C	-	-
1995	3	W	-	-
1996	0	W	-	-
1997	0	W	-	-
1998	1	W	-	-
1999	0	AN	-	-
2000	3	AN	-	-
2001	3	D	-	-
2002	5	D	-	-
2003	5	BN	-	-
2004	5	D	-	-

Year	Adult Salvage (>84 mm FL)	Water Year Type	First Flush	Turbidity Bridge
2005	1	W	-	-
2006	1	W	-	-
2007	1	C	-	-
2008	10	C	-	-
2009	0	BN	-	-
2010	0	AN	-	-
2011	1	W	No	-
2012	0	D	Yes	3
2013	2	C	No	3
2014	0	C	Yes	0
2015	0	C	No	2
2016	0	D	No	1
2017	0	W	Yes	3
2018	0	BN	No	0
2019	1	W	Yes	0
2020	0	D	No	1
2021	0	C	No	0
2022	0	C	Yes	1

First Flush indicates if First Flush conditions were exceeded in that year. Turbidity Bridge indicates the number of separate instances of turbidity bridge avoidance under 2020 Record of Decision requirements.

The **frequency** of the stressor is directly linked to changes in hydrology resulting from ongoing export operations and is **likely medium**.

Modeling analysis of adult longfin salvage presented in CDFW (2020) predicted increased adult salvage when X2 was near 65 km and when X2 was beyond 75 km. During periods of high outflow adult longfin smelt are less likely to be entrained because the low salinity zone is further away from the Delta, and more individuals may spawn in areas where freshwater flow creates ideal spawning environments. The increase in salvage when X2 was at 65 km is believed to be due to adult longfin staging in Suisun Bay before migrating into the Delta. In the winter, 9 out of 26 years (~35%), the median position of X2 was greater than 75 km and 3 out of 26 years (~12%) the median position of X2 was around 65 km (Figure 10-9).

The same analysis from CDFW (2020) also predicted salvage to be greater when mean OMR was more negative than -5000 cfs. In 16 out of 52 (~31%) years had a negative OMR flow of -5000 cfs or greater (Figure 10-6)

While changes to operations are targeted towards reducing entrainment of Delta Smelt, they may also benefit longfin smelt (California Department of Fish and Game 2009). Based on requirements for actions being taken for Delta smelt, the frequency of when "First Flush" conditions were exceeded occurred in 5 out of 12 years (~42%) based on analysis of historical water quality and flow data between WY2010 and WY2021. Only one out of 5 years (20%) that adult longfin smelt caught when "First Flush" conditions were exceeded. Analysis of historical turbidity data between WY 2012 and 2023 found turbidity bridge conditions were met in 8 out of 11 years (~73%).

Particle tracking modeling results for salmonids may be applicable for longfin smelt (see Chapter 5) depending on location.

To evaluate the **weight of evidence** for the entrainment stressor, multiple location- and species-specific datasets and studies have been evaluated to infer the proportion of the population that will be affected and the frequency of an increase in the stressor.

- Kimmerer and Gross (2022) used historical survey data (1959 – 2021) that are quantitative, species specific and location specific. The analysis is published in a peer reviewed journal. The data was used to examine the distribution of longfin smelt at different life stages across different salinity ranges and to develop an estimate of larval longfin smelt loss due to entrainment. The authors noted loss of larval longfin smelt to diversions was highly variable with large error bars, and that surveys do not fully cover the range of larval longfin smelt.
- First Flush conditions used historical data water quality data that are quantitative, not species specific and is location specific. The analysis is not published. The data was used to evaluate when first flush conditions would have occurred historically.
- Turbidity bridge conditions used historical data water quality data that are quantitative, not species specific and is location specific. The analysis is not published. The data was used to evaluate when turbidity bridge conditions would have occurred historically.
- Volumetric influence modeling is quantitative, not species-specific, and not location specific. This analysis is not published and is a simplified representation of the Bay-Delta (proportion of Sacramento inflow exported).
- PTM is quantitative, not species-specific, and location specific. The methodology has been used in multiple peer-reviewed publications (see Kimmerer and Nobriga 2008 above), PTM is a widely accepted method to estimate particle movement and can be evaluated with covariates.
- Zone of influence modeling is quantitative, not species-specific (but not expected to be, environmental variable), and not location specific. This analysis is not published but is a widely accepted method for evaluating spatial extent of varying levels of exports within the Bay-Delta.

Conservation measures in the Proposed Action that minimize or compensate for effects of the operation of the CVP and SWP on this stressor include:

- First Flush and Start of OMR Management
- January 1 and Start of OMR Management
- Adult Longfin Smelt Entrainment Protection Action

Conservation measures in the Proposed Action for other species, life stages and/or stressors that may exacerbate this stressor include:

- SHOT Reduction in Sacramento River Fall and Winter Flows
- Reduced Wilkins Slough Minimum Flows
- Drought Actions

10.2.2.2 Freshwater Flow

The proposed diversion of water may increase the freshwater flow stressor. During the adult migration and spawning period, the Proposed Action will store and divert water from the Delta and change the size and position of the LSZ. Higher outflow increases connectivity to cooler, low salinity habitat which supports higher spawning effort and success further seaward of the Delta (Grimaldo et al. 2020) and Bay Area tributaries (Lewis et al. 2019). The Proposed Action may also move the LSZ further landward which would reduce the size of the LSZ and suitable spawning habitat for longfin smelt. This may also lead to increased entrainment of adult longfin smelt, which is discussed in the entrainment stressor. Modeling analyses indicated that freshwater flow had a positive association with the number of recruits per spawner for longfin smelt (Nobriga and Rosenfeld 2016). Appendix J and Appendix K present analysis.

Adult longfin smelt are caught throughout the San Francisco Bay and the Sacramento San Joaquin Delta (Merz et al. 2013) and utilize the LSZ as habitat. The position of the LSZ is commonly measured using the position of X2 which is defined as the distance from the Golden Gate Bridge to where the salinity is 2 isohaline near the bottom of the water column (Jassby et al. 1995). The position of X2 responds to CVP and SWP operations, the more freshwater outflow into the Bay-Delta results in a more seaward X2 position; saltwater is unable to intrude further landward while less outflow results in a more landward X2 position. The size of the LSZ is largest when X2 is below 50 km in San Pablo Bay and second largest between 60 and 75 km, when the LSZ is in Suisun Bay (Kimmerer et al. 2013). The size of the LSZ is smallest when X2 is located near the Carquinez Strait (X2 ~ 50-60 km) and in at the confluence of the Sacramento and San Joaquin Rivers (X2 ~ 80-85 km).

An increase to the freshwater flow stressor would cause the size and location of the LSZ to decrease and be further landward, which is expected to be **sublethal to lethal**. This results in a smaller LSZ, less spawning habitat available for longfin smelt, and any available spawning habitat is further landward increasing the risk of entrainment. If the spawning habitat is constricted in a smaller region, this may increase vulnerability to localized, catastrophic events which can have devastating impacts on an entire spawning class (U.S. Fish and Wildlife Service 2022).

