— BUREAU OF —
RECLAMATION

Long-Term Operation – Biological Assessment

# Chapter 9 – Delta Smelt

October 2024

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# Chapter 9 Delta Smelt

The Delta smelt (*Hypomesus transpacificus*) is one of six species currently recognized in the *Hypomesus* genus (Bennett 2005) and is endemic to (native and restricted to) the Sacramento–San Joaquin Delta (Delta) Estuary in California, found only from the San Pablo Bay upstream through the Delta in Contra Costa, Sacramento, San Joaquin, Solano, and Yolo Counties (Moyle 2002). Delta smelt occupy a range of environmental conditions (e.g., salinity, turbidity, temperature, freshwater flow) (Moyle et al. 2016, Sommer and Mejia 2013, Sommer et al. 2011, Bennett 2002) and utilize different habitat types (deep and shallow open waters, tidal wetlands) (Hammock et al. 2019, Sommer and Mejia 2013, Aasen 1999) within the estuary for migration, spawning, egg incubation, rearing, and larval and juvenile transport from spawning to rearing habitats. Delta smelt are believed to require relatively turbid (not clear) waters to capture prey and avoid predators (Schreier et al. 2016, Hasenbein et al. 2013, Ferrari et al. 2014, Baskerville-Bridges et al. 2004). Delta smelt feed primarily on small planktonic (free-floating) crustaceans, and occasionally on insect larvae and larval fish (Slater et al. 2019, Hammock et al. 2019, Slater and Baxter 2014). Historically, the main prey of Delta smelt was the copepod *Eurytemora affinis* and the mysid shrimp *Neomysis mercedis* (Moyle et al. 1992, Slater and Baxter 2014). From late spring through fall and early winter, Delta smelt are typically located within the low-salinity zone, which moves depending upon San Francisco Bay-Delta water outflow (Dege and Brown 2004, USFWS 2008), to rear in brackish water, though other life history variants show preferences for freshwater and semi-anadromous rearing habitats (Hobbs et al. 2019). Delta smelt's LSZ ecosystem has been changing very rapidly during the past several decades. Once plentiful in the Delta ecosystem, this typically annual fish species is now rare in monitoring surveys.

## 9.1 Status of Species and Critical Habitat

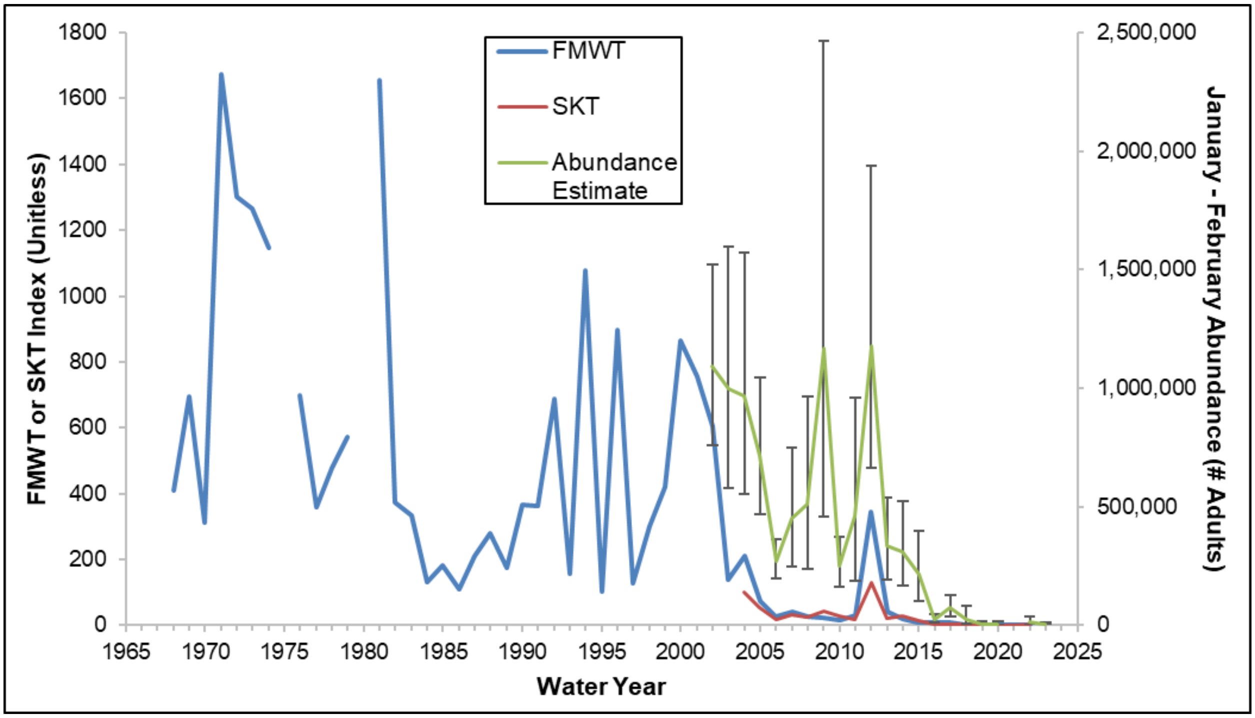
The U.S. Fish and Wildlife Service (USFWS) proposed listing the Delta smelt as threatened with proposed critical habitat on October 3, 1991 (USFWS 1991). The USFWS listed the Delta smelt as threatened on March 5, 1993 (USFWS 1993) and designated critical habitat for the species on December 19, 1994 (USFWS 1994). The Delta smelt was one of eight fish species addressed in the Recovery Plan for the Sacramento–San Joaquin Delta Native Fishes (USFWS 1996). A five-year status review of the Delta smelt was completed on March 31, 2004 (USFWS 2004).

The 2004 review concluded that Delta smelt remained a threatened species. A subsequent five-year status review recommended uplisting Delta smelt from threatened to endangered (USFWS 2010a). A 12-month finding on a petition to reclassify the Delta smelt as an endangered species was completed on April 7, 2010 (USFWS 2010b). After reviewing all available scientific and commercial information, the USFWS determined that reclassifying the Delta smelt from threatened to endangered was warranted but was precluded by other higher priority listing actions (USFWS 2010c). The USFWS annually reviews the status and uplisting recommendation for Delta smelt during its Candidate Notice of Review (CNOR) process. Each year, the CNOR has recommended the uplisting from threatened to endangered.

### 9.1.1 Distribution and Abundance

The California Department of Fish and Wildlife (CDFW) Spring Kodiak Trawl (SKT) monitors the adult spawning stock of Delta smelt and serves as the primary index for the relative number and distribution of spawners in the system until the establishment of the Enhanced Delta Smelt Monitoring Program. The 2022 SKT Abundance Index was 1.7, the fourth lowest on record. All CDFW relative abundance indices show a declining trend since the early 2000s (Figure 9-1).

In 2016, the USFWS began calculating an absolute abundance estimate using January and February SKT catch data, which have been available since 2002 (USFWS 2023). The January through February 2023 point estimate of 4,656 adults (95% confidence intervals: 1178 -lower bound, 12730 -upper bound) is the lowest since the SKT survey began in 2002. The extremely low spawning stock of Delta smelt relative to historical numbers suggests the population would continue to be vulnerable to stochastic events (e.g., not finding mates, toxic spill) and continued human-caused alteration of the Bay-Delta.

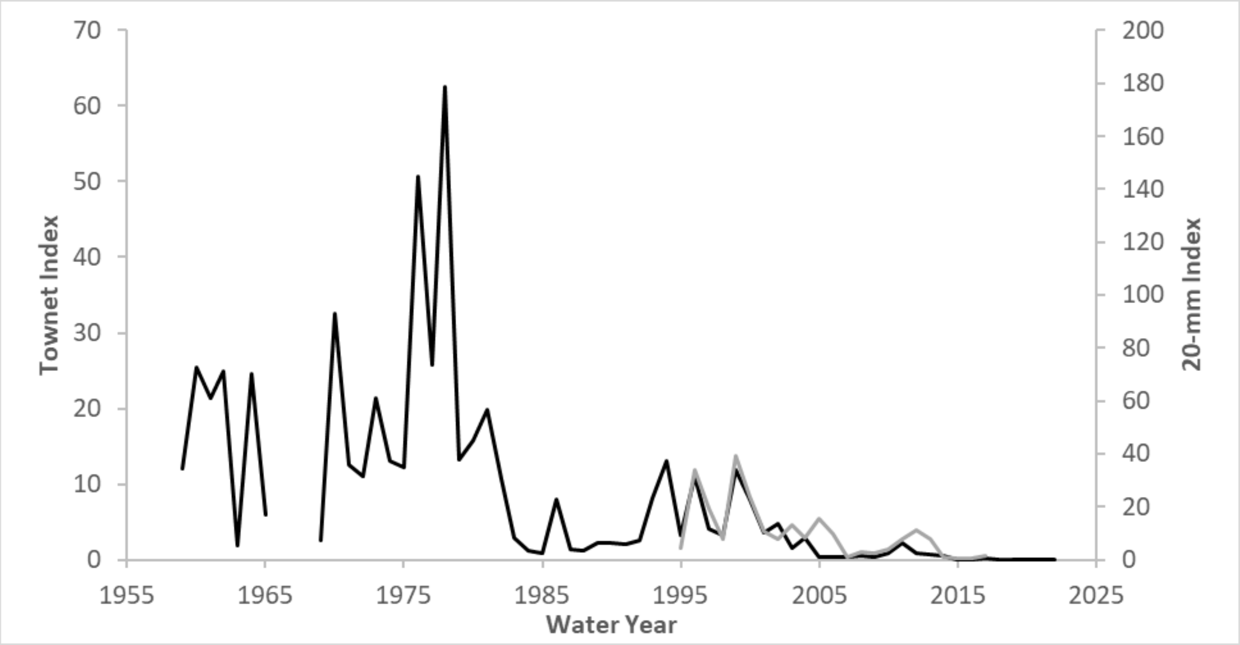


Source: California Department of Fish and Wildlife 2024a; 2024b; USFWS 2023.

Figure 9-1. Delta smelt Fall Midwater Trawl (FMWT) Index (Water Years 1968-2023), Spring Kodiak Trawl (SKT) Index (Water Years 2004-2022), and January-February Spring Kodiak Trawl Adult Abundance Estimate (with 95% Confidence Intervals; Water Years 2002-2023).

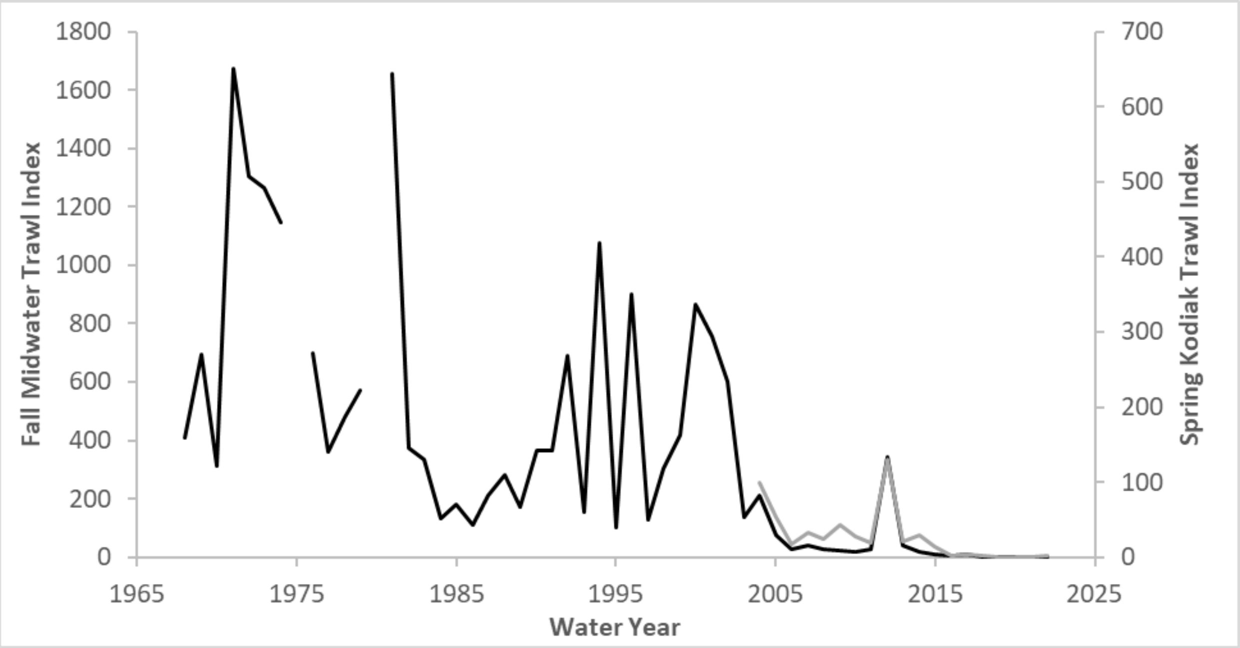
In addition to these abundance estimates, the CDFW conducts four fish surveys from which it develops indices of Delta smelt’s relative abundance. Each survey has variable capture efficiency (Mitchell et al. 2017), and in each, the frequency of zero catches of Delta smelt is very high, largely due to the species’ rarity (Latour 2016; Polansky et al. 2018).

The Townet Survey (TNS) and FMWT abundance indices for Delta smelt have documented the species' long-term decline, while the newer 20-mm and SKT abundance indices have generally confirmed the recent portions of the trends implied by the older surveys (Figure 9-2. and Figure 9-3.). During the period of record, Delta smelt relative abundance has declined from peak levels observed during the 1970s. The CDFW FMWT Delta smelt annual catch at 100 index stations has been zero every year between 2018 and 2022 (Water Years 2019-2023). The TNS and FMWT abundance indices both declined rapidly during the early 1980s, increased somewhat during the 1990s, and then collapsed in the early 2000s. Since 2005, the TNS and the FMWT have produced indices that reflect less year-to-year variation than their 20-mm and SKT analogs, but overall, the trends in both sets of indices are similar. During the past decade, the index has continued to decrease and the most recent values for three of the four indices, FMWT, TNS, and 20-mm, were zero. The latest SKT index value of 1.7 is only 1.3% of the peak value in 2012 of 103.2.



Source: California Department of Fish and Wildlife 2024c; 2024d.

Figure 9-2. Time Series of the Summer Townet Survey (TNS; black line; primary y-axis; Water Years 1959-2022) and 20-mm Survey (gray line; secondary y-axis; Water Years 1995-2021) Abundance Indices for Delta smelt.



Source: California Department of Fish and Wildlife 2024a; 2024b

Figure 9-3. Time Series of the Fall Midwater Trawl (FMWT; black line; primary y-axis; Water Years 1968-2023) and Spring Kodiak Trawl (SKT; gray line; secondary y-axis; Water Years 2004-2022) Abundance Indices for Delta smelt.

The distribution of Delta smelt is well understood due to its limited geographic distribution (Moyle et al. 1992; Bennett 2005; Hobbs et al. 2006, 2007). The potentially suitable habitat for Delta smelt within the Delta is a geographically limited area composed of high turbidity, tidally influenced low-salinity conditions, and cool to warm water temperatures. The additional suitable habitats utilized for spawning and migration are identified as predominantly seasonal use habitats as some Delta smelt exhibit freshwater life histories (Moyle et al. 2016, Hobbs et al. 2019). The geographic distribution extremes do not yield Delta smelt in most sampling years. Delta smelt have been observed as far west as San Francisco Bay, as far north as Knights Landing on the Sacramento River, as far east as Woodbridge on the Mokelumne River and Stockton on the Calaveras River, and as far south as Mossdale on the San Joaquin River. This distribution represents a range of salinity from essentially 0 ppt to about 20 ppt. However, most Delta smelt observed in the extensively surveyed San Francisco Estuary have been collected from locations within the defined ranges of the critical habitat rule. In addition, all habitats known to be occupied year-round by Delta smelt occur within the conditions defined in the critical habitat rule. Each year, the distribution of Delta smelt seasonally expands when adults disperse in response to winter flow increases, increases in turbidity, and decreases in water temperature. The annual range expansion of adult Delta smelt extends up the Sacramento River to about Garcia Bend in the Pocket neighborhood of Sacramento, up the San Joaquin River from Antioch to areas near Stockton, up the lower Mokelumne River system, and west throughout Suisun Bay and Suisun Marsh. Some Delta smelt seasonally and transiently occupy Old and Middle River in the south Delta each year but face a high risk of entrainment when they do (Grimaldo et al. 2009).

The relative abundance of Delta smelt has declined substantially for a small forage fish in an ecosystem the size of the San Francisco Estuary. The recent relative abundance reflects decades of habitat and food web changes and marginalization by nonnative species that prey on and outcompete Delta smelt. The anticipated effects of climate change on the San Francisco Estuary and watershed, such as warmer water temperatures, greater salinity intrusion, lower snowpack contribution to spring outflows from the Delta, and the potential for frequent extreme drought, indicate challenges to maintaining a sustainable Delta smelt population (Halverson et al. 2021, Brown et al. 2016). A rebound in relative abundance during the very wet and cool conditions during 2011 indicated that Delta smelt retained some population resilience (IEP MAST 2015). However, since 2012, declines to record low population estimates have been broadly associated with the 2012–2015 drought, and wetter conditions in 2017 and 2019 have not produced a similar rebound seen in 2011.

### 9.1.2 Life History and Habitat Requirements

The Delta smelt is a fish of the family Osmeridae. In the wild, very few individuals reach lengths over 3.5 inches (90 mm; Damon et al. 2016). At the time of its ESA listing, only the basics of the species' life history were known (Moyle et al. 1992). In the intervening 26 years, knowledge about the Delta smelt has grown to support its captive propagation over multiple generations (Lindberg et al. 2013), develop complex conceptual models of the species life history (IEP MAST 2015), and write mathematical simulation models of its life cycle (Rose et al. 2013a). Synthesis of the now extensive literature on the Delta smelt requires drawing conclusions across studies that had disparate objectives, but several syntheses have been compiled (Moyle et al. 1992; Bennett 2005; IEP MAST 2015; Moyle et al. 2016; FLOAT-MAST 2020). Figure 9-4 presents simplified geographic life stage domains for Delta smelt.

Most spawning occurs from February through May in various places from the Napa River and locations to the east including much of the Sacramento-San Joaquin Delta. Eggs hatch and larvae enter the planktonic stage primarily from March through May, and most individuals have metamorphosed into the juvenile life stage by June or early July (Figure 9-5). Most of the juvenile fish continue to rear in habitats from Suisun Bay and Marsh and locations east principally along the Sacramento River-Cache Slough corridor (identified as the 'North Delta Arc' Moyle et al. 2018).

The juvenile fish (or 'sub-adults') begin to develop into maturing adults in the late fall. Pre-spawning Delta smelt disperse from bays, embayments and channel areas to nearby freshwater shores or marshes to spawn (Murphy and Hamilton 2013). The first individuals begin to reach sexual maturity by January in some years, but most often in February (Damon et al. 2016; Kurobe et al. 2016). Delta smelt do not reach sexual maturity until they grow to at least 55 mm in length (~ 2 inches) and 50% of individuals are sexually mature at 60 to 65 mm in length (Rose et al. 2013b). In captivity, Delta smelt can survive to spawn at two years of age (Lindberg et al. 2013), but this appears to be rare in the wild (Bennett 2005; Damon et al. 2016). The spawning microhabitats of the Delta smelt are unknown but based on adult distribution data (Damon et al. 2016; Polansky et al. 2018) and the evaluation of otolith microchemistry (Hobbs et al. 2007; Bush 2017), most Delta smelt spawn in freshwater to slightly brackish-water habitats under tidal influence. Most individuals die after spawning, but as is typical for annual fishes, when conditions allow, some individuals can spawn more than once during their single spawning season (Damon et al. 2016). In a study spanning two to three months, captive males held at a constant water temperature of 12°C (54°F) spawned an average of 2.8 times and females spawned an average of 1.7 times (LaCava et al. 2015).