Although the Proposed Action may increase the freshwater flow stressor, the freshwater flow stressor for adult migration and spawning of longfin smelt exists in the **environmental baseline** (without the Proposed Action). Non-project exports can affect flow and the size and position of the LSZ (Hutton et al. 2017).

In the Delta, Reclamation's past operation of the Delta Cross Channel Gates and Reclamation and DWR's past operation of export facilities influenced the flow of water in the Delta. Reclamation and DWR have operated the CVP and SWP to reduce the risk of entrainment under Biological Opinions issued by the USFWS and NMFS in 2004/2005, 2008/2009, and 2019. SWP facilities have also operated under a 2020 ITP issued by the CDFW. Under those Biological Opinions, Reclamation and DWR have: (1) closed the Delta Cross Channel Gates; (2) controlled the net negative flows toward the export pumps in Old and Middle rivers to reduce the likelihood that fish would be diverted from the San Joaquin or Sacramento River into the southern or central Delta; and (3) improved fish screening and salvage operations to reduce mortality from entrainment and salvage. SWP facilities in the Delta have also operated consistent with an incidental take permit that addresses longfin smelt issued under CESA by CDFW on March 31, 2020.

The current Proposed Action involves several actions intended to minimize the freshwater flow stressor of adult longfin smelt. These actions included decreased exports from OMR during specific time frames, in response to abiotic conditions and in direct response to the salvage of longfin smelt.

The **proportion** of the population affected by the operation of the CVP is **likely medium**. Reclamation considered historic monitoring data and literature on freshwater flow to estimate the proportion of the population affected by an increase in the freshwater flow stressor.

Analysis of catch per trawl data from various environmental monitoring surveys in the upper estuary by Kimmerer and Gross (2022) found adult catch was highest in the low salinity zone using SKT data (Figure 10-4).

Historic data and modeling does not uniquely inform the proportion of the population.

The **frequency** of occurrence is annual, depends on the hydrology, and is **likely low**. In the spring, 2 out of 26 (~8%) years, the median position of X2 is at the confluence of the Sacramento and San Joaquin Rivers (X2 ~ 80-85 km), which results in a smaller LSZ compared to if it were more landward. In the winter, 4 out of 26 years (~15%), the median position of X2 is at the confluence of the Sacramento and San Joaquin Rivers (Figure 10-9).

To evaluate the **weight of evidence** for the freshwater flow stressor, multiple location- and species-specific datasets and studies have been evaluated to infer the proportion of the population that will be affected and the frequency of an increase in the stressor.

- Kimmerer and Gross (2022) used historical survey data (1959 - 2021) that are quantitative, species specific and location specific. The analysis is published in a peer reviewed journal. The data was used to examine the distribution of longfin smelt at different life stages across different salinity ranges and to develop an estimate of larval longfin smelt loss due to entrainment. The authors noted loss of larval longfin smelt to diversions was highly variable with large error bars, and that surveys do not fully cover the range of larval longfin smelt.

Conservation measures in the Proposed Action that minimize or compensate for effects of the operation of the CVP and SWP on this stressor include:

- Minimum Instream Flows
- Winter and Spring Delta Outflow

Conservation measures in the Proposed Action for other species, life stages and/or stressors that may exacerbate this stressor include:

- SHOT Reduction in Sacramento River Fall and Winter Flows
- Reduced Wilkins Slough Minimum Flows
- Drought Actions

10.2.2.3 Food Availability

The food availability stressor may increase. During the adult migration and spawning period, the proposed storage and diversion of water associated with the Proposed Action will reduce Delta inflows and outflows. Adult longfin smelt in the San Francisco Estuary feed primarily on mysids (U.S. Fish and Wildlife Service 2022) like other populations of longfin smelt in other regions (Sibley and Chigbu 1994), though they may rely more on copepod prey when mysids are less abundant (Feyrer et al. 2003). Abundances of historically important longfin smelt zooplankton prey taxa in the LSZ, including *Eurytemora affinis* and *Neomysis mercedis*, generally exhibit a positive correlation with Delta outflow (Kimmerer 2002). *Neomysis mercedis* had a higher abundance as X2 was more seaward but since the invasion of the overbite clam, it now has higher abundances when X2 is more landward (Kimmerer 2002), but its abundance remains drastically reduced post-overbite clam invasion (Winder and Jassby 2011; Avila and Hartman 2020). Appendix J analyzes the effect of Spring Delta Outflow on food resources for native fishes. Appendix K analyzes the effect of summer and fall food actions on zooplankton abundance in the Delta. Appendix P analyzes zooplankton abundance near different types of habitats.

The increase in food availability and quality stressor is **sublethal** to **lethal**. Higher food abundances in theory result in faster growth rates, leading to healthier and larger fish who produce larger clutches of eggs (California Department of Fish and Game 2009a). In other populations of longfin smelt, fecundity was a function of size and feeding success (Dryfoos 1965; Chigbu and Sibley 1994). Food limitation can also weaken longfin smelt, leading to such extremes as starvation, and alter behavior resulting in increased predation risk (Vehanen 2003; Borcherding and Magnhagen 2008).

Although the Proposed Action may increase the food availability stressor, changes in food availability for adult longfin smelt migration and spawning exists in the **environmental baseline** (without the Proposed Action). The SSA summarizes the major modifications to the physical, biological, and hydrological alterations that have occurred to the Bay-Delta from its historic conditions. Those alterations were driven by "five human activities that have changed ecological functions and habitats in many riverine and estuarine systems with increasingly dense human populations: diking, draining, dredging, diverting, and discharging." That has resulted in "an 80-fold decrease in the ratio of wetland to open water area in the Delta . . . [and] a substantial reconfiguration of the bays, sloughs, and channels, while large-scale water diversions, and discharge of contaminants have altered water quantity and quality. In addition, a wide variety of non-native plants and animals have been introduced and have become established in the [Delta] (Cohen and Carlton 1998; Light et al. 2005; Winder et al. 2011)." Since the introduction and establishment of the invasive overbite clam, *Eurytemora affinis* and other zooplankton have experienced long term declines (Winder and Jassby 2011; Kimmerer 2002b), experienced seasonal shifts in peak abundance (Merz et al. 2016) and have been replaced by non-native species (Winder and Jassby 2011). The native mysid species, *Neomysis mercedis* has experienced severe declines since the introduction and establishment of the invasive overbite clam (Winder and Jassby 2011) and has largely been replaced by a non-native mysid species, *Hyperacnthomysis longirostris,* which may be less favorable prey for fish species due to its smaller size (Feyrer et al. 2003).

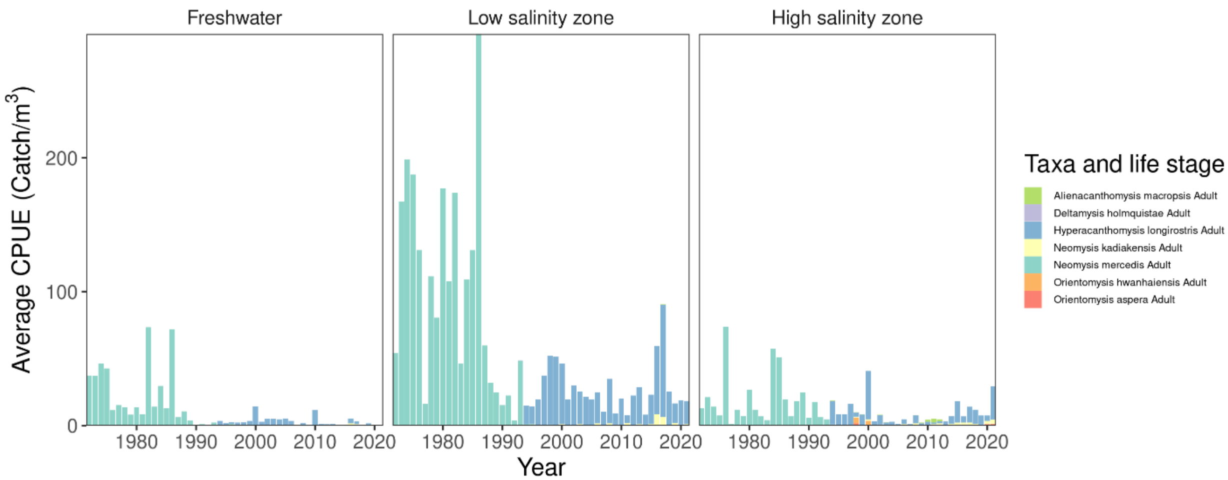
Operations at upstream CVP dams, SWP dams, and other dams, export operations at the CVP and SWP export facilities, and diversions by various water users have contributed to Delta inflows and outflows. CVP and SWP export facilities have operated under Biological Opinions issued by the USFWS and NMFS in 2004/2005, 2008/2009, and 2019. SWP facilities in the Delta have also operated consistent with an incidental take permit that addresses longfin smelt issued under CESA by CDFW on March 31, 2020.

Tidal restoration projects in the Delta may reduce the food availability stressor. Reclamation and DWR have completed consultation on Tidal Habitat Restoration projects in the Delta. The primary purpose of those projects is to protect, restore and enhance intertidal and associated subtidal habitat to benefit listed fishes, including longfin smelt, through increased food web production. To date, DWR has completed approximately 2,000 of 8,000 acres of tidal restoration in the Delta.

The **proportion** of the population affected by the operation of the CVP is **medium**. Reclamation considered environmental monitoring data on food availability and quality to estimate the proportion of the population affected by an increase in the food availability risk stressor. Food limitation is expected to impact somatic condition and gonad development of longfin smelt, which has direct consequences for fecundity and the subsequent generation of longfin smelt.

Historic data and modeling does not uniquely inform the proportion of the population.

Kimmerer and Gross (2022) found mean adult catch was the highest in the LSZ using FMWT and SKT data (Figure 10-4), which is where mysid density is the highest (Figure 10-14).



Source: Zooplankton data synthesizer: Version 2.4.19000.

Figure 10-14. Average Mysid Density from Fall to Spring for Freshwater, Low Salinity Zone and High Salinity Zone.

The Zooplankton- Delta Outflow Analysis, Appendix J, Attachment X, *[Attachment Title]*, provides context for fall zooplankton density available for longfin smelt in the LSZ during the fall (September – November). An analysis of the effects of winter zooplankton CPUE and Delta outflow is ongoing and will be presented in future update. During fall months, *Eurytemora affinis* (copepod) adults and mysids had a statistically significant positive relationship with Delta outflow. Adult longfin smelt predominantly consume mysids (U.S. Fish and Wildlife Service 2022). While there were some zooplankton taxa exhibited a relationship with outflow in the LSZ during spring, mysids did not.

CPUE of *Eurytemora affinis* was very low and did not differ among the Proposed Action phases. For mysids, the CPUE under the Proposed Action phases varied among water year types; the wet WYT had the highest CPUE for mysids, and the critical WYT had the lowest CPUE for mysids.

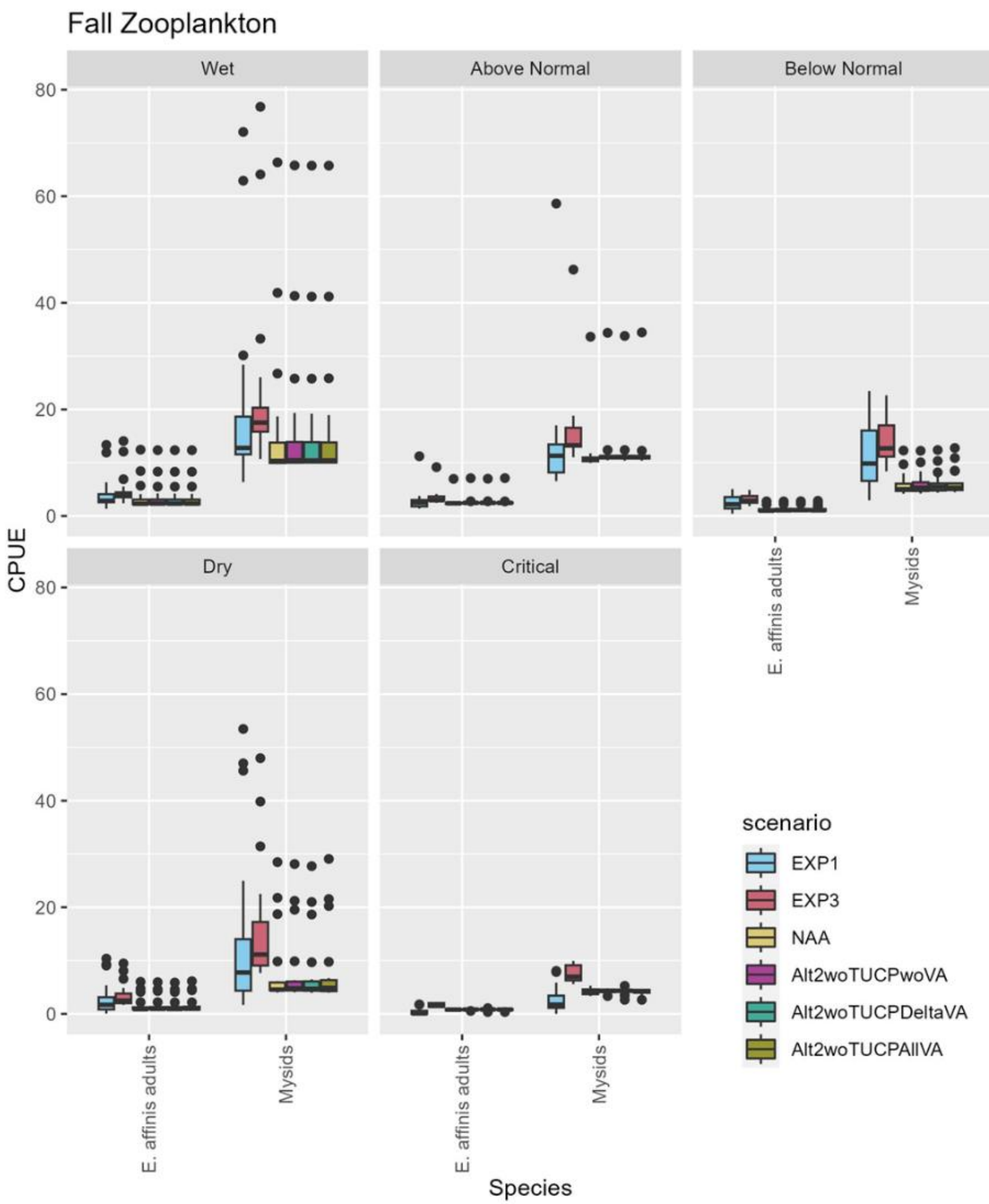


Figure 10-15. Boxplots of CPUE of Significant Zooplankton Species by Scenario across Different Water Year Types for Fall.