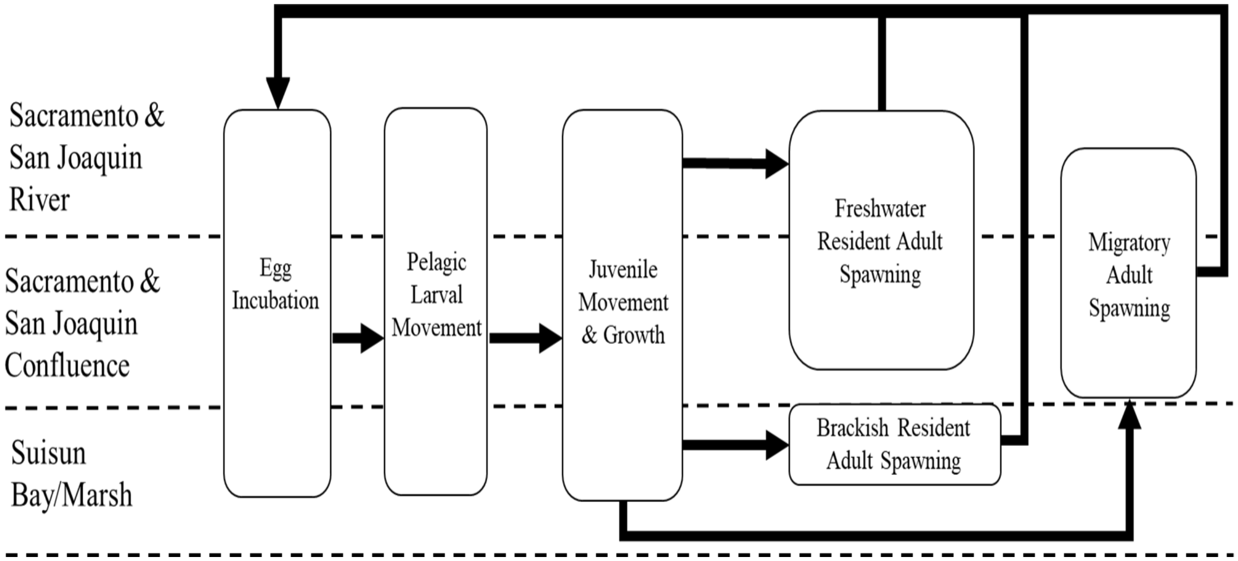


Figure 9-4. Simplified Geographic Life Stage Domains for Delta smelt

Hatching success peaks at temperatures of 15°C to 16°C (59°F to 61°F) and decreases at cooler and warmer temperatures. Hatching success nears 0 percent as water temperatures exceed 20°C (68°F) (Bennett 2005). Water temperatures suitable for spawning occur most frequently during the months of March to May, but ripe female Delta smelt have been observed as early as January and larvae have been collected as late as July. Delta smelt spawn in the estuary and have one spawning season for each generation, which makes the timing and duration of the spawning season important every year. Freshwater flow affects how much of the estuary is available for Delta smelt to spawn (Hobbs et al. 2007), but water temperature controls how long Delta smelt can spawn each season.

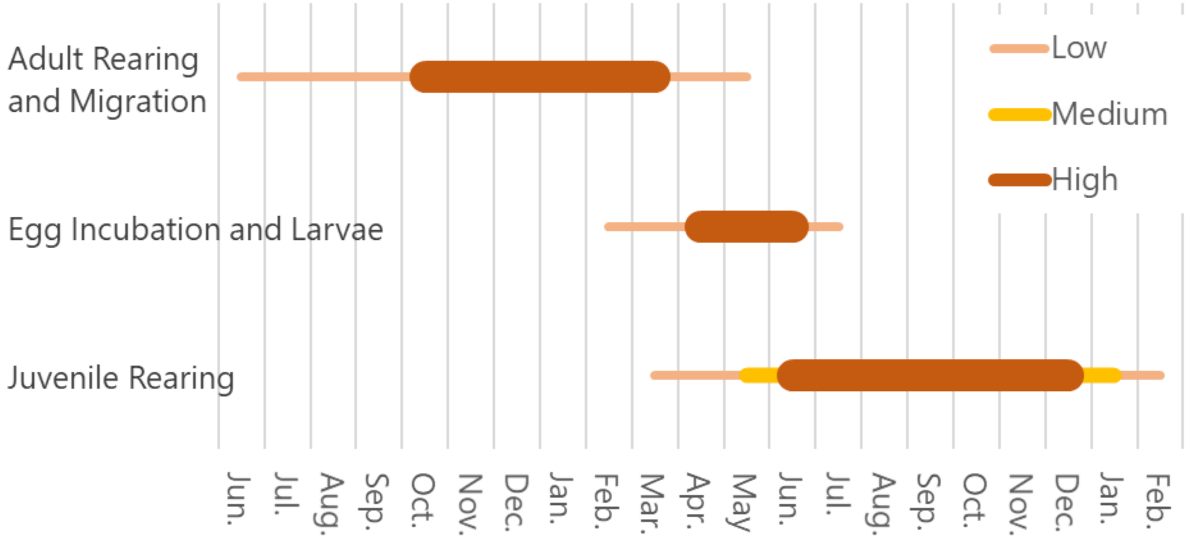


Figure 9-5. Temporal Life Stage Domains for Delta smelt (developed from IEP MAST 2015)

Although adult Delta smelt can spawn more than once, mortality is high during the spawning season and most adults die by May (Polansky et al. 2018). The egg stage averages about 10 days before the embryos hatch into larvae. The larval stage averages about 30 days. Metamorphosing "post-larvae" appear in monitoring surveys from April into July of most years. By July, most Delta smelt have reached the juvenile life stage. Delta smelt juveniles collected during the fall are sometimes called "sub-adults," a stage which lasts until winter when non-fecund fish disperse toward spawning habitats. This winter dispersal usually precedes sexual maturity (Sommer et al. 2011).

Delta smelt mainly occupy an arc of habitat in the north Delta, including Liberty Island and the adjacent reach of the Sacramento Deepwater Shipping Channel (Sommer and Mejia 2013), Cache Slough to its confluence with the Sacramento River, and the Sacramento River from that confluence downstream to Chipps Island, Honker Bay, and the eastern part of Montezuma Slough. The reasons Delta smelt are believed to permanently occupy this part of the estuary are the year-round presence of fresh- to low-salinity water that is comparatively turbid and of a tolerable water temperature. These appropriate water quality conditions overlap an underwater landscape featuring variation in depth, tidal current velocities, edge habitats, and food production (Sweetnam 1999; Nobriga et al. 2008). The area of low salinity is referred to as the LSZ and is thought to provide important nursery habitat to juvenile and sub-adult Delta smelt (Feyrer et al. 2007; Feyrer et al. 2011) during summer and fall. The LSZ is a dynamic habitat with size and location responding rapidly to changes in tidal and river flows. The LSZ is frequently defined as waters with a salinity range of about 0.5 to 6 parts per thousand (ppt) (Kimmerer 2004), based on analyses of historical peaks in phytoplankton and zooplankton abundance and the "centroid" of Delta smelt distribution (Sommer et al. 2011). By local convention the location of the low-salinity zone is described as "X2" in terms of the distance from the 2 ppt isohaline to the Golden Gate Bridge.

Field observations are increasingly supported by laboratory research on the physiological response of Delta smelt to variation in salinity, turbidity, water temperature, and environmental variables associated with changes in climate, freshwater flow, and estuarine bathymetry (Hasenbein et al. 2016; Komoroske et al. 2016). Recent physiological and molecular biological research has indicated that the salinities outside of the typical low-salinity zone range are also within the tolerance range (0 to 18 ppt) for Delta smelt (Komoroske et al. 2016).

The LSZ magnitude and dimensions change when river flows into the estuary are high, placing low-salinity water over a larger and more diverse set of nominal habitat types than occurs under low flow conditions. During periods of low outflow, the LSZ contracts and moves upstream. The size and the location of the LSZ has been used as an indicator of high-quality Delta smelt rearing habitat and, as such, has been the focus of flow management actions in summer and fall (see Appendix K, *Summer and Fall Delta Outflow and Habitat*). However, Murphy and Weiland (2019) caution against using the LSZ as a proxy for Delta smelt habitat based on similar reproduction and survival of Delta smelt across a broader salinity gradient of zero to 16 ppt.

### 9.1.3 Limiting Factors, Threats, and Stressors

The primary known threats cited in the 2010 Delta smelt uplisting document include entrainment by State and Federal water export facilities (Factor E), reduced LSZ habitat due to reductions in freshwater flow and summer and fall an increases in water clarity (Factor A) due to the interruption of sediment transport by upstream dams, and effects from introduced species, primarily the overbite clam and invasive aquatic weeds particularly, *Egeria densa* which traps sediment (Factor E). Additional threats included predation (Factor C), entrainment into power plants (Factor E), contaminants (Factor E), and small population size (Factor E). Since the 2010 warranted 12-month finding, USFWS has identified climate change as a threat in the 2012 Candidate Notice of Review. Climate change was not analyzed in the 2010 12- month finding document. Since the 2010 uplisting document, one of the two power plants within the range of the Delta smelt using water for cooling has shut down, and power plants are no longer thought to be a threat to the population as a whole.

The Proposed Action will affect certain threats that have been identified. The pertinent threats associated with the Proposed Action are entrainment in Federal and State water export facilities, food availability and quality, and reduced LSZ habitat in the summer and fall due to reductions in fall outflow and increases in water clarity.

The Delta Smelt MAST Report describes linkages between landscape attributes and environmental drivers to habitat attributes that may affect fish stressors based on life stage. To understand the Proposed Action stressors on fish, Reclamation referenced hypothesized stressors from the MAST conceptual models on adults, eggs and larvae, and juveniles. Reclamation has briefly summarized in this Biological Assessment each hypothesized stressor from the IEP MAST Report (2015) or updated the conceptual models in the IEP MAST Report (2015). While new information has since come out, such as the effect of contaminants on the larval and juvenile life stages, State Water Project (SWP) and Central Valley Project (CVP) are not a proximate cause of the toxicity stressor for Delta smelt. Therefore, the toxicity stressor was only analyzed for adult life stage in accordance with the MAST model.

- Adults

  - Toxicity: Chemical contaminants such as certain pesticides, mercury and selenium have been shown to have deleterious health effects on aquatic organisms in the Delta including Delta smelt.
  - Water Temperature: Delta water temperatures determine the beginning and duration of the Delta smelt spawning season.
  - Food Availability/Visibility: Variability in prey availability during winter and spring affects growth and fecundity (eggs per clutch and number of clutches) of female Delta smelt. Delta smelt feed optimally at turbidities less than 12 NTU.
  - Predation Risk: Hydrology interacting with turbidity affects predation risk for adult Delta smelt. Predator distribution affects predation risk of adult Delta smelt.
  - Entrainment Risk: Hydrology and water exports interact to influence entrainment risk for adult Delta smelt.
- Eggs & Larvae
  - Water Temperature: Delta smelt larvae numbers are positively affected by increased duration of the water temperature spawning window.
  - Food Availability/Visibility: Increased food availability results in increased Delta smelt larval abundance and survival. Larval fish require turbidity to feed; turbid conditions may provide better contrast between prey and background.
  - Predation Risk: Distributional overlap of Mississippi silverside with Delta smelt and high abundance of Mississippi silverside increases predation risk/rate on larval Delta smelt, whereas, increased turbidity decreases predation risk/rate on larval Delta smelt.
  - Entrainment Risk & Transport Direction: Hydrology and water exports interact with one another to influence direction of transport and risk of entrainment for larval Delta smelt.
- Juveniles
  - Toxicity from Harmful Algal Blooms: Juvenile Delta smelt survival and growth is reduced by harmful algal blooms (HAB) because of direct (habitat quality and toxic) effects.
  - Water Temperature: High water temperatures reduce juvenile Delta smelt growth and survival through lethal and sublethal (bioenergetic stress; reduced distribution) effects.
  - Food Availability & Quality: Juvenile Delta smelt growth and survival is affected by food availability. Juvenile Delta smelt survival and growth is reduced by HAB because of indirect (food quality and quantity) effects.
  - Predation Risk: Distribution and abundance of Striped Bass, temperature, and turbidity influence predation risk/rate on juvenile Delta smelt.

- Entrainment Risk & Transport Direction: Hydrology and water exports interact to influence entrainment risk for juvenile Delta smelt.
- Harmful Algal Blooms: Sub-adult Delta smelt abundance, survival and growth are reduced by HAB because of direct (habitat quality and toxic) effects and indirect (food quality and quantity) effects.
- Size and Location of LSZ: Sub-adult Delta smelt abundance, survival and growth are affected by the size and position of the low salinity zone during fall.

### 9.1.4 Management Activities

In 2016, the State of California issued the *Delta Smelt Resiliency Strategy* to address both immediate and long-term need of Delta smelt. The resiliency objectives and Proposed Actions for the benefit of Delta smelt are discussed below.

#### *9.1.4.1 Resiliency Objectives and Actions Related to the Long-Term Operation of the CVP and SWP:*

1. Improved Delta smelt vital rates, including:
    a. Higher growth rates
    b. Higher fecundity levels
2. Improved habitat conditions, including:
    a. Increased spawning and rearing habitat area
    b. Improved habitat quality
    c. Increased food resources
    d. Higher turbidity
    e. Reduced levels of invasive species (e.g., aquatic weeds, nonnative predators)
    f. Reduced levels of HAB

The following actions, as identified in the 2016 Resiliency Plan, are associated with Reclamation’s operation of the CVP and California Department of Water Resources' (DWR’s) operation of the SWP. The current status of these objectives are included.

1. *Aquatic weed control*
    a. Herbicide treatments (fluridone) were tested in the north and central Delta in a large-scale study from 2017-2018 but the treatments appeared to be ineffective at controlling submerged aquatic vegetation in these regions (Rasmussen et al. 2022).
2. *North Delta food web adaptive management projects*

   a. *DWR, Reclamation, and water users propose to increase food entering the north Delta through promoting food production and/or exporting food from augmented flow in the Yolo Bypass. DWR, Reclamation, and water users would work with partners to redirect water in the Colusa Basin Drain through Knight's Landing Ridge Cut and the Tule Canal to Cache Slough, improving the aquatic food web in the north Delta for fish species. Reclamation would work with DWR and partners to augment flow in the Yolo Bypass in July and/or September by closing Knights Landing Outfall Gates and routing water from Colusa Basin into Yolo Bypass to promote fish food production.* This activity was implemented and a recent synthesis (Davis et al. 2022) did not find clear, consistent responses in zooplankton, fish, or downstream chlorophyll or phytoplankton.

3. *Outflow augmentation*

   a. This ongoing activity is part of operations and addressed in this consultation.

4. *Reoperation of the Suisun Marsh Salinity Control Gates*

   a. *Suisun Marsh Salinity Control Gate (SMSCG) operations for up to 60 additional days (not necessarily consecutive) from June 1 through October 31 of below normal and above normal, years. This action may also be implemented in wet years if preliminary analysis shows expected benefits.* This ongoing activity is part of operations and addressed in this consultation.

5. *Sediment supplementation in the Low Salinity Zone*

   a. Reclamation proposed to develop and implement a sediment supplementation feasibility study; however, litigation and reinitation reduced the priority. This activity is not being currently pursued.

6. *Roaring river distribution system food production*

   a. *Water users proposed to add fish food to Suisun Marsh through coordinating managed wetland flood and drain operations in Suisun Marsh, Roaring River Distribution System food production, and reoperation of the Suisun Marsh Salinity Control Gates.* As noted in the Delta Smelt Resiliency Strategy, this management action may attract Delta smelt into the high-quality Suisun Marsh habitat in greater numbers, reducing use of the less food-rich Suisun Bay habitat (California Natural Resources Agency 2016). Infrastructure in the Roaring River Distribution System may help drain food-rich water from the canal into Grizzly Bay to augment Delta smelt food supplies in that area. In addition, managed wetland flood and drain operations can promote food export from the managed wetlands to adjacent tidal sloughs and bays. *Reclamation and DWR will monitor dissolved oxygen at Roaring River Distribution System drain location(s) to ensure compliance with Water Quality Objectives established in the San Francisco Bay Basin Plan when Delta smelt food* *actions are being taken*. Recent DWR investigations into the resiliency of the distribution system have found significant repairs will be necessary to meet the strategy's objective of the management action. This ongoing activity is concurrent but separate from this consultation.

7. *Coordinate managed wetland flood and drain operations in Suisun Marsh*
    a. *Based on the findings of a current study on Joice Island, DWR will coordinate with the Suisun Resource Conservation District and CDFW to develop a management plan for managed wetland flood and drain operations that can promote food export from the managed wetlands to adjacent tidal sloughs and bays.* This ongoing activity is concurrent but separate from this consultation.
8. *Adjust fish salvage operations during summer and fall*
    a. DWR used historical fish data to evaluate this proposal and found that the quantity of non-native fish potentially removed would be modest compared to total predator populations in the Delta. Several logistical issues also were identified with this concept.
9. *Rio Vista research station and Fish Technology Center*
    a. USFWS is proposing to construct a Fish Technology Center (FTC) to study Delta smelt and other imperiled species as part of a larger Delta Research Station located near Rio Vista, California. The FTC is envisioned to operate as a stand-alone facility for maintaining a refugial population of Delta smelt and for propagation research, conservation, and study of other imperiled fishes. Currently the construction of the FTC is at the 35% design review. This ongoing activity is concurrent but separate from this consultation.
10. *Near-term Delta smelt habitat restoration*
    a. Tidal habitat restoration projects in the Bay-Delta and the Suisun Marsh have been ongoing. Several of these projects are currently completed, have construction ongoing or are actively permitted either through specific Section 7(a)(2) consultations or under a Programmatic Biological Opinion for Tidal Habitat restoration in the Suisun Marsh that is expected to satisfy the 8,000 acre threshold set forth in the 2008 reasonable and prudent alternative (RPA). This ongoing activity is concurrent but separate from this consultation.
11. *Delta Smelt Supplementation*
    a. Beginning in 2021, cultured Delta smelt from the University of California, Davis Fish Culture and Conservation Laboratory were release into the north Delta arc. These releases are expected to continue and number of fish releases to increase as production capacity increases.

#### 9.1.4.2 Recovery Plan Activities Related to CVP and SWP

In 1996, the USFWS issued a "*Recovery Plan for the Sacramento-San Joaquin Delta Native Fishes*" which includes the Delta 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 Contra Costa Water District Rock Slough Intake (Priority 2)* - This ongoing activity is concurrent but separate from this consultation.
    - *Restrict diversions by the Contra Costa Water District 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.
  - *Conduct surveys for adult Delta smelt in the San Joaquin River and tributary sloughs from December through April (Priority 2)* - This ongoing activity is concurrent but separate from this consultation.
  - *Monitor the location of the 2 parts per thousand isohaline and relate to Delta 14-day running mean outflow and CDFW surveys that determine Delta smelt abundance (Priority 2)* - This ongoing activity is part of operations and addressed in this consultation.

#### *9.1.4.3 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)*

#### *9.1.4.4 Monitoring*

The Enhanced Delta Smelt Monitoring (EDSM) program began in November 2016 to acquire finer temporal resolution information than existing surveys provided about the spatial distribution and abundance of Delta smelt. EDSM is a year-round weekly sampling program that samples randomly selected locations using a probabilistic procedure aimed at providing a spatially dispersed sample. This is a significant improvement on existing surveys, which sample in the same locations again and again, and may find no fish. EDSM sampling is repeated until a fish is caught or an upper limit on the number of tows is reached. EDSM methodology attempts to lower the probability of a “False Zero,” that is, failing to catch fish when fish are present, while aiming to minimize the “take” of a threatened species. EDSM is the only survey that allowed agencies to measure where Delta smelt are located since 2018, given their increasingly low abundance. Table 9-1 through Table 9-3 summarize the Delta smelt take by life stage between the years of 2020 through 2022.

- CDFW’s 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’ Delta Beach Seine Survey (1976 - Present).
- CDFW’s Summer TNS (1959 - Present).
- CDFW’s Striped bass egg and larval survey (1968 - 1995).
- IEP’s 20mm survey (1995 - Present). This survey runs in the spring to catch larval and juvenile Delta smelt.
- U.S. Army Corps of Engineers Napa River Survey (2001 – Present). This survey catches Delta smelt in the Napa River.
- IEP’s SKT (2002 – 2024).
- North Bay Aqueduct Larval Fish Survey (1996 - Present).

Table 9-1. Summary of Delta smelt take and mortality by life stage, 2020.

| Delta Smelt - 2020 | Sum of Expected Take | Sum of Actual Take | Sum of Indirect Mortality | Sum of Actual Mortality |
|---|---|---|---|---|
| Adult | 0 | 8 | 0 | 0 |
| Adult Equivalent | 20328 | 50 | 0 | 0 |
| Egg | 0 | 0 | 0 | 0 |
| Juvenile | 0 | 34 | 0 | 0 |
| Larvae | 0 | 38 | 0 | 0 |
| Not Specified | 100 | 0 | 0 | 0 |
| **Grand Total** | **20428** | **130** | **0** | **0** |

Table 9-2. Summary of Delta smelt take and mortality by life stage, 2021.

| Delta Smelt - 2021 | Sum of Expected Take | Sum of Actual Take | Sum of Indirect Mortality | Sum of Actual Mortality |
|---|---|---|---|---|
| Adult | 0 | 16 | 0 | 0 |
| Adult Equivalent | 20331 | 21 | 0 | 0 |
| Egg | 0 | 0 | 0 | 0 |
| Juvenile | 0 | 8 | 0 | 0 |
| Larvae | 0 | 2 | 0 | 0 |
| Not Specified | 100 | 0 | 0 | 0 |
| **Grand Total** | **20431** | **47** | **0** | **0** |

Table 9-3. Summary of Delta smelt take and mortality by life stage, 2022.

| Delta Smelt – 2022 | Sum of Expected Take | Sum of Actual Take | Sum of Indirect Mortality | Sum of Actual Mortality |
|---|---|---|---|---|
| Adult | 0 | 65 | 0 | 0 |
| Adult Equivalent | 20331 | 69 | 0 | 0 |
| Egg | 0 | 0 | 0 | 0 |
| Juvenile | 0 | 18 | 0 | 0 |
| Larvae | 0 | 16 | 0 | 0 |
| Not Specified | 100 | 4 | 0 | 0 |
| **Grand Total** | **20431** | **172** | **0** | **0** |

### 9.1.5 Current Incidental Take Statement

Qualitative incidental take for the 2019 USFWS Biological Opinion on the Coordinated Long-term Operation of the CVP and SWP are described below.