The frequency of occurrence is annual, depending on the hydrology, and is **likely high** as the past 21 out of 26 years (~80%) exhibited lower outflow during the spring and 22 out of 26 years (~85%) exhibited lower outflow during the winter (Figure 10-13).

To evaluate the **weight of evidence** for the food availability stressor, multiple location- and species-specific datasets and studies have been evaluated to infer the proportion of the population that will be affected and the frequency of an increase in the stressor.

- Kimmerer and Gross (2022) used historical survey data (1959 - 2021) that are quantitative, species specific and location specific. The analysis is published in a peer reviewed journal. The data was used to examine the distribution of longfin smelt at different life stages across different salinity ranges and to develop an estimate of larval longfin smelt loss due to entrainment. The authors noted loss of larval longfin smelt to diversions was highly variable with large error bars, and that surveys do not fully cover the range of larval longfin smelt.
- The Zooplankton Flow Analysis Model is quantitative and location specific but not species specific. The model is a statistical analysis that incorporates historical biological data from long-term monitoring surveys for the low salinity zone. CPUE for multiple taxa groups was regressed against Delta outflow for each season. Statistically significant relationships were then applied to modelled conditions and operation scenarios.

Conservation measures in the Proposed Action that minimize or compensate for effects of the operation of the CVP and SWP on this stressor include:

- Minimum Instream Flows
- Winter and Spring Delta Outflow

Conservation measures in the Proposed Action for other species, life stages and/or stressors that may exacerbate this stressor include:

- Fall and Winter Base Flows for Shasta Reservoir Refill
- Reduced Wilkins Slough Minimum Flows
- Drought Actions

10.2.3 Eggs and Larvae

Longfin smelt larvae hatch during the winter through spring from December to May peaking in February (Baxter et al. 1999). Egg incubation averages from 16.5 to 23.7 days depending on temperatures (Yanagitsuru et al. 2021).

Stressors that may change at a level that is insignificant or discountable include:

- The Proposed Action may increase the *water temperature* stressor. CVP and SWP storage and diversion decreases Delta inflow. Delta water temperature is negatively correlated with Delta inflow in the spring (Bashevkin and Mahardja 2022) and reservoir operations may influence water temperature to a minimal extent in the lower reaches of the Sacramento River (Daniels and Danner 2020).

The range of potential reservoir operations is unlikely to have a measurable effect on Delta water temperatures as Bay-Delta water temperature is mainly driven by timing of snowmelt (Knowles and Cayan 2002), air temperature and meteorology (Vroom et al. 2017; Daniels and Danner 2020). While there is uncertainty about whether the decreased inflow due to American River operations is a cause for changes in Delta water temperatures, historical water temperatures do not exceed 59°F at Prisoner's Point (temperature at which detrimental effects to larvae and embryo rearing were observed, Yanagitsuru et al. 2021) in the winter. Water temperature does exceed 59°F in some years in the spring. However, the volume of water required to provide sufficient thermal mass to deviate from ambient air temperatures is substantially larger than releases outside of flood operations.

- The Proposed Action may increase the *toxicity* stressor. During the larval life stage, toxins may be mobilized through flooding of agricultural and urban areas; however, the seasonal operation of the CVP does not increase the flooding frequency. CVP and SWP operations are not a proximate cause of contaminants mobilized from the watershed, agricultural lands, and urban effluent (Guo et al. 2010).

  CVP and SWP storage and diversion of water decreases Delta inflow, limiting the potential for dilution of contaminants. In the Delta, the potential for dilution of contaminants depends on sampling location (Stillway et al. 2021). Contaminants are likely local and have little response to CVP and SWP flows (Werner et al. 2010).

- The Proposed Action many increase the *predation* stressor. During the larval rearing and migration period, the Proposed Action will store and divert water and reduce Delta inflows and outflow. Certain locations in the Delta (e.g., Clifton Court Forebay, the scour hole at Head of Old River, Delta fish collection facilities, the Delta Cross Channel gates) are considered predator hotspots and during operations of those that are CVP/SWP facilities, longfin smelt will be exposed to predation. Studies have been conducted as far back as the 1980s on the abundance of predatory fish inhabiting Clifton Court Forebay (Kano 1990; Gingras and McGee 1997) and more recent studies have predicted high predation hazard for scour holes like the Head of Old River site (Michel et al. 2020). Predation is widespread and exacerbated by disruption of habitat from land use and invasive aquatic vegetation, climate change, and altered predator dynamics from well-established invasive piscivorous non-native fish such as striped bass, largemouth bass and Mississippi silversides. Predation rates are a function of correlated variables such as predator presence, prey vulnerability, and environmental conditions (Grossman et al. 2013; Grossman 2016). Reduced turbidity from the Proposed Action can also increase predation risk (Ferrari et al. 2013; Schreier et al. 2016). Higher temperatures increase metabolic demands of fish which may cause longfin smelt to increase time spent foraging and exposure to predators. Effects of the Proposed Action on water temperature and food visibility that may interact with the predation stressor were analyzed in those sections. . Indirect effects of predation are described further in Appendix J, Appendix K, and Appendix I. Any residual effects of predation associated with the Proposed Action is considered insignificant.

Described below are stressors exacerbated by the Proposed Action, potentially resulting in incidental take. Also described below are conservation measures included as part of the Proposed Action to avoid or compensate for adverse effects.

10.2.3.1 Entrainment

The proposed diversion of water may increase the entrainment risk stressor during the larval rearing period, the Proposed Action will export water from the Delta and lead to the storage and diversion of water which will reduce Delta inflows and outflows. OMR flows towards the central and south Delta will also increase. Entrainment is discussed in two ways: [1] fish encountering CVP and SWP facilities where they may be pulled into diversions or the export facilities as they follow net flows (Grimaldo et al. 2009) and [2] fish routed/advected through water ways in the Delta where they may experience decreased survival. Longfin smelt larvae occur in the southern Delta due to adult utilizing spawning habitat in the South Delta resulting in larvae hatching in the region, entrainment into the region via hydrodynamic processes (e.g., negative OMR flows), or a combination of both (California Department of Fish and Game 2009). Entrainment is largely explained by OMR flows (Grimaldo et al. 2009).

Multiple topic-specific appendices address aspects of adult migration through the Delta.

- Appendix G includes sections for Tracy Fish Collection Facility and Skinner Fish Delta Fish Protective Facility
- Appendix I presents analysis of Old and Middle River Management and Delta Cross Channel Closure conservation measures

The increase in entrainment stressor is expected to be **lethal**. Entrainment at the export facilities may result in direct mortality (Kimmerer 2008). Entrainment can lead to consistently high rates of pre-screen losses of fish in CCF due to predation (Castillo et al. 2012). MacWilliams and Gross (2013) demonstrated wind velocity and export rates affected residence time in the forebay and therefore exposure to predation. When fish are entrained into the south Delta, they are exposed to greater predation risk since the invasive aquatic macrophyte, *Egeria densa*, dominates the littoral zone in the south Delta (Durand et al. 2016) and provides habitat for the invasive largemouth bass (Brown and Michniuk 2007) which prey on other fish species.

Although the Proposed Action may increase the entrainment risk stressor, entrainment of larvae longfin smelt exists in the **environmental baseline** (without the Proposed Action). The SSA summarizes the major modifications to the physical, biological, and hydrological alterations that have occurred to the Bay-Delta from its historic conditions. In addition, tidal conditions can facilitate downstream transport or entrainment depending on the flood and ebb of tides during the fortnightly spring-neap cycle (Arthur et al. 1996). Entrainment of longfin smelt also is influenced by non-CVP and non-SWP diversions in the Delta. Most of the 370 water diversions operating in Suisun Marsh are unscreened (Herren and Kawasaki 2001).

In the Delta, Reclamation's past operation of the Delta Cross Channel Gates and Reclamation and DWR's past operation of export facilities influenced the flow of water in the Delta. Reclamation and DWR have operated the CVP and SWP to reduce the risk of entrainment under Biological Opinions issued by the USFWS and NMFS in 2004/2005, 2008/2009, and 2019. Under those Biological Opinions, Reclamation and DWR have: (1) closed the Delta Cross Channel Gates; (2) controlled the net negative flows toward the export pumps in Old and Middle rivers to reduce the likelihood that fish would be diverted from the San Joaquin or Sacramento River into the southern or central Delta; and (3) improved fish screening and salvage operations to reduce mortality from entrainment and salvage. SWP facilities in the Delta have also operated consistent with an incidental take permit that addresses longfin smelt issued under the California Endangered Species Act by CDFW on March 31, 2020.

The current Proposed Action involves several actions intended to minimize the entrainment of larvae longfin smelt. These actions included decreased exports from OMR during specific time frames, in response to abiotic conditions.

The **proportion** of the population affected by the Proposed Action varies annually and depends on hydrology, and export rates and is likely **low**. Reclamation considered historic salvage and literature on entrainment to estimate the proportion of the population affected by an increase in the entrainment risk stressor.

Larval longfin smelt present in the south Delta are at higher risk of being entrained. Analysis of catch per trawl data from various environmental monitoring surveys in the upper estuary by Kimmerer and Gross (2022) found mean larval catch in the south Delta was 1.9% of the mean catch in the LSZ (Figure 10-4).

Using hydrodynamic and particle-tracking models, Gross et al. (2022) found proportional entrainment varied from near zero to 2% depending on hydrology. Estimated median cumulative proportional losses of larvae during a dry year (2013) was close to 2% around May, whereas during a wet year (2017) median cumulative proportional losses were close to zero (0.06%) in mid-April.

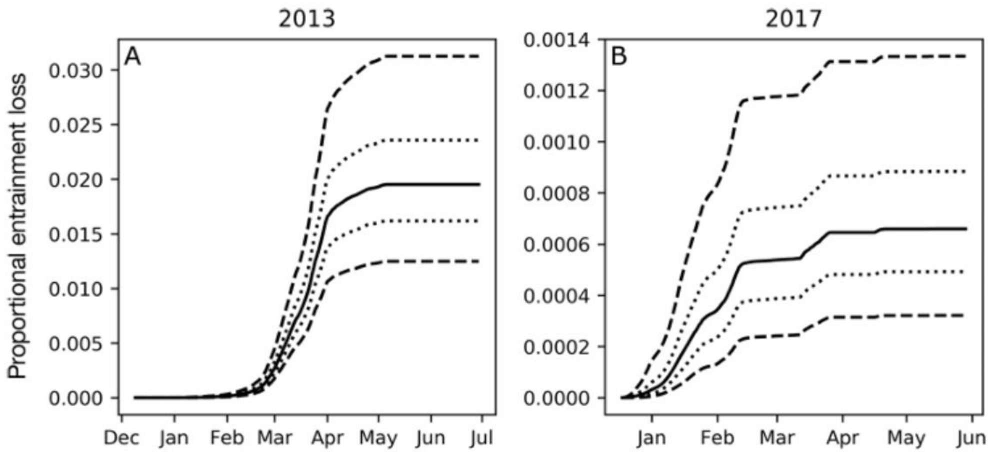


Fig. 11. Estimated median cumulative proportional entrainment of larvae for (A) 2013 and (B) 2017 with 5 and 95 % credible intervals shown with dashed lines and 25 and 75 % credible intervals shown with dotted lines

Source: Gross et al. 2022.

Figure 10-16. Estimated Proportional Entrainment of Longfin Smelt Larvae for a Dry (2013) and Wet (2017) Year.

Similarly, Kimmerer and Gross (2022) used the same data but utilized a Bayesian model and found estimate proportional losses averaged 1.5% of the population examining data from 2009-2020. During a year with low outflow and X2 was more landward (2014) the cumulative percent adjust loss over a 13-day period was 1.2%. During 2019 when outflow was higher and X2 was more seaward loss was 1.2%. Highest cumulative losses reported (2.9%) occurred during a year with moderate outflow (1155 m^3/s) and an X2 position of 69 km (2016) and during a year with lower outflow (479 m^3/s) and an X2 position of 75 km. (Kimmerer and Gross 2022:Table 1).

Historic data does not uniquely inform the proportion of the population.

The **frequency** when entrainment impacts species is **medium** to **high** based on the historical presence of adult and larval longfin smelt in the south Delta and historical hydrology.

Using SKT monitoring data from 2002-2022 the presence of adult longfin smelt was not detected in any south Delta stations (see also Figure 10-4), however salvage records from 1993 to 2022 indicate adult longfin salvage occurred in 15 out of 29 (~52%) years (see salvage table in entrainment stressor for adults). This implies the potential for presence of longfin eggs and larvae in the south Delta region if they were entrained.

Using SLS data, the presence of yolk sac longfin smelt larvae in the south Delta occurred in 8 out of 9 years (~88%) from 2011 to 2019 (Table 10-4). Entrainment of larval longfin smelt occurred in 6 out of 9 years (~66%) from 2011 to 2019 (Table 10-5).