#### *9.1.5.1* ***Adults***

Take from South Delta Entrainment:

- During the early winter, if and when the single annual, system-wide first flush has been identified pursuant to the criteria identified in the Proposed Action, net negative flow in Old and Middle River (OMR) should be held to no greater than a 14-day averaged OMR of -2000 cfs for 14 days to prevent turbidity from being pulled into the south Delta and creating a continuous band of turbidity from the Sacramento River to the export facilities.
- Following first flush, OMR would be no more negative than -5,000 cfs and may be limited by additional protections.
- During the winter and early spring, net negative OMR flows should be held at levels no more negative than a 14-day averaged OMR of -2000 cfs, for at least 5 days, when turbidity at the Old River at Bacon Island monitoring station (OBI) is a daily average of 12 NTU or greater.

Take of Delta smelt at the North Bay Aqueduct

- A cumulative total of no more than 30 TAF of water will be diverted through the North Bay Aqueduct diversions during the months of March, April, and May.

Take of Delta smelt at the Roaring River and Morrow Island Distribution Systems

- Approach velocity at the screens is limited to 0.2 ft/second except during mid-September – mid October, when Roaring River Distribution System diversion rates are controlled to maintain a maximum approach velocity of 0.7 ft/second for fall flood up operations.

#### *9.1.5.2* ***Eggs and Larvae***

Take from South Delta Entrainment

- The first flush action is anticipated to reduce adults spawning in locations where eggs and larvae would be subsequently entrained.
- During March-June, negative OMR flows should be managed at no more negative than -5000 cfs on a 14-day moving average or no more negative than -3,500 cfs when secchi depths are less than 1 meter in the south Delta.

Take of Delta smelt at the North Bay Aqueduct

- A cumulative total of no more than 30 TAF of water will be diverted through the North Bay Aqueduct diversions during the months of March, April, and May.

Take of Delta smelt at the Roaring River and Morrow Island Distribution Systems

- Approach velocity at the screens is limited to 0.2 ft/second except during mid-September – mid October, when RRDS diversion rates are controlled to maintain a maximum approach velocity of 0.7 ft/second for fall flood up operations.

#### *9.1.5.3* ***Juveniles***

Take from South Delta Entrainment

- The first flush action is anticipated to reduce adults spawning in locations where juveniles would be subsequently entrained
- During March-June, negative OMR flows should be managed at no more negative than -5000 cfs on a 14-day moving average

Take of Delta smelt at the North Bay Aqueduct

- A cumulative total of no more than 30 TAF of water will be diverted through the North Bay Aqueduct diversions during the months of March, April, and May.

Take of Delta smelt at the Roaring River and Morrow Island Distribution Systems

- Approach velocity at the screens is limited to 0.2 ft/second except during mid-September – mid October, when RRDS diversion rates are controlled to maintain a maximum approach velocity of 0.7 ft/second for fall flood up operations.

## 9.2 Effects Analysis

The following sections summarize potential effects of the Proposed Action to Delta smelt by life stage and stressors from *"An Updated Conceptual Model of Delta Smelt Biology: Our Evolving Understanding of an Estuarine Fish"* produced by the Delta Smelt Management Analysis, and Synthesis Team (IEP MAST 2015). 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, *Species Spatial and Temporal Domains*, 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 MAST conceptual models may or may not change from the proposed operation of CVP and SWP facilities 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 are 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 extremely unlikely to occur. Based on best judgment, a person would not be able to expect discountable effects to occur.

Stressors that may result in effects on listed species were documented and proposed conservation measures identified.

### 9.2.1 Adult Migration and Spawning

Delta smelt begin their spawning migration from the low salinity zone to more landward freshwater regions in the Bay-Delta in the winter and early-spring in response to “first flush” events (Grimaldo et al. 2009), which provide increased flow and turbidity (Sommer et al. 2011). A portion of the Delta smelt population are year-round residents of freshwater or brackish water regions (Hobbs et al. 2019). Spawning does not begin until mid-winter and peaks in the early to late spring (Bennett 2005). Female Delta smelt can produce multiple clutches of eggs depending on environmental conditions (Damon et al. 2016).

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

- The Proposed Action may decrease the *toxicity* stressor. During the adult life stage, CVP and SWP storage and diversion decreases Delta inflow. Increased runoff can increase mobilization of contaminants from agricultural and urban areas.

  Increased flows have been noted to increase loading of contaminants and mobilization of sediment bound contaminants in the Cache Slough as part of seasonal flow actions (Stillway et al. 2021, Davis et al 2022). Contaminant concentrations depend on the sampling location and contaminant (Stillway et al. 2021). Contaminants also vary in their half-life and thus longevity in the system depends on the contaminant (Gan et al. 2005). In any case, effects 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 may increase the *water temperature* stressor. During the adult life stage, CVP and SWP storage and diversion decreases Delta inflow during the spring. Delta water temperature is negatively correlated with Delta inflow in the spring (Bashevkin and Mahardja 2022).

  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). There is uncertainty about whether the decreased inflow is a cause for increased Delta water temperatures. 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 at Prisoner’s Point rarely exceed 68°F (adult Delta smelt non-lethal effects) in early 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 decrease the *food visibility* stressor. Delta smelt (~120 days post-hatch) ability to forage is optimal when turbidity levels are below 12 NTU (Hasenbein et al. 2013). CVP and SWP storage and diversions, including nondiscretionary flood control operations, decreases Delta inflow and outflow, which may reduce turbidity.

  The contribution of diversions, via reduced outflow, to reducing the total suspended sediment budget in the estuary is small (Schoellhamer et al. 2012). Wright and Schoellhamer (2005) estimated only about 2% of the sediment discharged at Freeport were diverted by CVP and SWP projects based on sediment deposition in Clifton Court Forebay. Additionally, the effect of larger scale decreases in turbidity can be explained largely by the proliferation of aquatic plants like *Egeria densa* (Hestir et al. 2015), and smaller scale changes in turbidity are largely tide- and wind-driven (Bever et al. 2018).

- The Proposed Action may increase the *predation* stressor. During the adult migration and spawning period, the Proposed Action reduces Delta inflow and outflow, which may alter hydrodynamic conditions in the Delta. 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, Delta 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). The operation of the Tracy Fish Collection Facility to achieve water approach velocities for striped bass may result in additional predation stressor on Delta smelt adults due to the salvage and release of this important Delta smelt predator. Effects of the Proposed Action on water temperature and food visibility that may interact with the predation stressor were analyzed in those sections. 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.

#### *9.2.1.1 Food Availability Stressor*

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. Delta smelt adults feed primarily on calanoid copepods, including *Eurytemora affinis* and *Sinocalanus doerrii*, during the winter and spring (Slater et al. 2019). Fish larvae from winter spawning fish such as Pacific herring and prickly sculpin were also found to be seasonally important for Delta smelt (Slater et al. 2019, Hammock et al. 2019). Abundances of historically important Delta smelt zooplankton prey taxa in the LSZ, including *Eurytemora affinis*, generally exhibit a positive correlation with Delta outflow in the spring (Kimmerer 2002a). Hamilton et al. (2020) found pulse spring flows in dry water years can increase copepod biomass near Suisun Bay. Appendix J, *Winter and Spring Pulses and Delta Outflow: Smelt, Chinook Salmon, and Steelhead Migration and Survival*, analyzes the effect of the spring Delta outflow conservation measure 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 **sub-lethal** to **lethal**. Higher food abundances in theory result in greater consumption and faster growth rates, leading to healthier and larger fish who produce larger clutches of eggs and possibly even multiple clutches of eggs in a spawning season (Damon et al. 2016). Food availability is hypothesized to be important for adult spawning and survival (Miller et al. 2012), larval recruitment (Polansky et al. 2021), and population growth rate (Rose et al. 2013b) but information on adult feeding in the wild during the winter-spring spawning period is insufficient (IEP MAST 2015) to differentiate effects of summer and fall food limitation from potential winter food limitation. Polansky et al. (2021) found the availability of large prey items for late juveniles and adults to be one of the factors that affects larval recruitment most. Hung et al. (2014) found cultured female Delta smelt with early-stage eggs had higher stomach content than males and spawning females, suggesting that feeding may be important for egg development. Kurobe et al. (2022) found reduced reproductive performance during drought years compared to a wet year and hypothesized that food limitation during the drought years may have reduced growth and fecundity. Food limitation can also weaken Delta 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 Delta smelt migration and spawning exists in the **environmental baseline** (without the Proposed Action). The MAST Report summarizes the “dramatic morphological, hydrological, chemical, and biological alterations [to the Delta] since the onset of the California Gold Rush in the middle of the 19th century (Nichols et al. 1986, Arthur et al. 1996, Baxter et al. 2010, Brooks et al. 2012, NRC 2012, Whipple et al. 2012, Cloern and Jassby 2012).” 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 2002a), 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* (Avila and Hartman 2020, 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 National Marine Fisheries Service (NMFS) in 2004/2005, 2008/2009, and 2019.

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 Delta 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 decreased food availability and quality in the Delta depends on outflow and is **likely medium**. Reclamation considered historical environmental monitoring data on food availability and historical adult Delta smelt regional distributions to estimate the proportion of the population affected by an increase in the food availability stressor.

Within the literature, Merz et al. (2011) found the pre-spawning adult average annual frequency of occurrence from Jan. – April 2002-2009 in the low salinity zone regions (Suisun Bay, Suisun Marsh and the Confluence) ranged from 23.3% (Suisun Bay SW) to 62% (Suisun Marsh) to 30% (Confluence).

Datasets use historical conditions and observation to inform how Delta smelt may respond to the Proposed Action. Historical monitoring may support or refute hypotheses and informs the reasonableness of information generated by models. Zooplankton abundance differs regionally, freshwater regions tend to have higher mesozooplankton density, except on occasion during years with higher outflow have higher density (see 2006 and 2017). Adults present in the low salinity zone (0.5-6) and high salinity zones (>6) may experience food limitation compared to fish in freshwater regions.

Figure 9-6 shows the average catch per unit effort (CPUE) of selected Delta smelt mesozooplankton prey from EMP surveys in the freshwater, low salinity zone, and high salinity zone regions.

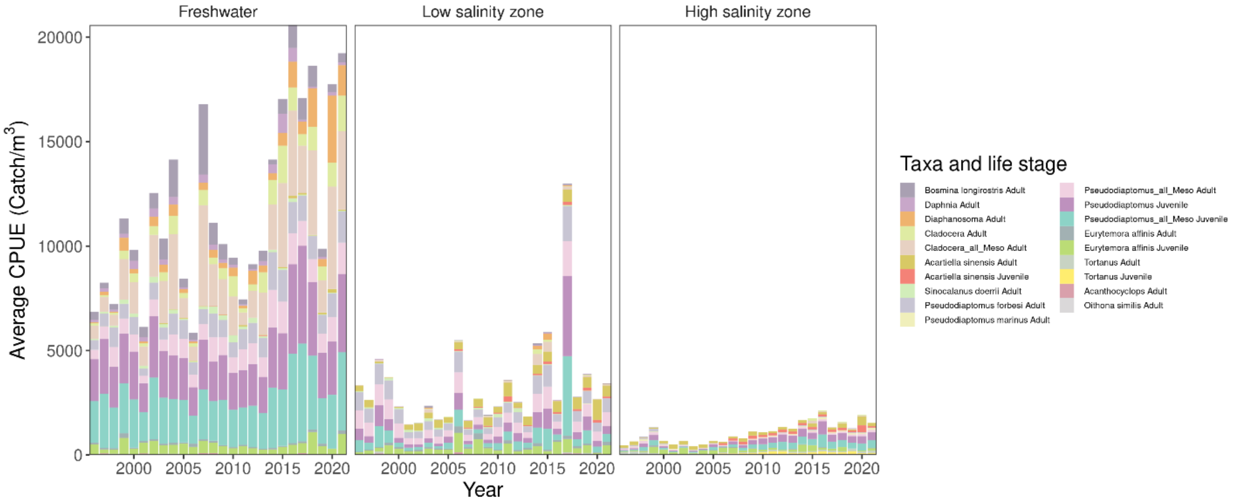


Figure 9-6. Average CPUE of selected Delta Smelt mesozooplankton prey from January to May of 1996-2021 from EMP surveys. Selected prey species were from major prey categories in Slater et al. 2019.

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, provides context for zooplankton density available for Delta smelt adults in the LSZ during the winter (December – February) and spring (March- May). The analysis is a regression of the relationship between historical seasonal zooplankton abundance (CPUE) and seasonal Delta outflow (cfs).

During the winter months, *Daphnia* adults, decapod larvae, *Eurytemora affinis* (copepod) adults, 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. Modeled abundance of zooplankton CPUE resulting from different CalSim3 simulated Delta outflow are presented in Figure 9- 7. All the above taxa/groupings have been found in adult Delta smelt gut content studies (Slater et al. 2019).

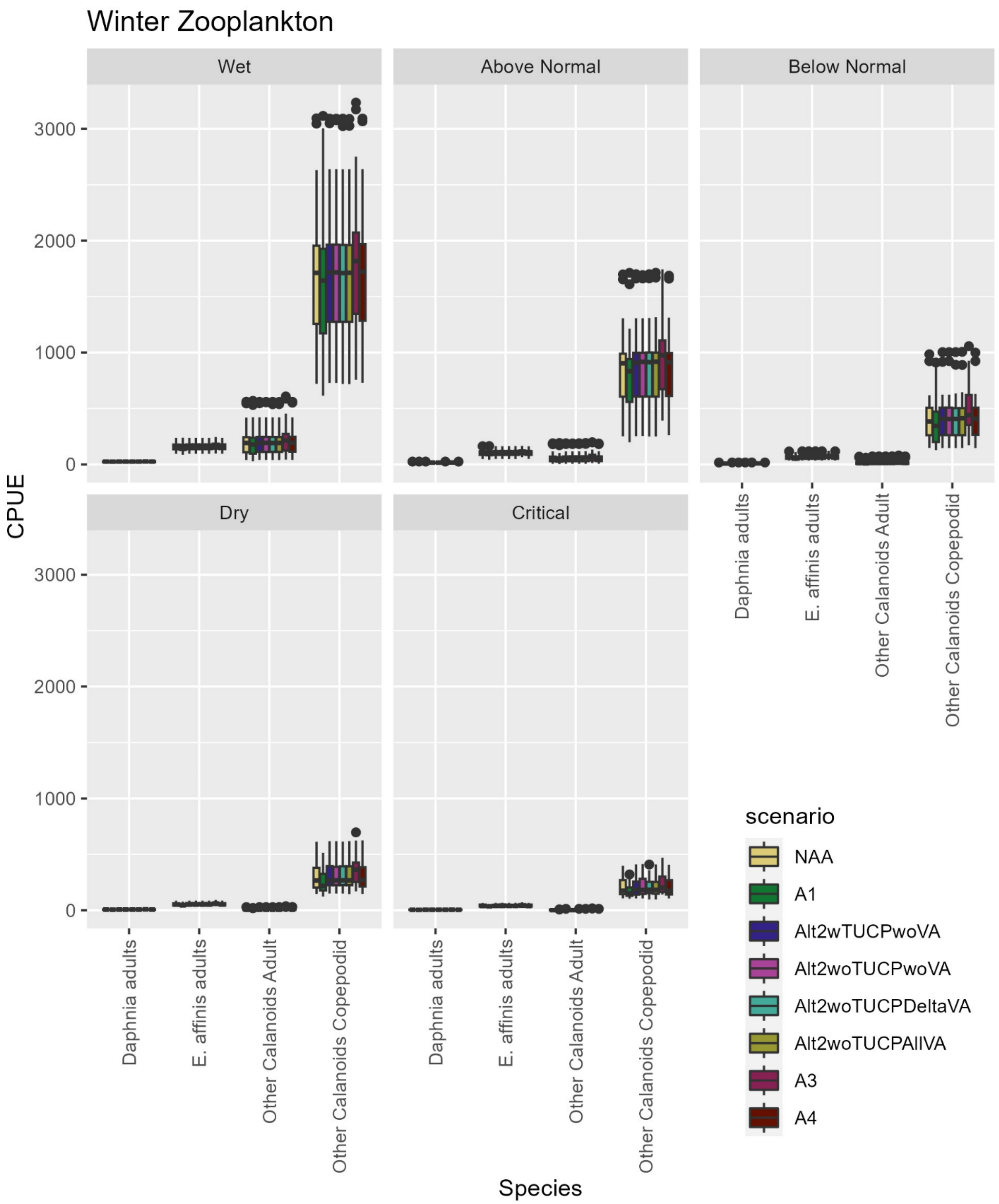


Figure 9-7. Median, quartile and interquartile ranges of CPUE of significant zooplankton species by scenario across different water year types for winter. Scenarios EXP1, EXP3 and NAA included as reference.

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. Modeled abundance of zooplankton CPUE resulting from different CalSim3 simulated Delta outflow are presented in figure 9- 7. All the above taxa/groupings have been found in adult Delta smelt gut content studies (Slater et al. 2019).

The CPUE under the Proposed Action phases varied among water year types; the wet water year type (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 (2002a) 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).

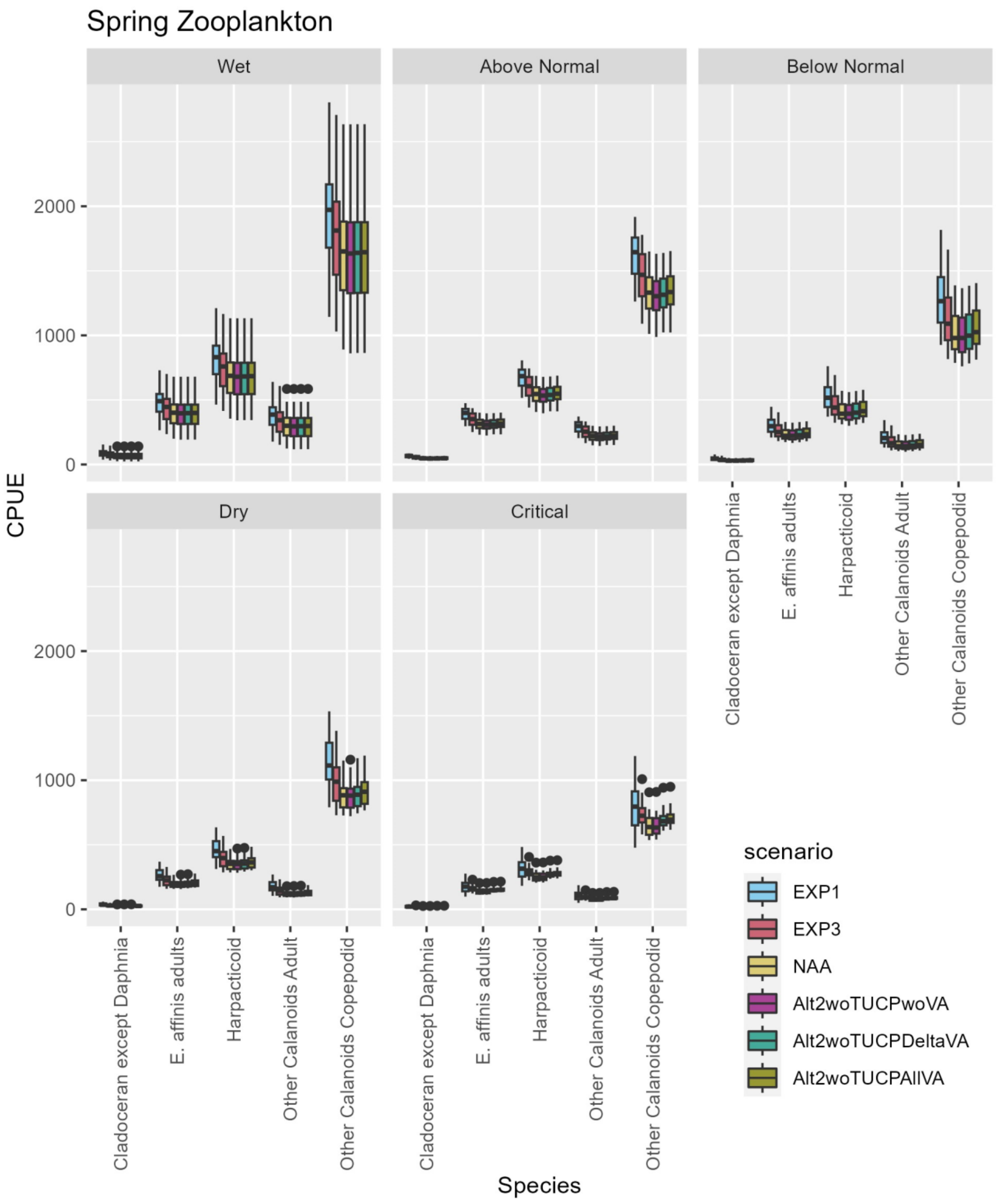


Figure 9-8. Median, quartile and interquartile ranges of CPUE of significant zooplankton species by scenario across different water year types for spring. Scenarios EXP1, EXP3 and NAA included as reference.