Table 10-4. Annual Catch of Longfin Smelt Yolk-sac Larvae in Regions within Influence of South Delta Water Export Facilities, 2011–2019.

Sampling Regions	Sampling Station	Year									Grand Total
		2011	2012	2013	2014	2015	2016	2017	2018	2019	
Sacramento River	704	78	133	119	108	22	10		32	2	504
	705	33	58	55	99	12	1		6	5	269
	706	55	162	145	110	18	15	2	24	12	543
	707	88	188	116	112	26	17		19	1	567
Near Barker Slough	716	67	108	95	107	5	4	1	2	1	390
	723	92	118	124	96	3	8		5	2	448
San Joaquin River	809	50	59	102	131	1	17		6	3	369
	812	12	46	12	68	6	7	1	2	1	155
	815	7	12	6	10		3				38
	906	1	5	7							13
	910	1	1								2
	912	1									1
Mokelumne River	919	1	2	13							16
South Delta	901	27	59	62	24	1	5		2		180
	902	3	19	3	1					1	27
	914		3								3
	915	1	7	5	2	1	2				18
	918		4	2	1				1		8
Grand Total		**358**	**758**	**647**	**666**	**87**	**77**	**3**	**92**	**25**	**2713**

Source: California Department of Fish and Wildlife 2020, Table 5.
Record of the presence of a yolk-sac for larvae began in 2011. Such larvae were likely captured in the vicinity of their hatch location, though the presence of a yolk-sac can last for 10 days for LFS larvae.

Table 10-5. Frequency of Salvage Delta Smelt and Longfin Smelt Larvae from State Water Project and Central Valley Project Facilities, 2008–2019.

Year	Days Checked		Delta Smelt Larvae		Longfin Smelt Larvae		Starting Dates for Larva Presence Determination	
	SWP	CVP	SWP	CVP	SWP	CVP	SWP	CVP
2008	138	135	0	10	1	19	February 2	February 2
2009	108	120	12	19	3	10	March 3	February 25
2010	131	89	9	0	0	1	February 20	February 24
2011	99	93	3	0	0	0	March 17	March 17
2012	136	136	27	42	29	31	February 16	February 16
2013	105	102	14	8	13	17	March 6	March 11
2014	122	87	10	5	13	2	February 24	March 13
2015	101	111	1	0	8	5	March 2	February 24
2016	100	99	0	0	0	1	March 1	March 1
2017	115	122	0	0	0	0	February 27	February 20
2018	72	82	0	0	2	0	March 29	March 29
2019	91	100	0	0	0	0	March 18	March 18

Source: California Department of Fish and Wildlife 2020, Table 4.
Annual initiative of larval sampling at the facilities varied in time, often triggered by presence of one or more Delta smelt females in Spring Kodiak Trawling or presence of Delta smelt larvae in Smelt Larval or 20-mm surveys; thus, detections underrepresent the presence of longfin smelt larvae at the fish salvage facilities.
SWP = State Water Project; CVP = Central Valley Project.

Net negative OMR flow increases entrainment risk. CDFW (2020) analyzed mean monthly from December to March OMR flows for 1967 through 2019. In 42 out of 52 (~81%) years negative OMR flow was net negative and 16 out of 52 (~31%) years had a negative OMR flow of -5000 cfs or greater (Figure 10-6).

While changes to operations are targeted towards reducing entrainment of Delta Smelt, they may also benefit longfin smelt (California Department of Fish and Game 2009). Analysis of historical secchi depth and Dayflow data between WY 2010 and 2019 found in 7 out of 9 years (~78%) larval and juvenile protection conditions (QWEST was negative after March 15th and secchi depth in the south Delta is less than 1m) were met.

Particle tracking modeling results for salmonids may be applicable for smelt (see Chapter 5) depending on location. Further results for particle injection points in parts of the Bay-Delta (such as Suisun Bay and Suisun Marsh) will be presented in a future update.

The **weight of evidence** for the entrainment stressor includes multiple analyses and modeling using historical monitoring data, which is species and location specific.

- Kimmerer and Gross (2022) used historical survey data (1959 - 2021) that are quantitative, species specific and location specific. The analysis is published in a peer reviewed journal. The data was used to examine the distribution of longfin smelt at different life stages across different salinity ranges and to develop an estimate of larval longfin smelt loss due to entrainment. The authors noted loss of larval longfin smelt to diversions was highly variable with large error bars, and that surveys do not fully cover the range of larval longfin smelt.
- Gross et al. (2022) used data from a monitoring survey and a larval longfin study from 2013 and 2017, that are quantitative, species specific and location specific. The analysis is published in a peer reviewed journal. The data was combined with a particle tracking model to estimate location and timing of hatching, natural larvae mortality and loss due to entrainment. The authors note that some important factors were not integrated into the model such as behavioral movement of larval-juvenile transitioning fish, and turbidity.
- Volumetric influence modeling is quantitative, not species-specific, and not location specific. This analysis is not published and is a simplified representation of the Bay-Delta (proportion of Sacramento inflow exported).
- PTM is quantitative, not species-specific, and location-specific. The methodology has been used in multiple peer-reviewed publications (see Kimmerer and Nobriga 2008 above), PTM is a widely accepted method to estimate particle movement and can be evaluated with covariates.
- Zone of influence modeling is quantitative, not species-specific (but not expected to be, environmental variable), and not location specific. This analysis is not published, but is a widely accepted method for evaluating spatial extent of varying levels of exports within the Bay-Delta,
- Juvenile and larval protection conditions used historical data water quality data that are quantitative, not species specific and is location specific. The analysis is not published. The data was used to evaluate when first flush conditions would have occurred historically.

Conservation measures in the Proposed Action that minimize or compensate for effects of the operation of the CVP and SWP on this stressor include:

- January 1 and Start of OMR Management
- Larval and Juvenile Longfin Smelt Protection Action
- Spring Delta Outflow
- Barker Slough Pumping Plant, Maximum Spring Diversions, Larval Longfin Smelt

Conservation measures in the Proposed Action for other species, life stages and/or stressors that may exacerbate this stressor include:

- SHOT Reduction in Sacramento River Fall and Winter Flows
- Reduced Wilkins Slough Minimum Instream Flow
- Drought Actions

10.2.3.2 Freshwater Flow

The proposed diversion of water may increase the freshwater flow stressor. During the larval rearing and migration period, the Proposed Action will store and divert water from the Delta and decrease the size and position of the LSZ. Young of the year longfin smelt tend to aggregate in the LSZ (Dege and Brown 2004). Longfin smelt may benefit when the LSZ coincides with the increased shallow water and marsh habitats in Suisun Bay, by allowing early-stage longfin smelt to maintain horizontal position and access food resources in higher quality habitat (Hobbs et al. 2006; Grimaldo et al. 2017). Increased freshwater flow also increases turbidity which can benefit longfin smelt by making them less visible to predators (Ferrari et al. 2014) and improve foraging efficiency (Hasenbein et al. 2013). Longfin smelt abundance is positively correlated with freshwater flow and the average position of X2 (Jassby et al. 1995; Kimmerer 2002; Kimmerer et al. 2009; Thomson et al. 2010; U.S. Fish and Wildlife Service 2022). The mechanism behind X2/freshwater flow and longfin smelt abundance may not only be related to salinity but could also be related to more dynamic aspects such as retention by estuarine circulation or transport to rearing areas (Kimmerer et al. 2013). Appendix J and Appendix K present analysis.