The **frequency** of occurrence is annual, depends on the hydrology, and is **likely high**. In 21 out of 27 (~78%) years, spring outflow was low (Figure 9). In 22 out of 27 (~81%) years, winter outflow was low.

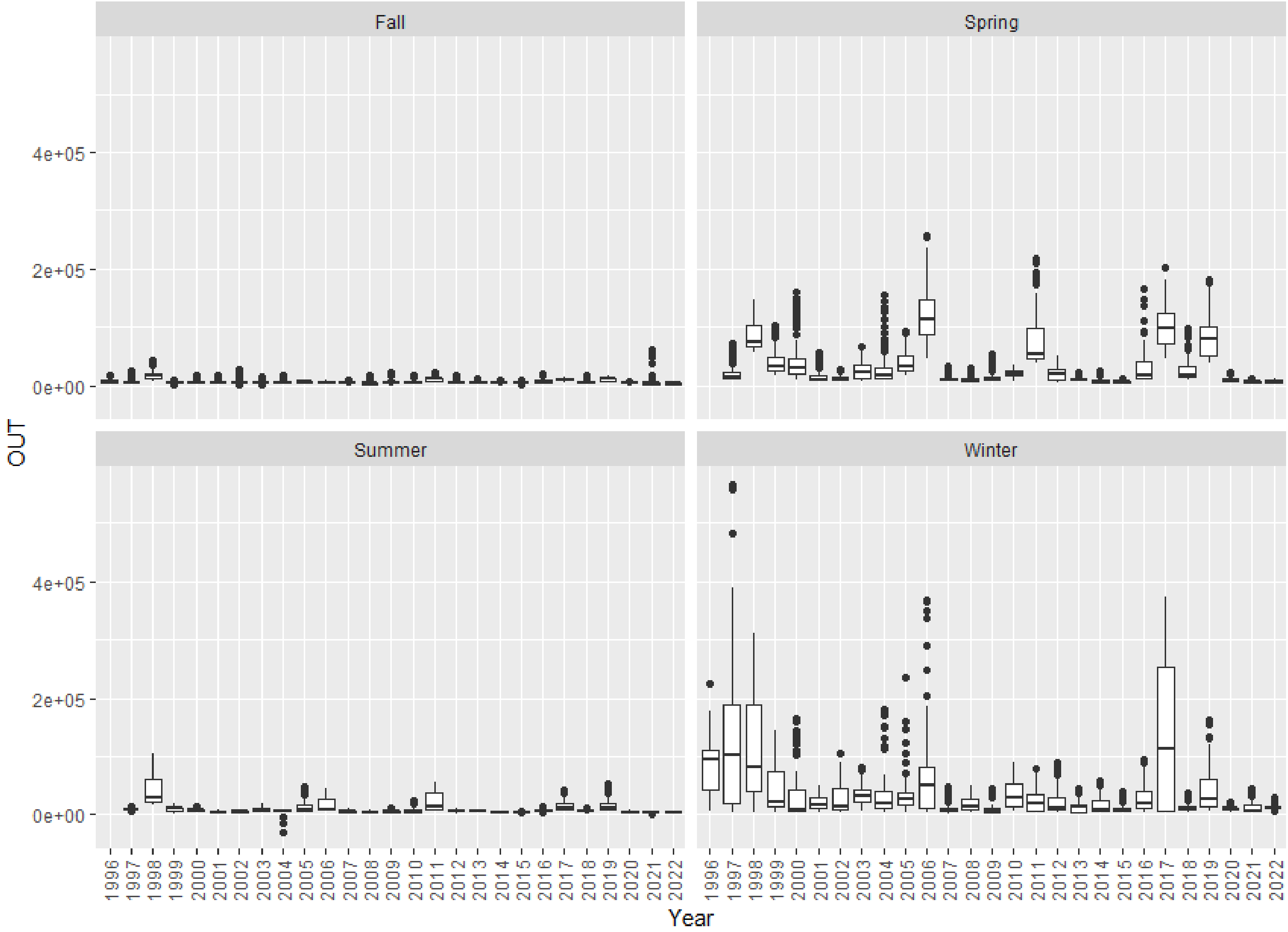


Figure 9-9. Boxplots for outflow (CFS) at Chipps Island (from California Data Exchange Center) from 1996-2022.

To evaluate the **weight of evidence** for the food availability stressor, 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.

- Merz et al. 2011 used historical survey data that are quantitative, species specific, and location specific. The analysis is published in the white literature and uses several years of historical data across multiple water year types but does not reflect the more recent decline of Delta smelt.

- The Zooplankton Flow Analysis Model is quantitative and location 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
- Delta Smelt Supplementation

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

#### *9.2.1.2 Entrainment Stressor*

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 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 through specific migratory pathways in the Delta where tidal surfing behaviors (Sommer et al. 2011) route Delta smelt into areas with increased entrainment risk. Entrainment of adult Delta smelt into the South Delta and the facilities is most likely during the movement of fish from brackish waters to freshwater regions (Smith et al. 2021, Grimaldo et al. 2021, Grimaldo et al. 2009, Kimmerer 2008). Entrainment into the facilities tends to be highest when OMR flows are negative (i.e., reversed) and when turbidity is high (Smith et al. 2021). Multiple topic-specific appendices address aspects of adult migration through the Delta.

- Appendix F, *Alternatives Modeling* including Section 5.1, *Delta Smelt Life Cycle Model with Entrainment (LCME)* and Section 5.4, *Delta Smelt Maunder and Deriso in R Model*
- Appendix G, including sections for *Tracy Fish Collection Facility* and *Skinner Fish Delta Fish Protective Facility*
- Appendix H, *Conservation Measure Deconstruction*, presents analyses of the conservation measures for *Old and Middle River Management Real Time Operation* (Section 5.5) and *Delta Cross Channel Gates Closures* (Section 5.1)

The current Proposed Action involves several actions intended to minimize the entrainment of adult Delta 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 Delta smelt.

The increase in entrainment risk stressor is expected to be **lethal**. Entrainment can result in direct mortality by removal through the Delta fish collection facilities or by routing fish into areas of poor survival. Pre-screen losses of Delta smelt are likely due to predation (IEP MAST 2015, Castillo et al. 2012). Entrainment into the south Delta can lead to consistently high rates of pre-screen losses of adult and juvenile Delta smelt in Clifton Court Forebay due to predation (Castillo et al. 2012). When Delta smelt 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 adult Delta smelt.

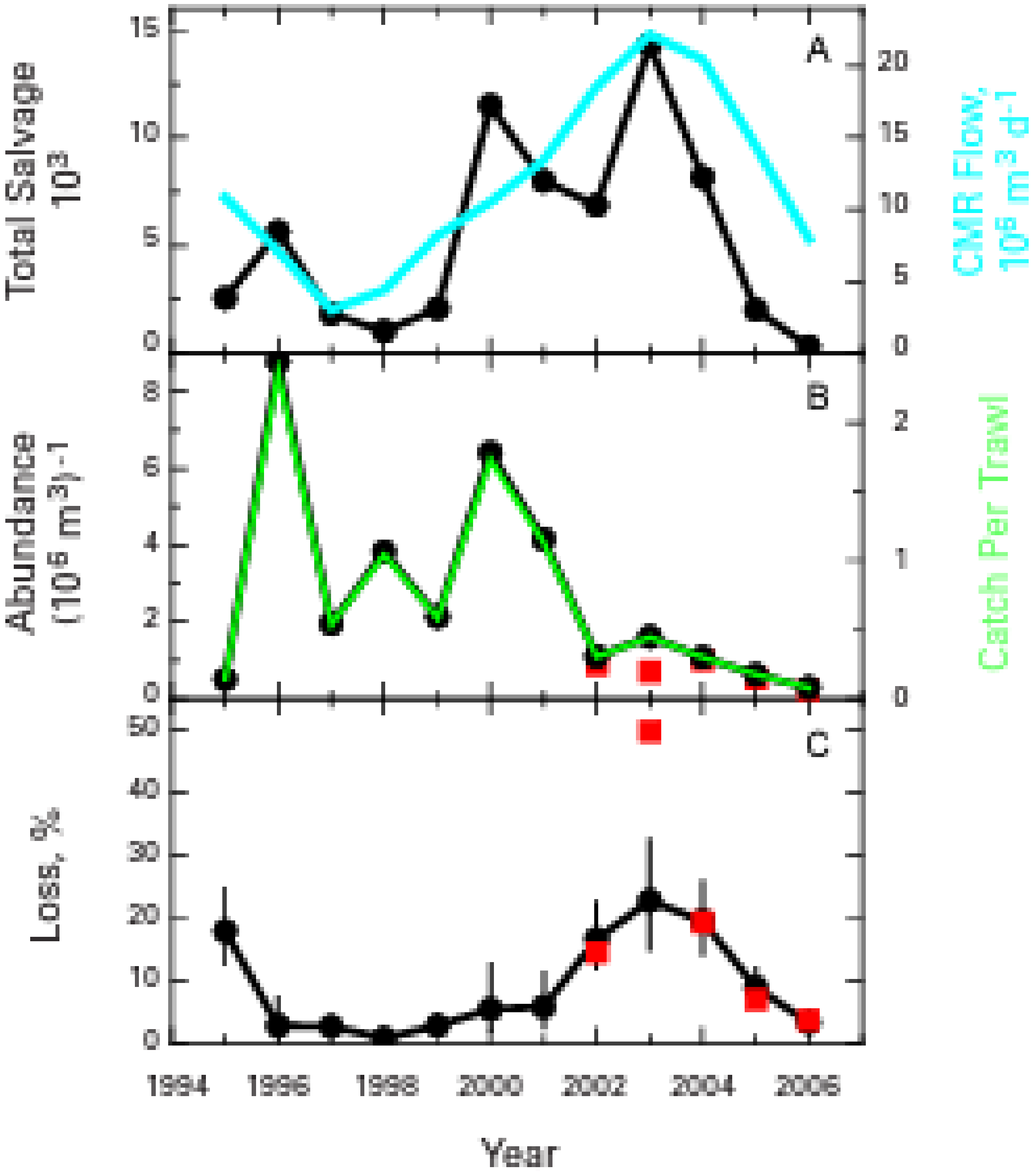
Although the Proposed Action may increase the entrainment risk stressor, entrainment of adult Delta smelt exists in the **environmental baseline** (without the Proposed Action). The MAST Report summarizes the “dramatic morphological, hydrological, chemical, and biological alterations [to the Delta] since the onset of the California Gold Rush in the middle of the 19th century.” 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 Delta 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.

The **proportion** of the population affected by the Proposed Action varies annually and depends on hydrology, turbidity, 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.

Literature evaluates historical entrainment of Delta smelt. Delta smelt residing in the south Delta are at higher risk of being entrained. Merz et al. (2011) found the average annual frequency of adult pre-spawning Delta smelt occurrence in the South Delta was 7.1%.

During past operations, Kimmerer (2008) estimated the proportional loss of adult Delta Smelt due to entrainment to range from 1-50% (median of 15%) (Figure 9-9). Kimmerer (2011) re-analyzed the adult proportional losses in response to comments by Miller (2011). During the high flow years of the mid 1990’s predicted proportional losses due to entrainment were low, while during lower flow years (early to mid-2000’s), the proportional losses were medium.

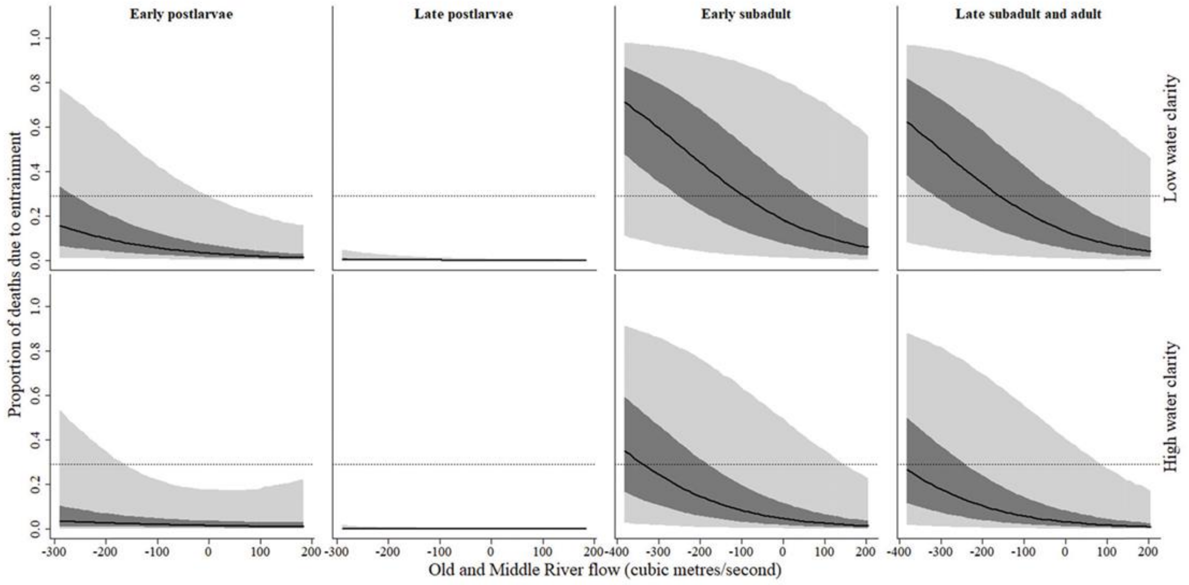


Source: Kimmerer 2008

Figure 9-10. Reconstructed Delta smelt export losses for 1995-2006.

Smith et al. (2021) developed a model to predict entrainment mortality at two levels of water clarity for late sub-adult and adult Delta Smelt (Figure 9-10). Predicted estimates of proportional mortality due to entrainment indicate that when OMR was negative and water clarity was low the proportion affected was medium. When OMR was negative and water clarity was high, the proportion affected was medium. When OMR was positive and water clarity was low, the proportion affected was low. When OMR was positive and water clarity was high, the proportion affected was low (Smith et al. 2021).

**Fig. 3.** Posterior distributions of predicted entrainment mortality at two levels of water clarity (2007–2015 interquartile range) and a range of Old and Middle river flows. The dark shaded regions indicate the interquartile range of posterior predictions, and the light shaded regions indicate the 95% credible intervals. The dotted horizontal lines indicate the reference point 0.41 × natural mortality, or 0.29 × total mortality (Zhou et al. 2012).



Source: Smith et al. 2021.

Figure 9-11. Predicted entrainment mortality for Delta Smelt based on OMR flows for two different water clarity scenarios.

Using a behavioral-driven movement model, Korman et al. 2021 paper estimated proportional entrainment losses for water year 2002 (a year with high salvage year) was 35% (medium) compared to the estimates from Kimmerer 2008 of 15%. Estimates of proportional entrainment loss varied from 2 – 40% depending on the modelled behavior. The highest ranked model (which particles did a tidal migration behavior when perceived salinity was increasing but with holding behavior when turbidity was > 12 NTUs) explained 70% of the spatial and temporal variation of the SKT catch data from all regions.

Historic records of adult salvage generally show fewer fish were entrained during wet years compared to dry and below normal years (Table 9-4). Fewer fish were salvaged after 2008, likely due to a combination of changes to operations and the continued decline of the Delta Smelt population.

Table 9-4. Historic adult delta smelt salvage (> 58 mm FL) from SWP and CVP facilities, Spring Kodiak Trawl Delta Smelt Index and Water Year type based on the Sacramento Valley Index.

| Year | Adult Salvage (>58 mm FL) | CDFW SKT Index | Water Year Type | First Flush | Turbidity Bridge |
|---|---|---|---|---|---|
| 1993 | 84 | - | W | - | - |
| 1994 | 30 | - | C | - | - |
| 1995 | 133 | - | W | - | - |
| 1996 | 216 | - | W | - | - |
| 1997 | 102 | - | W | - | - |
| 1998 | 19 | - | W | - | - |
| 1999 | 98 | - | AN | - | - |
| 2000 | 463 | - | AN | - | - |
| 2001 | 367 | - | D | - | - |
| 2002 | 264 | - | D | - | - |
| 2003 | 471 | - | BN | - | - |
| 2004 | 334 | 99.7 | D | - | - |
| 2005 | 102 | 52.9 | W | - | - |
| 2006 | 50 | 18.2 | W | - | - |
| 2007 | 6 | 32.5 | C | - | - |
| 2008 | 90 | 24.1 | C | - | - |
| 2009 | 8 | 43.8 | BN | - | - |
| 2010 | 21 | 27.4 | AN | - | - |
| 2011 | 15 | 18.8 | W | No | - |
| 2012 | 78 | 130.2 | D | Yes | 3 |
| 2013 | 48 | 20.4 | C | No | 3 |
| 2014 | 0 | 30.1 | C | Yes | 0 |
| 2015 | 7 | 13.8 | C | No | 2 |
| 2016 | 3 | 1.8 | D | No | 1 |
| 2017 | 15 | 3.8 | W | Yes | 3 |
| 2018 | 1 | 2.1 | BN | No | 0 |
| 2019 | 2 | 0.4 | W | Yes | 0 |
| 2020 | 0 | 0.3 | D | No | 1 |
| 2021 | 0 | 0 | C | No | 0 |
| 2022 | 0 | 1.7 | C | Yes | 1 |

Average OMR from mean monthly December to March OMR flows for 1993-2022. 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.

Volumetric influence, flow into junctions, zone of influence (ZOI), and particle tracking modeling results may be applicable for smelt depending on location. Modeling analysis results are presented in Chapter 5, Winter-Run Chinook Salmon. 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 **frequency** of the stressor is directly linked to changes in hydrology resulting from ongoing export operations. Historical salvage records indicate that adult Delta smelt have been entrained in 26 of the past 30 years (86%) (Table 9-4).

The frequency of when First Flush conditions (when the running 3-day average of daily flows and turbidity at Freeport is greater than 25,000 CFS and 50 NTU respectively) were exceeded occurred in 4 out of 11 years (~36%) based on analysis of historical water quality and flow data between WY2010 and WY2021. Adult Delta smelt were salvaged in 3 out of 5 years (60%) where 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%). Adult Delta smelt were salvaged in 4 out of 7 years (~57%) when turbidity conditions were met. Historical monitoring data from the SKT study from 2002-2022 found adult Delta smelt were caught in the south Delta in 8 out of 20 years (40%).

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.

- Merz et al. (2011) used historical survey data that are quantitative, species specific, and location specific. The analysis is published in the white literature and uses several years of historical data across multiple water year types but does not reflect the more recent decline of Delta smelt.
- Kimmerer (2008) used several years of historical data (2002-2006) that are quantitative, species specific, and location specific. The analysis is published in a peer-reviewed journal. The data encompasses multiple water year types to model and reconstruct proportional historical losses, however the estimates have large confidence limits. Additionally, Kimmerer responded to criticisms of his methods with updated equations (Kimmerer 2011).
- Smith et al. (2021) used several years of historical data (1995-2015) that are quantitative, species specific, and location specific. The analysis is published in a peer-reviewed journal. The data was used to develop a hierarchical state-space life cycle model to evaluate entrainment risk and natural mortality.
- Korman et al. (2021) developed a behavioral-driven model paired with a population model (using survey data and salvage estimates) that is quantitative, species specific, and location specific. This analysis is published in a peer-reviewed journal. The results were used to evaluate adult Delta smelt entrainment. The authors considered their proportional entrainment loss estimates to be preliminary and the estimates of proportional entrainment losses varied widely depending on the behavior model used (from 2 – 40%).

- 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).
- 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.
- ZOI 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 Delta Smelt Entrainment Protection Action (Turbidity Bridge)

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

- Drought Actions

### 9.2.2 Eggs and Larvae

Eggs hatch after an average of 10 days in the spring and planktonic larvae are transported (advected) by the Sacramento River and tidal flows from March through May. The larval stage lasts for an average of 30 days. Larval Delta smelt develop into post larvae and most Delta smelt reach the juvenile life stages by July.

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

- The Proposed Action may increase the *water temperature* stressors. 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 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). Historical water temperatures at Prisoner's Point do not exceed 84°F (late-larval Delta smelt critical thermal maximum) in early spring (Komoroske et al. 2014). There is uncertainty about whether the decreased inflow is a cause for increased Delta water temperatures. The uncertainty is due to hypotheses that American River operations is a cause for changes in Delta water temperatures. 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 *food visibility* stressors. CVP and SWP storage and diversions decreases Delta inflow and outflow which may reduce the transport of fine sediment and other particulates that increase turbidity. The foraging ability of Delta smelt larvae is optimal in turbidity levels greater than 25 NTU (Hassenbein et al. 2016).

  During periods of high inflow and outflow (e.g., storm events in the winter and spring), increased storage and diversion of water may result in reduced suspended sediment in regions of the Delta. However, the contribution of diversions to the total suspended sediment budget in the estuary is small (Schoellhamer et al. 2012). Wright and Schoelhamer (2005) estimated only about 2% of the sediment discharged at Freeport were diverted by the CVP and SWP based on sediment deposition in Clifton Court Forebay. Additionally, the effect of larger scale decreases in turbidity can be explained largely by the proliferation of aquatic plants like *Egeria densa* (Hestir et al. 2015), and smaller scale changes in turbidity are largely tide- and wind-driven (Bever et al. 2018).

- The Proposed Action may increase the *predation* stressor. During the larvae development and transport period, the Proposed Action will store and divert water and reduce Delta inflows and outflow, which may alter hydrodynamic conditions in the Delta. Some Delta smelt predators have been found to have a relationship to flows. Higher summer inflows and spring water exports are followed by lower abundances of Mississippi silversides, however the mechanism behind this relationship remains unknown (Mahardja et al. 2016). Historically, on average, catch of silversides declines during the winter and spring months and is less than 2 CPUE (Mahardja et al. 2016). DNA studies of the gut content of Mississippi silversides have found Delta smelt DNA, likely from larval or early juvenile fish (Schreier et al. 2016, Baerwald et al. 2012). In addition, 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. During operations of the CVP/SWP export facilities, larval Delta smelt will be exposed to predation at the Delta fish collection facilities. 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). Predation rates are a function of correlated variables such as predator presence, prey vulnerability, and environmental conditions (Grossman et al. 2013; Grossman 2016).The operation of the Tracy Fish Collection Facility to achieve water approach velocities for striped bass may result in additional predation stressor on Delta smelt larvae due to the salvage and release of this important Delta smelt predator. Reduced turbidity from the Proposed Action can also increase predation risk (Ferrari et al. 2013, Schreier et al. 2016). Effects of the Proposed Action on water temperature and food visibility that may interact with the predation stressor were analyzed in those sections. Other 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 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.

#### *9.2.2.1 Food Availability Stressor*

The food availability stressor may increase. During the planktonic larvae stage, the storage and diversion of water will reduce Delta inflows and outflows. Delta smelt larvae (5-8 mm) consume copepod nauplii and copepodites before switching to adult copepods at larger sizes (> 13 mm) (Nobriga 2002, Slater and Baxter 2014). During the early spring, larvae feed mainly on cyclopoids in the early spring before switching to *Eurytemora affinis* in mid-spring (April-May) and then to *Pseudodiaptomus forbesi* and cladocerans in late-spring, early summer (May-June) (Norbriga 2002, Slater and Baxter 2014). Nobriga (2002) also found a positive relationship between feeding incidence and prey density and suggested long term declines in copepod abundance impacts Delta smelt larvae feeding success. Abundances of historically important Delta smelt zooplankton prey taxa in the LSZ, including *Eurytemora affinis*, generally exhibit a positive correlation with Delta outflow in the spring (Kimmerer 2002a). Hamilton et al. (2020) found pulse spring flows in dry water years can increase copepod biomass near Suisun Bay. Decreased Delta outflows may also limit critical allochthonous subsidies of alternate larval Delta smelt food resources (e.g., *Pseudodiaptomus forbesi*) through reduced advection from more productive upstream areas to Delta smelt rearing habitats. Local zooplankton productivity in these habitats is severely impacted by competition with clams (Kimmerer et al. 2019).

Multiple analyses have shown prey abundance and density are important factors in explaining Delta smelt abundance (Miller et al. 2012, Mac Nally et al. 2010, Thomson et al. 2010, Maunder and Deriso 2011). Hamilton and Murphy (2018) observed effects of food limitation in the spring when modeling Delta smelt abundance over a 40-year period. Food limitation stressors vary on spatial, seasonal, and yearly time scales (Hammock et al. 2015). *Appendix J* analyzes the effect of Spring Delta Outflow on food resources for native fishes. *Appendix P* analyzes zooplankton abundance near different types of habitat.

The increase in food availability and quality stressor is **sub-lethal** to **lethal**. Higher food abundances in theory result in greater consumption and faster growth rates (Beck et al. 2003), leading to healthier and larger fish which presumably are less vulnerable to predation. Food limitation can weaken Delta smelt, leading to such extremes as starvation, and can 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. 2022, Lopes et al. 2022) resulting in higher mortality.

Although the Proposed Action may increase the food availability stressor, changes in food availability for Delta smelt larvae exist in the **environmental baseline** (without the Proposed Action). The MAST Report summarizes the “dramatic morphological, hydrological, chemical, and biological alterations [to the Delta] since the onset of the California Gold Rush in the middle of the 19th century (Nichols et al. 1986, Arthur et al. 1996, Baxter et al. 2010, Brooks et al. 2012, NRC 2012, Whipple et al. 2012, Cloern and Jassby 2012).” 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).”

*Eurytemora affinis* and other zooplankton have experienced long term declines since the introduction of the overbite clam (Winder and Jassby 2011, Kimmerer 2002a), have experienced seasonal shifts in peak abundance (Merz et al. 2016), and have been replaced by non-native species (Winder and Jassby 2011). In the low-salinity zone, the presence of invasive predatory copepods and the overbite clam have caused the decline of *Pseudodiaptomus forbesi* (Kayfetz and Kimmerer 2017, Slaughter et al. 2016). The presence of *Pseudodiaptomus forbesi* in the LSZ is mainly due to subsidies from freshwater regions upstream (Kimmerer et al. 2019). 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.

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 Delta 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** based on the location of past historical catch of larval Delta smelt. Reclamation considered literature and 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.

From the literature, Merz et al. (2011) found larval Delta smelt average annual frequency of occurrence from April to June 1995-2009 in the low salinity zone regions (Suisun Bay, Suisun Marsh and the Confluence) ranged from 17.8% in SW Suisun Bay to 21.4% in Suisun Marsh to 35.7% in the Confluence.

Datasets use historical conditions and observation to inform how Delta smelt may respond to the Proposed Action. Historical monitoring may support or refute hypotheses and informs the reasonableness of information generated by models. Zooplankton abundance differs regionally, freshwater regions tend to have higher mesozooplankton density, except on occasion during years with higher outflow (see 2006 and 2011). Larvae present in the low salinity zone (0.5-6) and high salinity zones (>6) may experience food limitation compared to fish in freshwater regions.

Figure 9-12 shows the CPUE of selected Delta smelt mesozooplankton prey from DWR Environmental Monitoring Program surveys in the freshwater, low salinity zone, and high salinity zone regions.

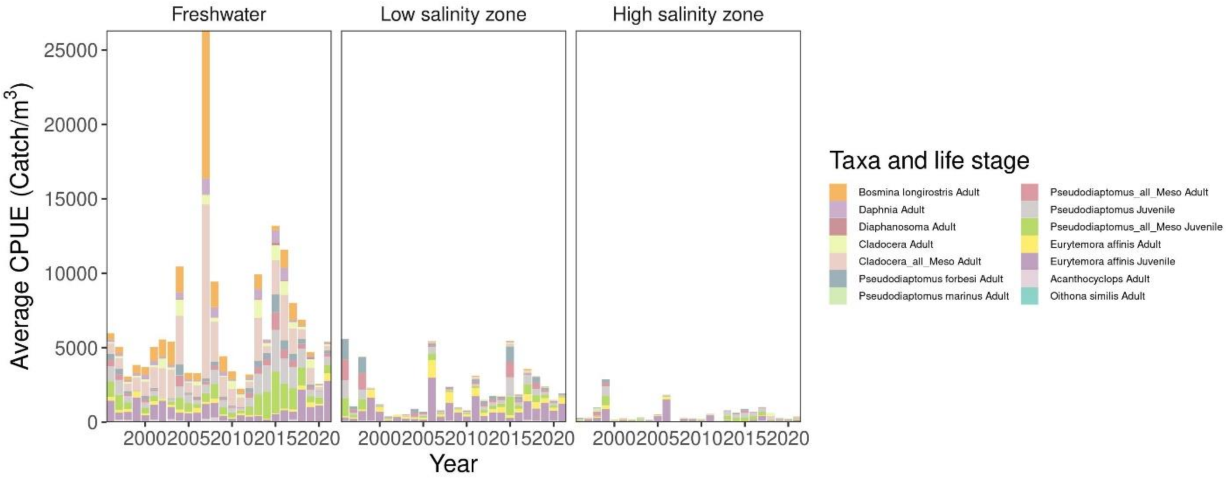


Figure 9-12. Average CPUE of selected Delta smelt mesozooplankton prey from March to May of 1996-2021 from DWR Environmental Monitoring Program surveys. Selected prey species were from major prey categories in Nobriga (2002) and Slater and Baxter (2014).

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 3, provides context for zooplankton density available for Delta smelt larvae in the LSZ during the spring (March- May). The analysis is a regression of the relationship between historical zooplankton abundance (CPUE) and Delta outflow (cfs) (Figure 9-12). 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 larval Delta smelt gut content studies (Slater and Baxter 2014, Nobriga 2002).

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 (2002a) 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).

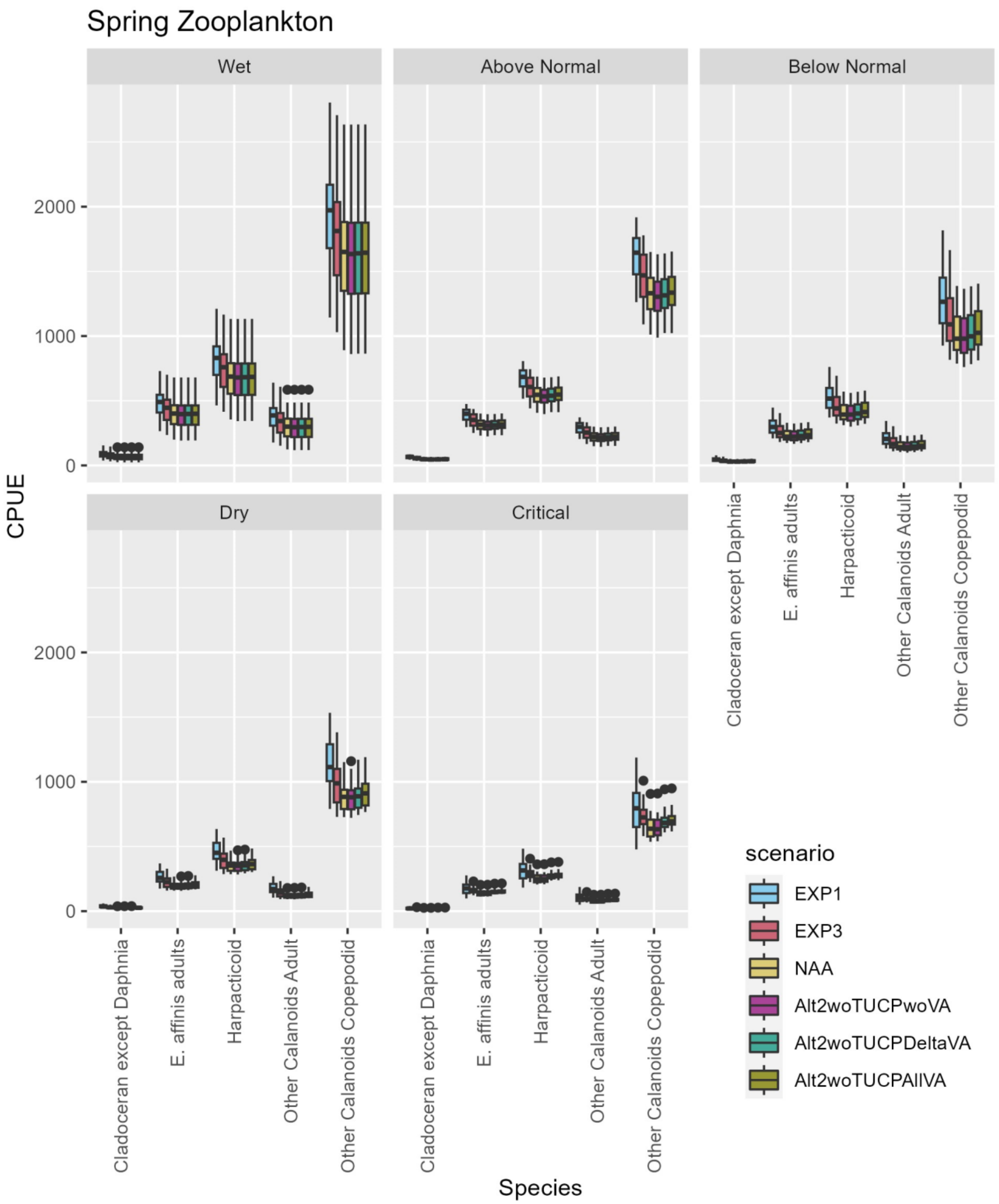


Figure 9-13. Box Plots of significant zooplankton species CPUE by scenario across different water year types for spring. Scenarios EXP1, EXP3 and NAA included as reference.

The **frequency** of occurrence is annual, depends on the hydrology, and is likely **high** based on past historical data. Based on past historical data, 21 out of 26 years (~80%) had low outflow in the spring (Figure 9-13).

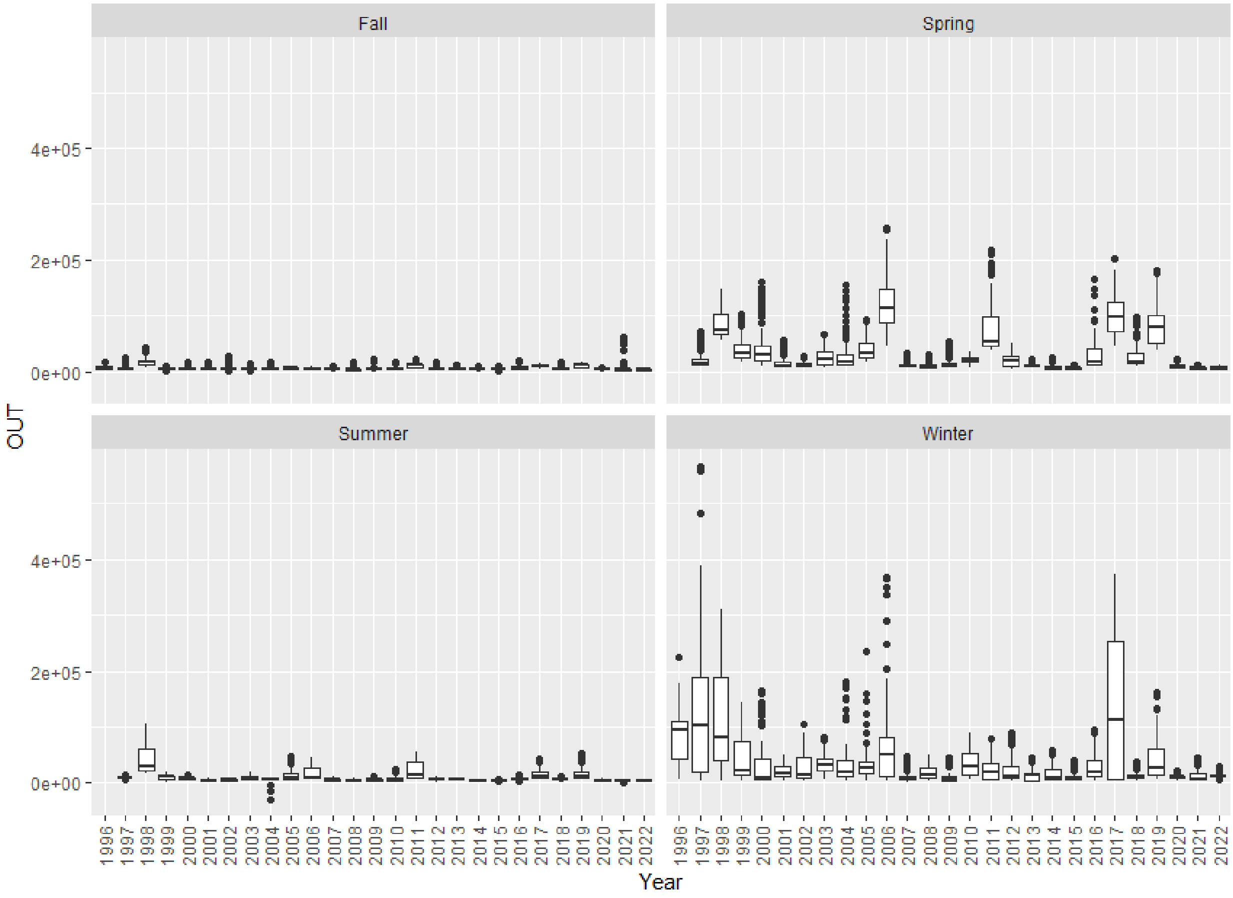


Figure 9-14. Boxplots for outflow at Chipps Island (from California Data Exchange Center) from 1996-2022.

To evaluate the **weight of evidence** for the food availability stressor, 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.

- Merz et al. 2011 used historical survey data that are quantitative, species specific, and location specific. The analysis is published in the white literature and uses several years of historical data across multiple water year types but does not reflect the more recent decline of Delta smelt.
- The Zooplankton Flow Analysis Model is quantitative and location 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

#### *9.2.2.2 Entrainment Stressor*

The proposed diversion of water may increase the entrainment risk stressor. During the planktonic larvae stage, the Proposed Action will export water from the Delta and lead to the storage and diversion of water will reduce Delta inflows and outflows. Entrainment, for the purposes of this document, is defined and discussed in two ways: 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. Entrainment is largely explained by exports, OMR flows and water clarity (Smith et al. 2021, Grimaldo et al. 2021, Grimaldo et al. 2009, Kimmerer 2008). Entrainment at the export facilities may result in direct mortality (Kimmerer 2008). When adult Delta Smelt spawn in the south Delta, new hatched larvae have an increased chance of being entrained compared to larvae that hatched elsewhere in the Bay-Delta. When Delta smelt 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), which can reduce turbidity (Hestir et al. 2015) and potentially cause more predation on eggs and larvae (Bennett 2005, Schreier et al. 2016). *Appendix I* presents analysis.

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

Although the Proposed Action may increase the entrainment risk stressor, entrainment of Delta smelt larvae exists in the **environmental baseline** (without the Proposed Action). 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 Delta 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 Delta smelt 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.