An increase to the freshwater flow stressor would cause the size and location of the LSZ to decrease and be further landward, decrease turbidity, and alter hydrodynamic processes that may benefit longfin smelt which is expected to be **sublethal to lethal.** Reduction of LSZ results in less suitable habitat for longfin smelt. Suitable rearing habitat would be further landward and subject to increased entrainment risk. Decreased flows may also decrease turbidity which may increase predation risk and decrease feeding efficacy. Additionally, with decreased flows, retention and transport processes may be disrupted, resulting in lower survival of larval fish.

Although the Proposed Action may increase the freshwater flow stressor, the freshwater flow stressor for larvae longfin smelt exists in the **environmental baseline** (without the Proposed Action). Non-project exports can affect flow and the size and position of the LSZ (Hutton et al. 2017).

In the Delta, Reclamation's past operation of the Delta Cross Channel Gates and Reclamation and DWR's past operation of export facilities influenced the flow of water in the Delta. Reclamation and DWR have operated the CVP and SWP to reduce the risk of entrainment under Biological Opinions issued by the USFWS and NMFS in 2004/2005, 2008/2009, and 2019. SWP facilities have also operated under a 2020 ITP issued by the CDFW. Under those Biological Opinions, Reclamation and DWR have: (1) closed the Delta Cross Channel Gates; (2) controlled the net negative flows toward the export pumps in Old and Middle rivers to reduce the likelihood that fish would be diverted from the San Joaquin or Sacramento River into the southern or central Delta; and (3) improved fish screening and salvage operations to reduce mortality from entrainment and salvage. SWP facilities in the Delta have also operated consistent with an incidental take permit that addresses longfin smelt issued under CESA by CDFW on March 31, 2020.

The current Proposed Action involves several actions intended to minimize the freshwater flow stressor of larvae longfin smelt. These actions included decreased exports from OMR during specific time frames, in response to abiotic conditions and in direct response to the salvage of longfin smelt.

The proportion of the population affected by the Proposed Action is likely **medium**. Reclamation considered literature and environmental monitoring data on freshwater flow to estimate the proportion of the population affected by an increase in the freshwater flow stressor.

Analysis of catch per trawl data from various environmental monitoring surveys in the upper estuary by Kimmerer and Gross (2022) found mean larval catch was the highest LSZ when using the Smelt Larva survey data (Figure 10-4).

Historic data and modeling does not uniquely inform the proportion of the population.

The **frequency** when freshwater flow impacts species is **likely medium to large** and dependent position of X2 during the winter and spring seasons. In the summer 13 out of 26 years (50%), the median position of X2 was greater than 80 km. In the fall, 22 out of 27 years (~81%), the median position of X2 was greater than 80 km (Figure 10-9).

To evaluate the **weight of evidence** for the freshwater flow stressor, multiple location- and species-specific datasets and studies have been evaluated to infer the proportion of the population that will be affected and the frequency of an increase in the stressor.

- Kimmerer and Gross (2022) used historical survey data (1959 - 2021) that are quantitative, species specific and location specific. The analysis is published in a peer reviewed journal. The data was used to examine the distribution of longfin smelt at different life stages across different salinity ranges and to develop an estimate of larval longfin smelt loss due to entrainment. The authors noted loss of larval longfin smelt to diversions was highly variable with large error bars, and that surveys do not fully cover the range of larval longfin smelt.

Conservation measures in the Proposed Action that minimize or compensate for effects of the operation of the CVP and SWP on this stressor include:

- Minimum Instream Flows
- Spring Delta Outflow

Conservation measures in the Proposed Action for other species, life stages and/or stressors that may exacerbate this stressor include:

- SHOT Reduction in Sacramento River Fall and Winter Flows
- Reduced Wilkins Slough Minimum Flows
- Drought Actions

10.2.3.3 Food Availability

The food availability stressor may increase. During the larval rearing the proposed storage and diversion of water associated with the Proposed Action will reduce Delta inflows and outflows. Abundances of historically important longfin smelt zooplankton prey taxa in the LSZ, including *Eurytemora affinis* and *Neomysis mercedis*, generally exhibit a positive correlation with Delta outflow (Kimmerer 2002). Larval longfin smelt (< 18 mm) prey primarily on calanoid copepods such as *Eurytemora affinis* (Barros et al. 2022) but do consume other taxa (Lojkovic-Burris et al. 2022). Appendix J analyzes the effect of the spring Delta outflow conservation measure on food resources for native fishes. Appendix P analyzes zooplankton abundance near different types of habitats.

The increase in food availability and quality stressor is **sublethal** to **lethal**. Higher food abundances in theory results in faster growth rates (Beck et al. 2003), leading to healthier and larger fish which presumably are less vulnerable to predation. Food limitation can also weaken longfin smelt, leading to such extremes as starvation, and alter behavior resulting in increased predation risk (Vehanen 2003; Borcherding and Magnhagen 2008). Food limitation can interact negatively with other stressors such as high-water temperatures and contaminants (Bennett et al. 1995; Le et al. 2020; Lopes et al. 2022) resulting in higher mortality.