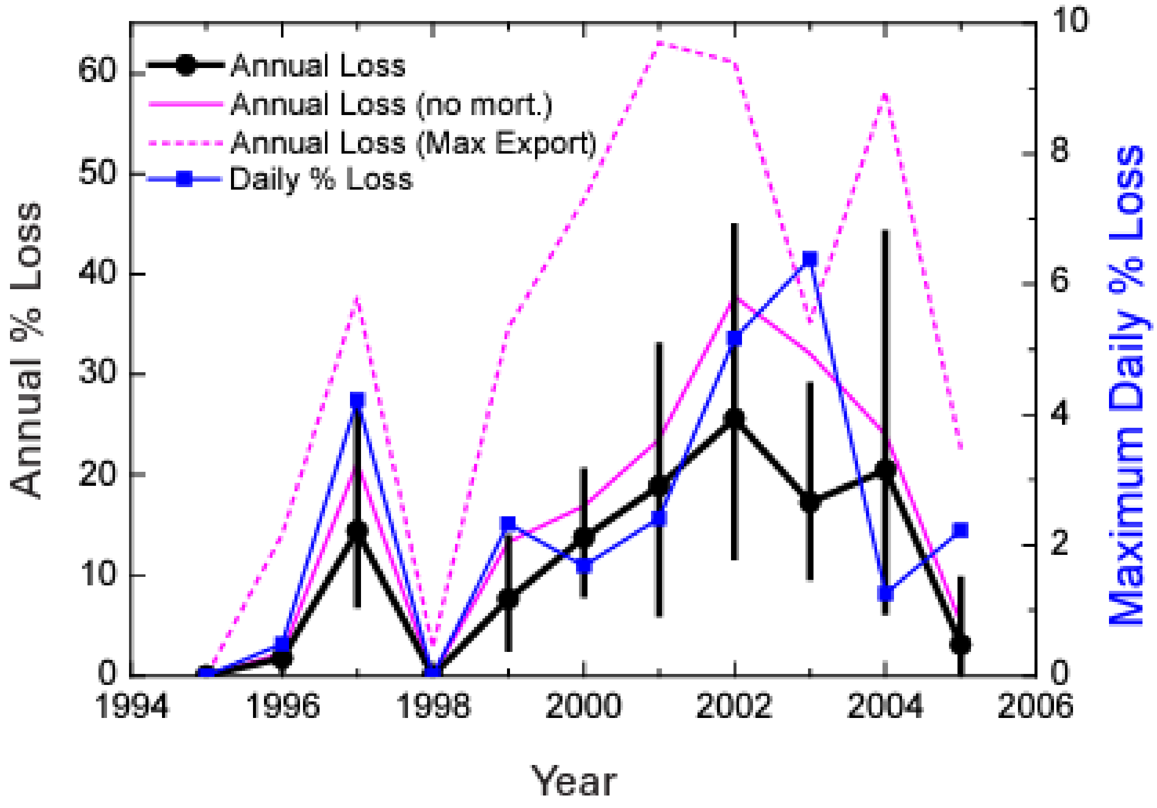
The **proportion** of the population affected by the Proposed Action varies annually and depends on hydrology, turbidity, export rates, and adult spawning distribution. Reclamation considered historic salvage and literature on entrainment to estimate the proportion of the population affected by an increase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

The effect of the stressor on eggs is very low since eggs are not transported.

Delta smelt residing in the south Delta are at higher risk of being entrained. Using past historical data from 1995-2009, Merz et al. (2011) found the average annual frequency of larval Delta smelt occurrence in the South Delta was 18.4%. The presence of larval Delta smelt in the south Delta is related to the distribution of spawning adult Delta smelt.

Adult presence in the south Delta may indicate that Delta smelt are spawning in the South Delta which increases the likelihood of entrainment of larvae hatched in the region. Average annual frequency of spawning adults in the South Delta was 1.1.%. More contemporary historical monitoring data from the SKT study from 2002-2022 found adult Delta Smelt were caught in the south Delta in 8 out of 20 years (40%).

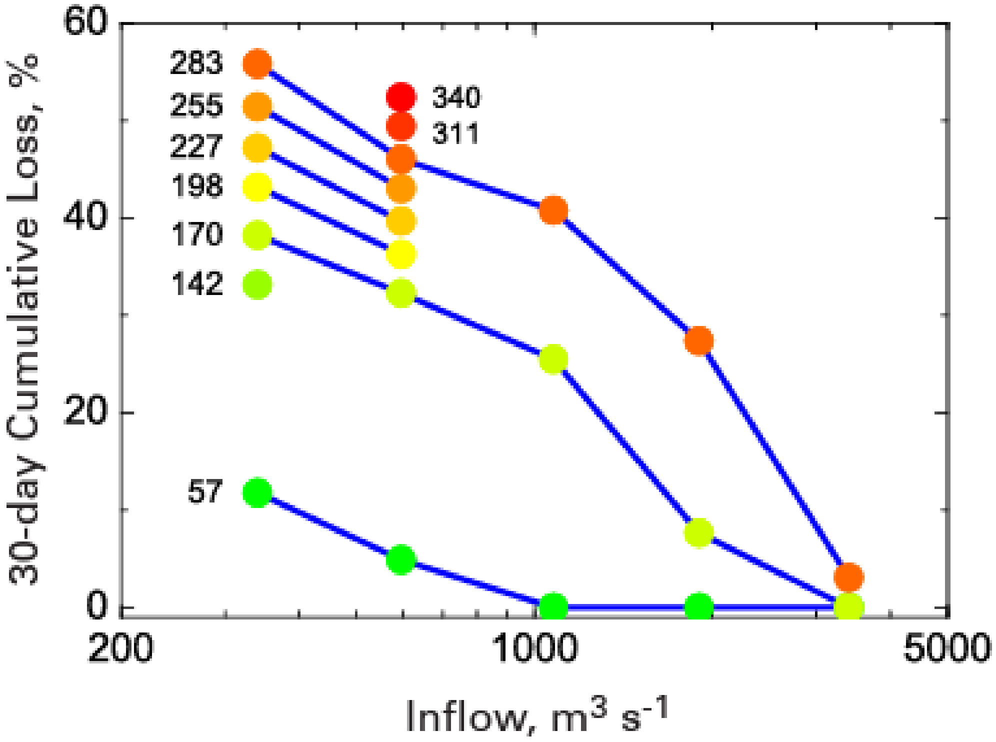
Kimmerer (2008) estimated the seasonal proportional loss of Delta smelt juveniles and larvae due to entrainment ranged from 0-25% (median of 13%). During the dry years of 2001-2003 the annual percentage loss was as high as around 25%, while during certain wet years (e.g., 1998), the annual loss was 0% (Figure 9-15).



Source: Kimmerer 2008

Figure 9-15. Estimated annual losses of Delta smelt due to entrainment across different export scenarios based on 20-mm survey catch.

Kimmerer and Nobriga (2008) use a particle tracking model to examine fractional losses of Delta smelt larvae at various export flows and inflow over a 20-day period. High export flows and low inflows resulted in greater cumulative loss (**medium**) than lower export flows at low inflows (**medium**). High export flows and high inflows result in **low** cumulative losses, as well as low export flows and high inflows (Figure 9-15).



Source: Kimmerer and Nobriga 2008

Figure 9-16. Modeled fractional losses of larval Delta smelt with different inflow and export flows.

Historic records of larval Delta smelt salvage generally show fewer fish were entrained during wet years compared to dry and below normal years (Table 9-5). Fewer fish were salvaged after 2008, likely due to a combination of changes to operations and the continued decline of the Delta smelt population. Historically, larval Delta smelt were not identified and counted at SWP and CVP facilities until 2008 (Morinaka et al. 2013). The salvage facilities were not designed for salvage of larval stages, but larval smelt have been regularly detected at the facilities.

Table 9-5. Historic larval Delta smelt salvage (< 20 mm FL) from SWP and CVP facilities, SKT Delta Smelt Index and Water Year type based on the Sacramento Valley Index. Larval and juvenile protection conditions are years when QWEST, (the estimated net outflow at Jersey Point), was negative after March 15th, and larval or juvenile Delta smelt are within entrainment zone based on real-time sampling of spawning adults or young of year life stages.

| Year | Number of Delta Smelt Larvae entrained | Water Year Type | Larval and Juvenile Protection Conditions |
|---|---|---|---|
| 2008 | 10 | C | - |
| 2009 | 31 | BN | - |
| 2010 | 9 | AN | Yes |
| 2011 | 3 | W | No |
| 2012 | 69 | D | Yes |
| 2013 | 22 | C | Yes |
| 2014 | 15 | C | Yes |
| 2015 | 1 | C | Yes |
| 2016 | 0 | D | Yes |
| 2017 | 0 | W | No |
| 2018 | 0 | BN | Yes |
| 2019 | 0 | W | No |

Modified from Table 4 from CDFW 2020. Larval and juvenile protection conditions are years when QWEST was negative after March 15th, and larval or juvenile Delta smelt are within entrainment zone based on real-time sampling of spawning adults or young of year life stages.

Volumetric influence, flow into junctions, ZOI, and PTM results may be applicable for smelt depending on location. Modeling analysis results are presented in Chapter 5. 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 **frequency** of the stressor is directly linked to changes in hydrology resulting from ongoing export operations.

Historical salvage records from 2008-2019 found larval Delta smelt were detected in 8 of 12 years (75%) (Table 9-5).

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 larval or juvenile Delta smelt are within entrainment zone based on real-time sampling of spawning adults or young of year life stage) were met. Historical catch of larval Delta smelt in the south Delta occurred in 2 out of 9 years (~22%) (Table 10, CDFW 2020). Entrainment of larval Delta smelt occurred in 8 out of 12 years (~75%) from 2008 to 2019 (Table 4, CDFW 2020).

To evaluate the **weight of evidence** for the entrainment stressor, multiple location- and species and non-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.

- Merz et al. 2011 used historical survey data that are quantitative, species specific, and location specific. The analysis is published in the white literature and uses several years of historical data across multiple water year types but does not reflect the more recent decline of Delta smelt.
- Kimmerer 2008 used several years of historical data (2002-2006) that are quantitative, species specific, and location specific. The analysis is published in a peer-reviewed journal. The data encompasses multiple water year types to model and reconstruct proportional historical losses, however the estimates have large confidence limits. Additionally, Kimmerer responded to criticisms of his methods with updated equations (Kimmerer 2011).
- Kimmerer and Nobriga 2008 used the DSM-2 model and the particle tracking model to examine different scenarios for different flow conditions to simulate losses of larval Delta smelt to entrainment. The analysis was quantitative, species specific, and location specific. This analysis was published in a peer-reviewed journal. The authors note that the model is less suitable for small scales or alternate configurations of the Delta and is probably only suitable for describing Delta-wide movement.
- 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 TM 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.
- ZoneOI 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:

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

**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
- Drought Actions

### 9.2.3 Juveniles

Juvenile Delta smelt (> 20 mm fork length) migrate to the low salinity zone in the spring. A portion of the Delta smelt population are year-round residents of freshwater or brackish water regions (Hobbs et al. 2019). During the summer and fall season juvenile Delta smelt feed on zooplankton prey, focusing on somatic growth before the winter adult migration.

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

- The Proposed Action may increase or decrease the *toxicity from HarmfulAB* stressors, depending on the season. CVP and SWP storage and diversion increases or decreases Delta inflow. In general, HABs presence is negatively correlated with flow and is a function of climatic hydrological conditions. The effect of operations-scale alterations in flow is relatively minor and difficult to isolate from the greater effect of large-scale inter-annual hydrologic variation on HABs (Hartman et al. 2022, Reclamation and DWR 2023). Toxicity from HAB is a function of factors contributing to increased occurrence or persistence of cyanobacterial blooms, greater levels of toxin production within those blooms, and the incorporation of toxins into the food web.

  The drivers of toxin production by HABs such as *Microcystis* are not fully understood but include the prevalence of certain genetic variants and possibly environmental conditions, such as nutrient concentrations, outflow, and residence time (Yancey et al. 2022; Lehman et al. 2022). CVP and SWP operations do not influence the prevalence of toxin-producing genetic variants. The potential for CVP and SWP operations to influence the uptake and transfer of toxins through the food web is unknown and would be difficult to distinguish from other drivers.

- The Proposed Action may increase or decrease the *water temperature* stressors, depending on the season. CVP and SWP storage and diversion increases or decreases Delta inflow depending on the season.

  Delta water temperature is negatively correlated with Delta inflow in the spring and positive correlated from July – September in Western regions (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 2002), air temperature and meteorology (Vroom et al. 2017, Daniels and Danner 2020). There is uncertainty about whether the decreased inflow is a cause for increased Delta water temperatures. 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 at Prisoner's Point do not exceed 81°F (juvenile Delta smelt 50% chronic morbidity) (Komoroske et al. 2014).

- The Proposed Action may increase the *predation* stressor. During the juvenile rearing period, the Proposed Action will store and divert water and reduce Delta inflows and outflow, which may alter hydrodynamic conditions in the Delta. 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. During operations of those that are CVP/SWP facilities, juvenile Delta 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). 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). The operation of the Tracy Fish Collection Facility to achieve water approach velocities for striped bass may result in additional predation stressor on Delta smelt juveniles due to the salvage and release of this important Delta smelt predator. Reduced turbidity from the Proposed Action can also increase predation risk (Ferrari et al. 2013, Schreier et al. 2016). Effects of the Proposed Action on water temperature and food visibility that may interact with the predation stressor were analyzed in those sections. 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.

#### 9.2.3.1 Food Availability and Quality Stressor

The food availability and quality stressor may increase. During the juvenile rearing period, the Proposed Action will store and divert water on average, which will affect food availability and quality. Juvenile Delta smelt primarily feed on calanoid copepods, such as *Eurytemora affinis* and *Pseudodiaptomus forbesi*, throughout the spring, summer and fall seasons (Slater and Baxter 2014). Abundances of historically important Delta smelt zooplankton prey taxa in the LSZ, including *Eurytemora affinis*, generally exhibit a positive correlation with Delta outflow (Kimmerer 2002a). Hamilton et al. (2020) found pulse spring flows in dry water years can increase copepod biomass near Suisun Bay. Decreased Delta outflows may also limit critical allochthonous subsidies of alternate larval Delta smelt food resources (e.g., *Pseudodiaptomus forbesi*) through reduced advection from more productive upstream areas to Delta smelt rearing habitats. Local zooplankton productivity in these habitats is severely impacted by competition with clams (Kimmerer et al. 2019). Hassrick et al. (2023) found proportional subsidies to the low salinity zone in the fall increased with further seaward positions of X2. Multiple analyses have shown prey abundance and density are important factors in explaining Delta smelt abundance (Miller et al. 2012, Mac Nally et al. 2010, Thomson et al. 2010, Maunder and Deriso 2011, Hamilton and Murphy 2018). Food availability is considered an important component of Delta smelt growth. Food limitation stressors vary on spatial, seasonal and yearly time scales (Hammock et al. (2015). *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 habitat.

The increase in food availability and quality stressor is **sub-lethal** to **lethal**. Higher food abundances in theory result in greater consumption and 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 Delta 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. 2022, Lopes et al. 2022) resulting in higher mortality.

Although the Proposed Action may increase the food availability and quality stressor, changes in food availability and quality for Delta smelt juveniles and sub adults exists in the **environmental baseline** (without the Proposed Action). The MAST Report summarizes the *"dramatic morphological, hydrological, chemical, and biological alterations [to the Delta] since the onset of the California Gold Rush in the middle of the 19th century (Nichols et al. 1986, Arthur et al. 1996, Baxter et al. 2010, Brooks et al. 2012, NRC 2012, Whipple et al. 2012, Cloern and Jassby 2012)."* 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)." Eurytemora affinis* and other zooplankton have experienced long term declines since the introduction of the overbite clam (Winder and Jassby 2011, Kimmerer 2002a), experienced seasonal shifts in peak abundance (Merz et al. 2016) and have been replaced by non-native species (Winder and Jassby 2011). In the low-salinity zone, the presence of invasive predatory copepods and the overbite clam, have caused the decline of *Pseudodiaptomus forbesi* (Kayfetz and Kimmerer 2017, Slaughter et al. 2016), and the presence of the species is mainly due to subsidies from freshwater regions upstream (Kimmerer et al. 2019). Food limitation can interact negatively with other stressors such as high-water temperatures and contaminants (Bennett et al. 1995, Le et al. 2022, Lopes et al. 2022) resulting in higher mortality. 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.

Tidal restoration projects in the Delta may reduce the food availability and quality stressor on juvenile and sub-adult Delta smelt. 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 Delta 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** based on location of past historical catch of juvenile Delta smelt. Reclamation considered literature and 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.

From the literature, Merz et al. (2011) found juvenile (including sub-juveniles) average annual frequency of occurrence from 1995-2009 in the low salinity zone regions (Suisun Bay, Suisun Marsh and the Confluence) ranged from 17.5% in SW Suisun Bay to 19.2% (Suisun Marsh) to 36.1% (Confluence) from the Summer Tow Net survey (Jun-Aug). In the Fall Midwater Trawl survey (Sep-Dec), average annual frequency of occurrence ranged from 4.3% in SW Suisun Bay to 27.2% in Suisun Marsh to 24.5% in the Confluence.

Datasets use historical conditions and observation to inform how Delta smelt may respond to the Proposed Action. Historical monitoring may support or refute hypotheses and informs the reasonableness of information generated by models. Zooplankton abundance differs regionally, freshwater regions tend to have higher mesozooplankton density. Juveniles present in the low salinity zone (0.5-6) and high salinity zones (>6) may experience food limitation compared to fish in freshwater regions.

Figure 9-17 shows the CPUE of selected Delta smelt mesozooplankton prey from EMP surveys in the freshwater, low salinity zone, and high salinity zone regions.

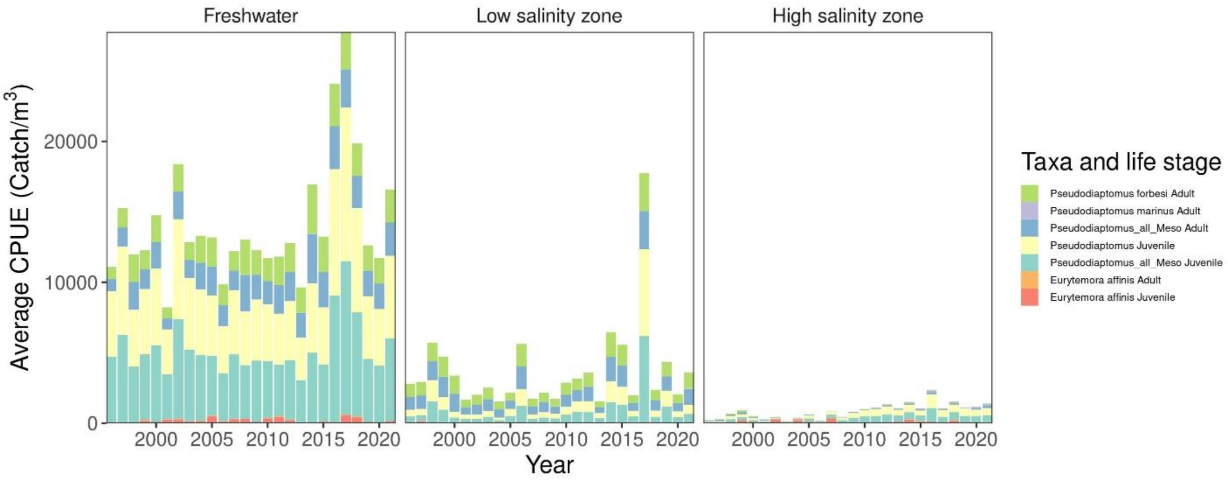


Figure 9-17. Average CPUE of selected Delta smelt mesozooplankton prey from June to Nov. of 1996-2021 from EMP surveys.

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 3, provides context for summer and fall zooplankton density available for Delta smelt in the LSZ during the summer (June - August) and fall (September – November). During summer months, no zooplankton taxa had a statistically significant relationship with outflow in the low salinity zone. During fall months, *Eurytemora affinis* (copepod) adults and mysids had a statistically significant positive relationship with Delta outflow (Figure 9-18).

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 9-18).

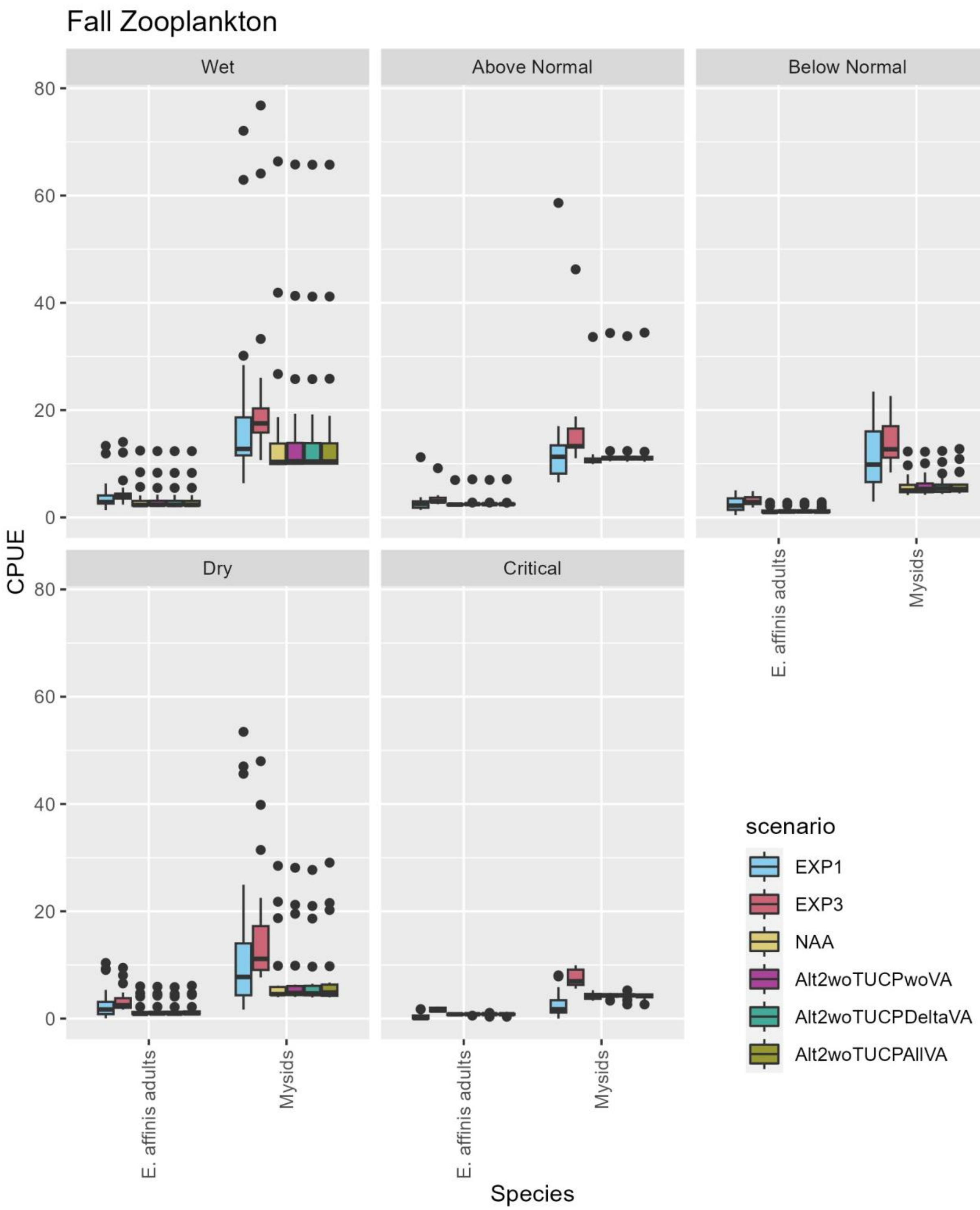


Figure 9-18. Box Plots of CPUE of significant zooplankton species by scenario across different water year types for fall.

The **frequency** of occurrence is annual, depends on the hydrology, and is **likely medium** to **high** based on past historical data; summer outflow was low in 21 out of 26 years in summer (~81%) and fall outflow was low in 22 out of 26 years in fall (~85%) (Figure 9-18).

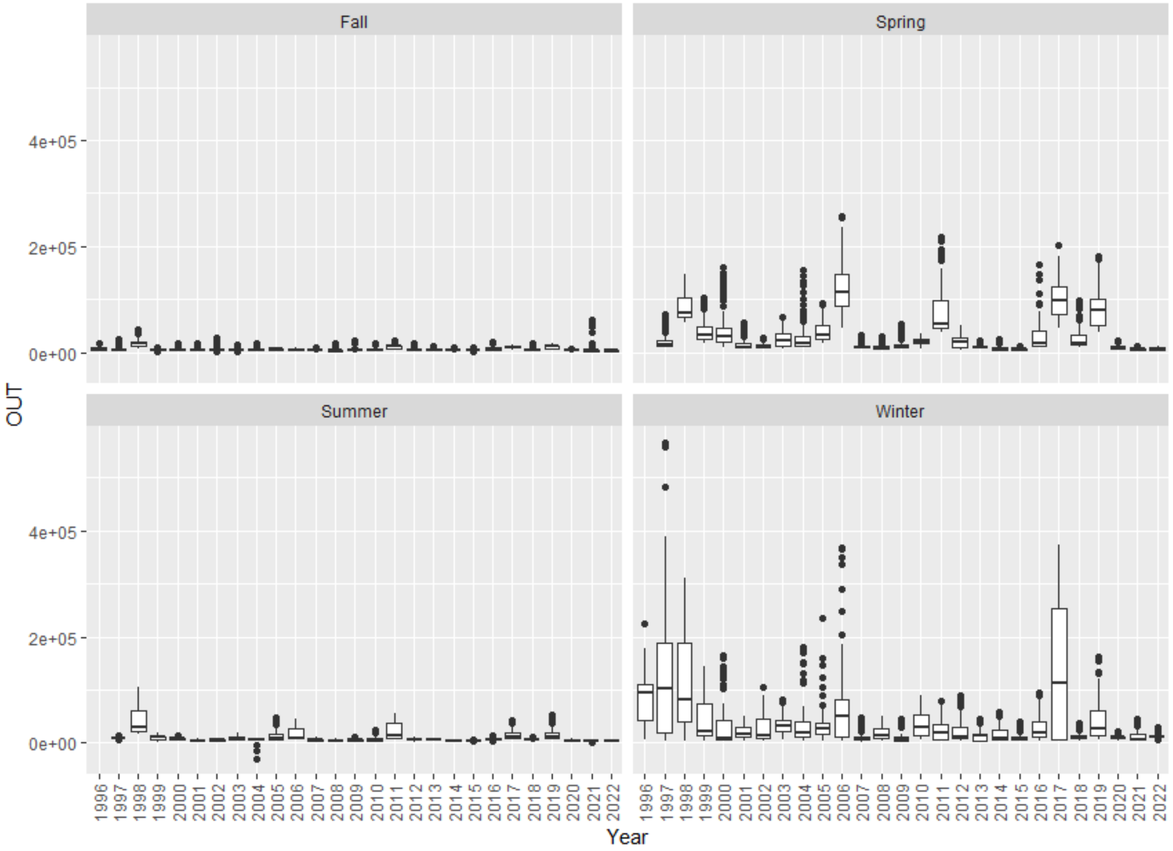


Figure 9-19. Boxplots for outflow at Chipps Island (from California Data Exchange Center) from 1996-2022.

To evaluate the **weight of evidence** for the food availability stressor, 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.

- Merz et al. 2011 used historical survey data that are quantitative, species specific, and location specific. The analysis is published in the white literature and uses several years of historical data across multiple water year types but does not reflect the more recent decline of Delta smelt.
- The Zooplankton Flow Analysis Model is quantitative and location 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
- Delta Smelt Supplementation

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

#### *9.2.3.2 Entrainment Stressor*

The proposed diversion of water may increase the entrainment risk stressor. During the juvenile migration and rearing life stage, the Proposed Action store and divert water, which will reduce Delta inflows and outflows. 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. Direct entrainment is largely explained by exports, OMR flows and water clarity (Smith et al. 2021, Grimaldo et al. 2021, Grimaldo et al. 2009, Kimmerer 2008). Entrainment at the export facilities may result in direct mortality (Kimmerer 2008). When Delta smelt 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 Delta smelt. *Appendix I* presents analysis.

The current Proposed Action involves several actions intended to minimize the entrainment of juvenile and subadult Delta 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 Delta 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 by routing fish into areas of poor survival. Pre-screen losses of Delta Smelt are likely due to predation (IEP MAST 2015, Castillo et al. 2012).

Although the Proposed Action may increase the entrainment risk stressor, entrainment of Delta smelt juveniles and sub adults exists in the **environmental baseline** (without the Proposed Action). 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 Delta 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.

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.

From literature, Delta smelt residing in the south Delta are at higher risk of being entrained. Merz et al. (2011) found the average annual frequency of sub-juvenile Delta smelt occurrence in the south Delta was 10.8%.

Kimmerer (2008) estimated the seasonal proportional loss of Delta smelt juveniles and larvae due to entrainment ranged from 0-25% (median of 13%) in operations prior to 2008. During the dry years of 2001-2003 the annual percentage loss was around 25%, while during certain wet years (e.g., 1998), annual loss was 0% (Figure 9-20).

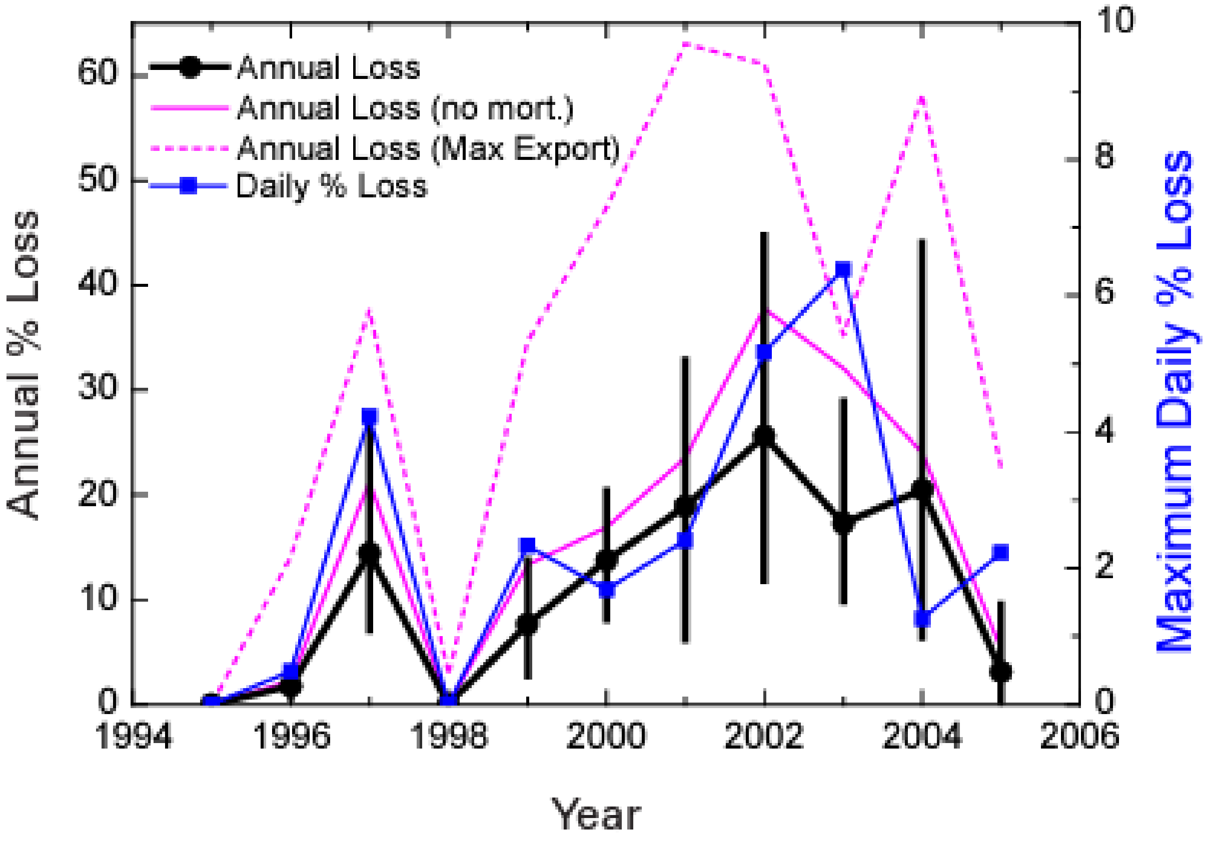


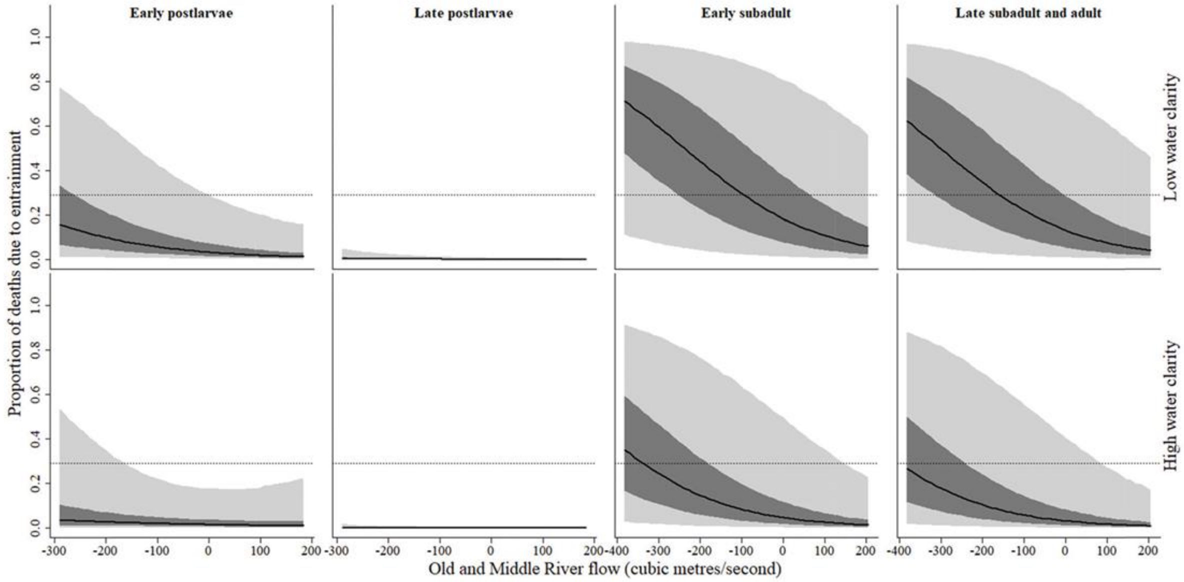
**Figure 15.** Estimated annual losses to export pumping of delta smelt from the 20-mm survey. The black line gives the estimated loss with 95% confidence limits allowing for mortality; red lines give annual losses without mortality (solid), and at the maximum export flow rate (dashed). The blue line with squares (right axis) gives the maximum daily percent loss determined in a single survey for each year.

Source: Kimmerer 2008

Figure 9-20. Estimated annual losses of Delta smelt due to entrainment across different export scenarios based on 20-mm survey catch.

Smith et al. (2021) developed a model to predicted entrainment mortality at two levels of water clarity for early and late postlarvae Delta Smelt. Predicted estimates of proportional mortality for early postlarvae due to entrainment when OMR was negative and water clarity was low the proportion affected was **medium**. When OMR was negative and water clarity was high, the proportion affected was **low**. When OMR was positive and water clarity was low, the proportion affected was **low**. When OMR was positive and water clarity was high, the proportion affected was **low** (Smith et al. 2021) (Figure 9-21).

**Fig. 3.** Posterior distributions of predicted entrainment mortality at two levels of water clarity (2007–2015 interquartile range) and a range of Old and Middle river flows. The dark shaded regions indicate the interquartile range of posterior predictions, and the light shaded regions indicate the 95% credible intervals. The dotted horizontal lines indicate the reference point 0.41 × natural mortality, or 0.29 × total mortality (Zhou et al. 2012).



Source: Smith et al. 2021.

Figure 9-21 Predicted entrainment mortality for Delta smelt based on OMR flows for two different water clarity scenarios.

Datasets use historical conditions and observation to inform how Delta smelt may respond to the Proposed Action. Historical monitoring may support or refute hypotheses and informs the reasonableness of information generated by models. Historic records of juvenile Delta smelt salvage generally show fewer fish were entrained during wet years compared to dry and below normal years (Table 9-6). Fewer fish were salvaged after 2008, likely due to a combination of changes to operations and the continued decline of the Delta Smelt population. Since the 1990s, juvenile salvage has declined since Delta smelt no longer resides in the Central-South Delta during the summer (Moyle et al. 2016).

Table 9-6. Historic juvenile Delta smelt salvage (<58 mm FL) from SWP and CVP facilities, 20mm Delta Smelt Index and Water Year type based on the Sacramento Valley Index.

| Year | Juvenile Salvage (≤58 mm FL) | CDFW 20mm Delta Smelt Index | Water Year Type | Larval and Juvenile Protection Conditions |
|---|---|---|---|---|
| 1993 | 386 | - | W | - |
| 1994 | 822 | - | C | - |
| 1995 | 20 | 4.4 | W | - |
| 1996 | 543 | 33.9 | W | - |
| 1997 | 570 | 19.2 | W | - |
| 1998 | 2 | 7.7 | W | - |
| 1999 | 1372 | 39.4 | AN | - |
| 2000 | 949 | 23.7 | AN | - |
| 2001 | 308 | 10.9 | D | - |
| 2002 | 726 | 7.7 | D | - |
| 2003 | 713 | 13 | BN | - |
| 2004 | 511 | 8.2 | D | - |
| 2005 | 98 | 15.4 | W | - |
| 2006 | 2 | 9.8 | W | - |
| 2007 | 197 | 1 | C | - |
| 2008 | 293 | 2.9 | C | - |
| 2009 | 159 | 2.3 | BN | - |
| 2010 | 7 | 3.8 | AN | Yes |
| 2011 | 0 | 8 | W | No |
| 2012 | 205 | 11.1 | D | Yes |
| 2013 | 259 | 7.8 | C | Yes |
| 2014 | 18 | 1.1 | C | Yes |
| 2015 | 5 | 0.3 | C | Yes |
| 2016 | 3 | 0.7 | D | Yes |
| 2017 | 0 | 1.5 | W | No |
| 2018 | 0 | - | BN | Yes |
| 2019 | 0 | 0.1 | W | No |
| 2020 | 0 | - | D | - |
| 2021 | 0 | 0 | C | - |
| 2022 | 1 | - | C | - |

Volumetric influence, flow into junctions, ZOI, and PTM results may be applicable for smelt depending on location. Modeling analysis results are presented in Chapter 5. 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 **frequency** of the stressor is directly linked to changes in hydrology resulting from ongoing export operations. Historical salvage records from 1993-2022 found juvenile Delta smelt were detected in 24 of 30 years (80%) (Table 9-6). 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.

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.

- Merz et al. 2011 used historical survey data that are quantitative, species specific, and location specific. The analysis is published in the white literature and uses several years of historical data across multiple water year types but does not reflect the more recent decline of Delta smelt.
- Kimmerer 2008 used several years of historical data (2002-2006) that are quantitative, species specific, and location specific. The analysis is published in a peer-reviewed journal. The data encompasses multiple water year types to model and reconstruct proportional historical losses, however the estimates have large confidence limits. Additionally, Kimmerer responded to criticisms of his methods with updated equations (Kimmerer 2011).
- Smith et al. 2021 used several years of historical data (1995-2015) that are quantitative, species specific, and location specific. The analysis is published in a peer-reviewed journal. The data was used to develop a hierarchical state-space life cycle model to evaluate entrainment risk and natural mortality.
- 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 TM 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.
- ZoneOI 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 Delta Smelt Protection Action
- Spring Delta Outflow
- End of OMR Management
- Barker Slough Pumping Plant, Maximum Spring Diversions, Larval Delta Smelt
- Delta Smelt Supplementation

**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

#### *9.2.3.3 Size and Location of LSZ Stressor*

The size and location of the LSZ may decrease and be more landward. The Proposed Action will store and divert water that may result in position of the LSZ being further landward which would reduce the size of the LSZ, and thus available habitat for juvenile Delta smelt. This shift may result in lower growth and, thus, lower survival (IEP MAST 2015). 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 at the confluence of the Sacramento and San Joaquin Rivers (X2 ~ 80-85 km).

Delta smelt was commonly found in the LSZ (Moyle et al. 1992) and LSZ regions (Merz et al. 2011). Delta smelt once had a positive relationship with X2 up until 1981, and a negative non-significant relationship with X2 from 1982-2000 (Kimmerer 2002b). More recently Delta smelt abundance was found to have a non-significant and essentially flat relationship with spring X2 (IEP MAST 2015, Kimmerer et al. 2009). While there appears to be a weak response to spring X2 the effect of X2 may be masked or weakened by changes in other habitat attributes (IEP MAST 2015). Feyrer et al. (2011) found the amount of suitable habitat (as measured using a habitat index) does increase with a more seaward X2 and this habitat index was positively correlated with the Delta smelt abundance index.

Juveniles migrate to the low salinity zone during the summer and spend summer and fall growing before the spawning migration. Bever et al. (2016) found higher historical catch of Delta smelt when low salinity habitat overlapped with low water velocity, shallow, turbid regions of Grizzly and Suisun Bay. The size and location of the LSZ is correlated with freshwater flow; Smith et al. (2021) found using a state space life cycle model that as outflow declined in the summer, the estimated mortality of postlarvae (juveniles) increased. Some Delta smelt exhibit a completely freshwater life history and may not utilize the LSZ habitat at all (Hobbs et al. 2019). Appendix K presents analysis.

A decrease in the size and location of LSZ is expected to be **sublethal**. Reduction of LSZ means less suitable habitat. The position and area of the LSZ is one component of the quantity and quality of habitat available for juvenile Delta smelt rearing (IEP MAST 2015). While the size and location of the LSZ is determined by salinity, salinity is only one abiotic component of Delta smelt habitat (Kimmerer et al. 2013) and other abiotic components such as turbidity are important as well too (Bever et al. 2016, Feyrer et al. 2007, Bennett 2005). The size, location, and dynamics of the LSZ likely interacts with other environmental variables such as turbidity, nutrients, and recruitment of competitors such as *P. amurensis* (IEP MAST 2015). Temperature can be a dominating factor in determining habitat quality as well, and higher temperatures may have produced stressful conditions for Delta smelt in otherwise ideal habitat for Delta smelt in 2017 (FLOAT-MAST 2020).