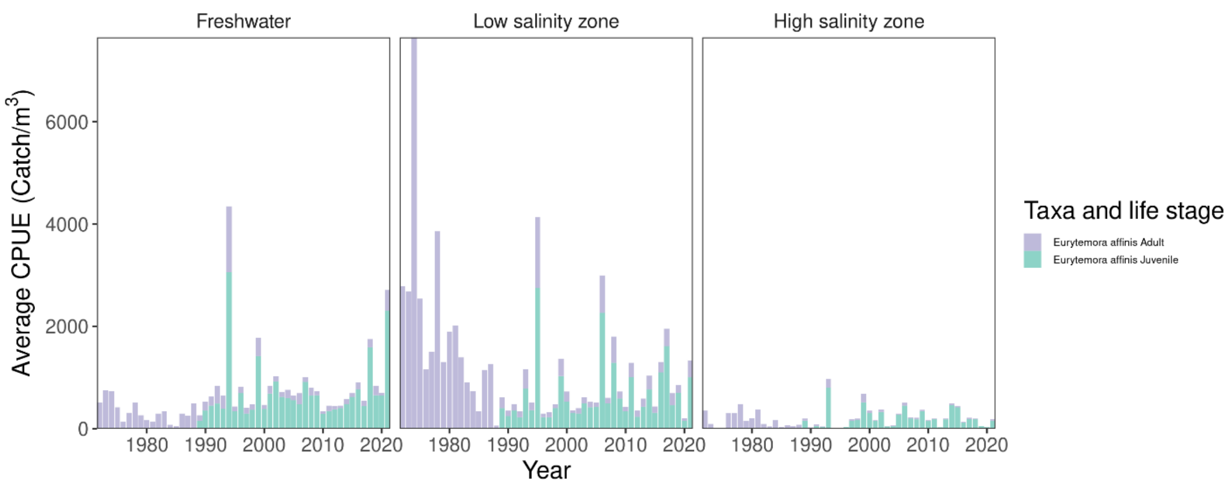
Although the Proposed Action may increase the food availability stressor, changes in food availability for larvae exists in the **environmental baseline** (without the Proposed Action). The SSA summarizes the major modifications to the physical, biological, and hydrological alterations that have occurred to the Bay-Delta from its historic conditions. Those alterations were driven by "five human activities that have changed ecological functions and habitats in many riverine and estuarine systems with increasingly dense human populations: diking, draining, dredging, diverting, and discharging." That has resulted in "an 80-fold decrease in the ratio of wetland to open water area in the Delta . . . [and] a substantial reconfiguration of the bays, sloughs, and channels, while large-scale water diversions, and discharge of contaminants have altered water quantity and quality. In addition, a wide variety of non-native plants and animals have been introduced and have become established in the [Delta] (Cohen and Carlton 1998, Light et al. 2005, Winder et al. 2011)." This has contributed to a decline in longfin smelt food sources including mysids and calanoid copepods. *Eurytemora affinis* and other zooplankton have experienced long term declines since the introduction of the overbite clam (Winder and Jassby 2011; Kimmerer 2002b), experienced seasonal shifts in peak abundance (Merz et al. 2016) and have been replaced by non-native species (Winder and Jassby 2011).

Operations at upstream CVP dams, SWP dams, and other dams, export operations at the CVP and SWP export facilities, and diversions by various water users have contributed to Delta inflows and outflows. CVP and SWP export facilities have operated under Biological Opinions issued by the USFWS and NMFS in 2004/2005, 2008/2009, and 2019. SWP facilities in the Delta have also operated consistent with an incidental take permit that addresses longfin smelt issued under CESA by CDFW on March 31, 2020.

Tidal restoration projects in the Delta may reduce the food availability stressor. Reclamation and DWR have completed consultation on Tidal Habitat Restoration projects in the Delta. The primary purpose of those projects is to protect, restore and enhance intertidal and associated subtidal habitat to benefit listed fishes, including longfin smelt, through increased food web production. To date, DWR has completed approximately 2,000 of 8,000 acres of tidal restoration in the Delta.

The proportion of the population affected by the operation of the CVP is **likely medium**. Reclamation considered environmental monitoring data on food availability to estimate the proportion of the population affected by an increase in the food availability stressor.

Analysis of catch per trawl data from the Smelt Larvae survey in the upper estuary by Kimmerer and Gross (2022) found mean catch is the highest in the LSZ and a portion are present in freshwater regions (Figure 10-4, panel A). Food resources are greatest in the freshwater and low salinity zone regions (Figure 10-17). Since flows influence the abundance of key longfin smelt prey *Eurytemora affinis*, larvae present in the LSZ and freshwater regions are subject to greater food availability stressors when flow is lower.



Source: Zooplankton data synthesizer: Version 2.4.19000.

Figure 10-17. Average *Eurytemora affinis* Density from Winter to Spring for Freshwater, Low Salinity Zone and High Salinity Zone.

The Zooplankton-Delta Outflow Analysis, Appendix J, Attachment X, *[Attachment Title]*, provides context for zooplankton density available for Delta smelt larvae in the LSZ during the spring (March- May). This can be applied to larval longfin smelt, as well, which consume some of the same prey, particularly *Eurytemora affinis*. The analysis is a regression of the relationship between historical zooplankton abundance (CPUE) and Delta outflow (cfs). During spring months, cladocerans (except *Daphnia*), *Eurytemora affinis* (copepod) adults, harpacticoid copepods, other calanoid copepod adults (*Acartia* spp., unidentified calanoids, *Sinocalanus doerrii*, *Tortanus* spp., and Diaptomidae), and other calanoid copepod copepodites (*Acartia* spp., *Acartiella* spp., unidentified calanoids, *Eurytemora affinis*, *Sinocalanus doerrii*, *Tortanus* spp., and Diaptomidae) had a statistically significant positive relationship with Delta outflow. All the above taxa/groupings have been found in larval Delta smelt gut content studies (Barros et al. 2022; Burris et al. 2022).

The CPUE under the Proposed Action phases varied among water year types; the wet WYT had the highest CPUE for each taxa/grouping, and the critical WYT had the lowest CPUE for each taxa/grouping.

The mechanism for why CPUE increases in the low salinity zone during higher outflow has not been clearly and definitively established. Kimmerer (2002) found lower trophic level taxa (zooplankton) responded inconsistently with flow across seasons and historical periods.

Kimmerer also found that chlorophyll showed little response to flow, suggesting a bottom up, "agricultural model" explanation for increased CPUE with higher flows is unlikely. Another possible mechanism is that increased flows also increase subsidies of zooplankton from higher abundance freshwater seasons into the LSZ (Hassrick et al. 2023; Kimmerer et al. 2019) (Figure 10-12).

The **frequency** of occurrence is annual, depends on the hydrology, and is **likely high**. In 21 out of 27 (~77%) years, spring outflow was lower, and in 22 of 27 (~81%), winter outflow was lower which in theory results in lower densities of *Eurytemora affinis* which historically had a positive relationship with increased outflow (Kimmerer 2002) (Figure 10-13).

To evaluate the **weight of evidence** for the food availability stressor, multiple location- and species-specific datasets and studies have been evaluated to infer the proportion of the population that will be affected and the frequency of an increase in the stressor.

- Kimmerer and Gross (2022) used historical survey data (1959 - 2021) that are quantitative, species specific and location specific. The analysis is published in a peer reviewed journal. The data was used to examine the distribution of longfin smelt at different life stages across different salinity ranges and to develop an estimate of larval longfin smelt loss due to entrainment. The authors noted loss of larval longfin smelt to diversions was highly variable with large error bars, and that surveys do not fully cover the range of larval longfin smelt.
- The Zooplankton Flow Analysis Model is quantitative and location specific but not species specific. The model is a statistical analysis that incorporates historical biological data from long-term monitoring surveys for the low salinity zone. CPUE for multiple taxa groups was regressed against Delta outflow for each season. Statistically significant relationships were then applied to modelled conditions and operation scenarios.

Conservation measures in the Proposed Action that minimize or compensate for effects of the operation of the CVP and SWP on this stressor include:

- Minimum Instream Flow
- Winter and Spring Delta Outflow

Conservation measures in the Proposed Action for other species, life stages and/or stressors that may exacerbate this stressor include:

- Fall and Winter Base Flows for Shasta Reservoir Refill
- Reduced Wilkins Slough Minimum Flows
- Drought Actions

10.3 Lifecycle Analysis

There is no literature, dataset, or model to support a lifecycle analysis for longfin smelt.

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10.4.1 Personal Communications

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