Although the Proposed Action may decrease in the size and location of the LSZ, LSZ fluctuations exists in the **environmental baseline** (without the Proposed Action). Non-project exports can affect outflow and thus the size and position of the LSZ (Hutton et al. 2017). CVP and SWP facilities, including export facilities in the Delta, have operated under biological opinions issued by the USFWS and NMFS in 2004/2005, 2008/2009, and 2019. For a more complete description of CVP and SWP facilities, relevant regulatory requirements, and contractual obligations, please see Appendix A, Facilities *Description*. Since 2008, Reclamation and DWR have operated to provide sufficient Delta outflow to lower X2 and increase the area of the LSZ in the fall. Figure 9 illustrates X2 position by year and season from 1996 to 2022.

The **proportion** of the population affected by the Proposed Action is **likely medium to high** and depends on the proportion of the population utilizing LSZ habitat. Reclamation considered literature and environmental monitoring data on the size and location of the LSZ to estimate the proportion of the population affected by an increase in the size and location of the LSZ stressor.

From literature, Merz et al. (2011) found juvenile (including sub-juveniles) average annual frequency of occurrence from 1995-2009 in the low salinity zone regions (Suisun Bay, Suisun Marsh and the Confluence) ranged from 17.5% in SW Suisun Bay to 19.2% (Suisun Marsh) to 36.1% (Confluence) from the Summer Tow Net survey (Jun-Aug). In the Fall Midwater Trawl survey (Sep-Dec), average annual frequency of occurrence ranged from 4.3% in SW Suisun Bay to 27.2% in Suisun Marsh to 24.5% in the Confluence.

Furthermore, the frequency of the semi-anadromous migratory phenotype (implying that the fish utilized the LSZ at some point in its life) is as high as 81% of fish studied using otolith geochemistry (Hobbs et al. 2019).

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. Modeled CalSim3 X2 position and the Summer and Fall Habitat X2 Modeling and Analysis (which uses a habitat suitability index, HSI) supports the evaluation of this stressor.

CalSim3 models provide quantitative estimates of future conditions under the Proposed Action. Figure 9-22 shows the location of X2 averaged across all water year types. The run of river scenario falls outside the range of conditions training the artificial neural network and is more an indicator of conditions rather than a precise comparison.

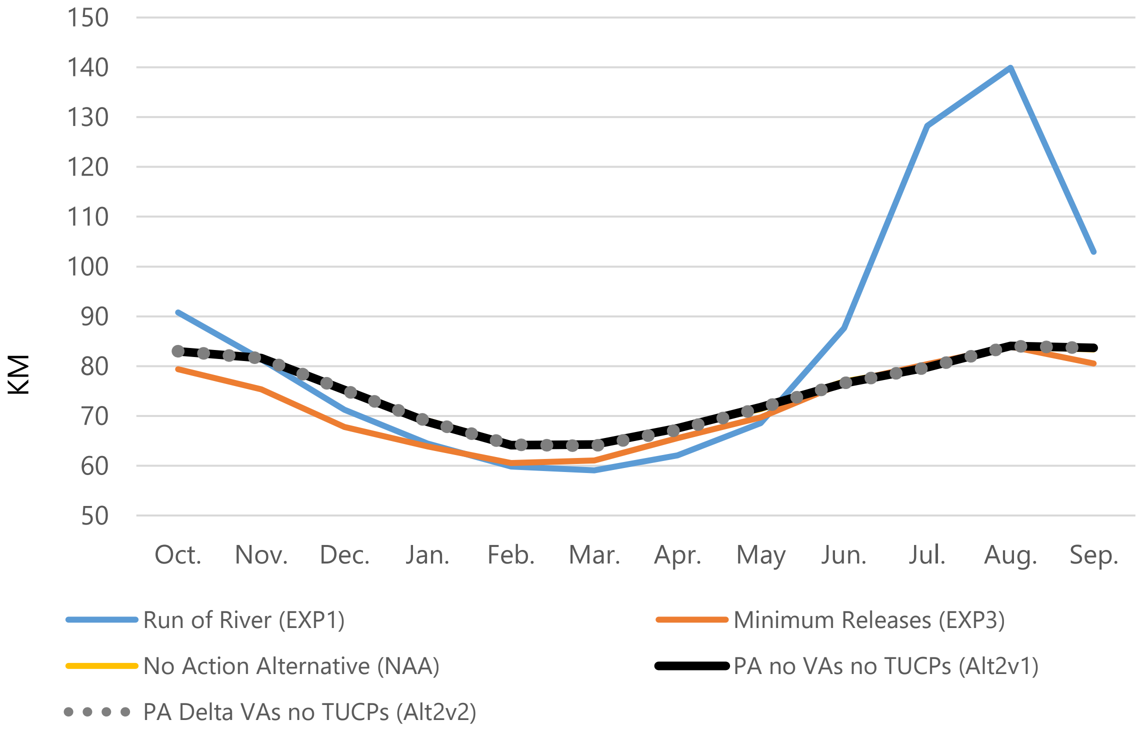


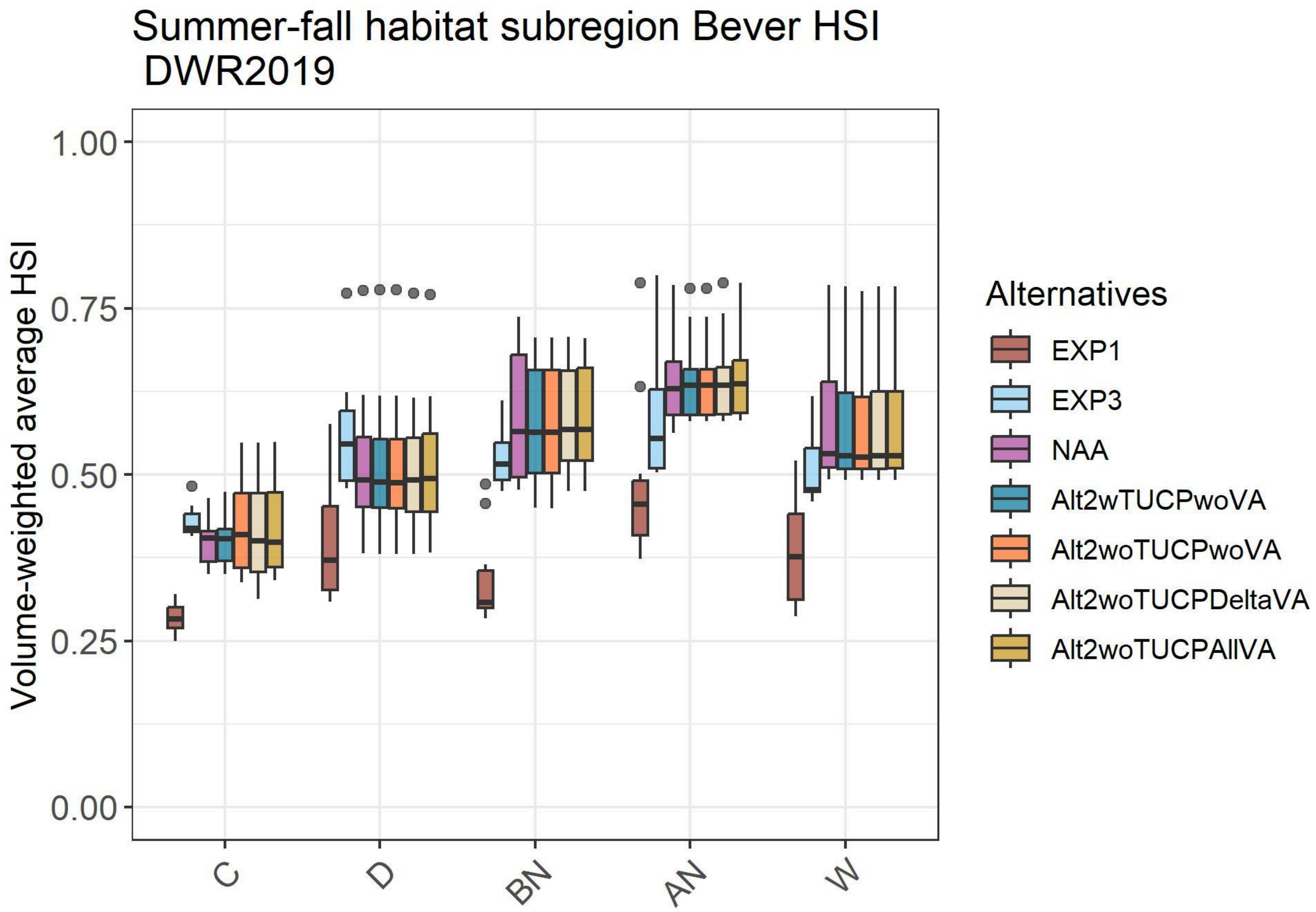
Figure 9-22. Average location of X2 under Run of the River, Minimum Releases, No Action, and the Proposed Action.

The *Summer and Fall Habitat X2 Modeling and Analysis*, Attachment K.1, provides context for habitat suitability for juvenile Delta smelt during the summer and fall season. A habitat suitability index (HSI), was calculated using a methodology derived from Bever et al. (2016) and RMA (2021), with model runs performed using the 3D Bay-Delta SCHISM model. The HSI represents spatially- and temporally averaged suitability of habitats within delineated subregions in the Bay-Delta based on four abiotic variables: salinity, temperature, turbidity, and current speed.

Results presented below are for the summer and fall habitat arc which includes the confluence, lower Sacramento River, northwest Suisun Bay, and Suisun Marsh subregions targeted by the Summer Fall Habitat Actions (Figure K.1-27), . Another set of results include a temperature threshold of 22ºC (Figure K.1-28). This was based on sub-lethal physiological and behavioral effects described in Komoroske et al. (2015, 2021), Davis et al. (2019, 2022), Lewis et al. (2021), and Hammock et al. (2022).

The HSI under the Proposed Action phases varied among water year types; the HSI values were highest for the above normal WYT and lowest for the critical WYT. Similarly, for the HSI results with the 22 ºC threshold, HSI values were highest for the above normal WYT and lowest for the Critical WYT, however HSI values for the wet WYT were also relatively low, likely due to relatively warmer air temperatures during 2019, which was used to model the wet WYT. HSI values were lower across all WYT for the results with the 22 ºC threshold.

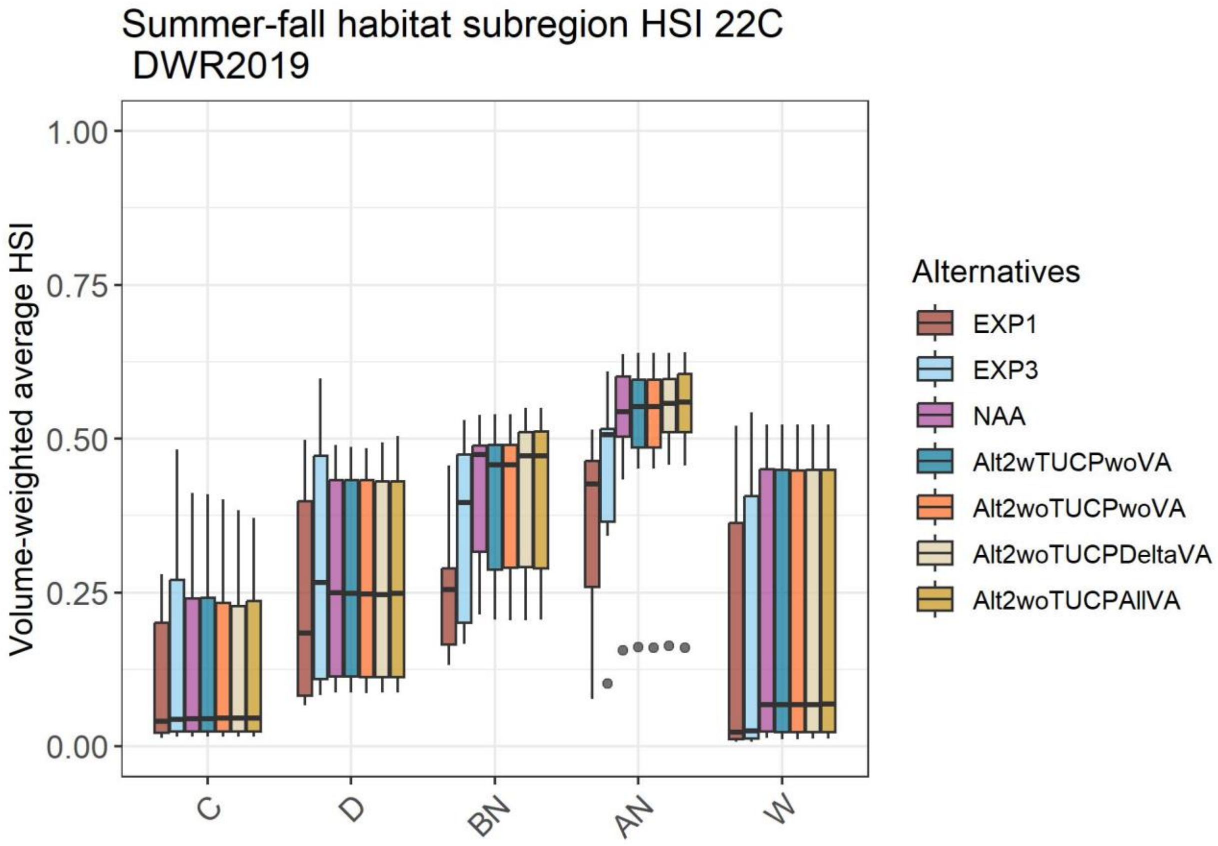
Differences in HSI between the phases of Alternative 2 and the No Action Alternative are most likely due to differences in salinity and current speed among alternatives for each water year. Differences in HSI with the 22 ºC threshold between the phases of Alternative 2 and the No Action Alternative are most likely due to small differences in salinity and water temperature among the phases for each water year type.



Source: Bever et al. (2016).

The median is shown as the horizontal line, the box indicates the 25th and 75th percentiles, the vertical lines indicate the 25th and 75th percentiles plus 1.5 times the interquartile range, and the dots indicate potential outliers. Water year types presented from left to right are: critical (C); dry (D); below normal (BN); above normal (AN); wet (W). The alternatives, from left to right for each water year type are: exploratory 1 (EXP1); exploratory 3 (EXP3); no action alternative (NAA), alternative 2 with temporary urgency change, without Voluntary Agreements (Alt2wTUCPwoVA); alternative 2 without temporary urgency change, without Voluntary Agreements (Alt2woTUCPwoVA); alternative 2 without temporary urgency change, with Delta Voluntary Agreements (Alt2woTUCPDeltaVA); alternative 2 without temporary urgency change, with all Voluntary Agreements (Alt2woTUCPAllVA).

Figure 9-23. Habitat suitability indices in the summer and fall habitat arc for each alternative and water year type for July 1 – November 18.



Source: Bever et al. (2016)

The median is shown as the horizontal line, the box indicates the 25th and 75th percentiles, the vertical lines indicate the 25th and 75th percentiles plus 1.5 times the interquartile range, and the dots indicate potential outliers. Water year types presented from left to right are: critical (C); dry (D); below normal (BN); above normal (AN); wet (W). The alternatives, from left to right for each water year type are: exploratory 1 (EXP1); exploratory 3 (EXP3); no action alternative (NAA); alternative 2 with temporary urgency change, without Voluntary Agreements (Alt2wTUCPwoVA); alternative 2 without temporary urgency change, without Voluntary Agreements (Alt2woTUCPwoVA); alternative 2 without temporary urgency change, with Delta Voluntary Agreements (Alt2woTUCPDeltaVA); alternative 2 without temporary urgency change, with all Voluntary Agreements (Alt2woTUCPAllVA).

Figure 9-24. Habitat suitability indices modified by a 22-degree Celsius threshold in the summer and fall habitat arc for each alternative and water year type for July 1 – November 18.

The **frequency** when habitat impacts species is **likely medium to large** and dependent on the 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 (Figure 9-25).

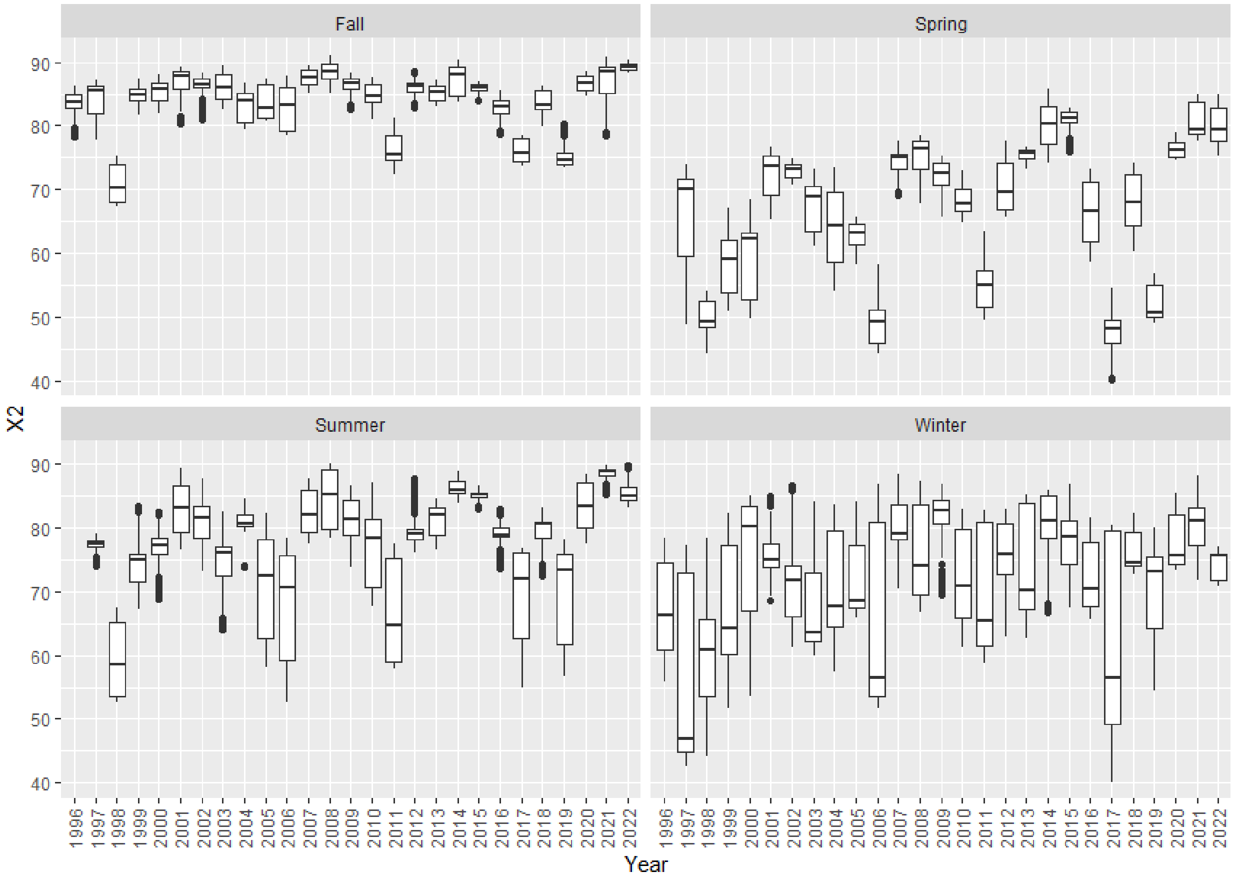


Figure 9-25. Boxplot of X2 position by year and season for 1996-2022. Data from California Data Exchange Center.

To evaluate the **weight of evidence** for the size and location of LSZ 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.

- Merz et al. 2011 used historical survey data that are quantitative, species specific, and location specific. The analysis is published in the white literature and uses several years of historical data across multiple water year types but does not reflect the more recent decline of Delta smelt.

- Hobbs et al. 2019 used otolith isotope profiles and measurements data that are quantitative, species specific, and location specific. The analysis is published in a peer-reviewed journal, and uses otoliths from Delta smelt caught by the FMWT and SKT surveys from 2011 and 2012 respectively to determine what portion of the Delta smelt population utilizes brackish water habitats, but may not reflect more recent population declines.

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

- Spring Delta Outflow
- Summer SMSCG Operation
- Fall X2

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

- Drought Actions

## 9.3 Designated Critical Habitat Analysis

USFWS designated critical habitat for the Delta smelt on December 19, 1994 (USFWS 1994). The geographic area encompassed by the designation includes all water and all submerged lands below ordinary high water and the entire water column bounded by and contained in Suisun Bay (including the contiguous Grizzly and Honker Bays); the length of Goodyear, Suisun, Cutoff, First Mallard (Spring Branch), and Montezuma Sloughs; the Napa River; and the existing contiguous waters contained within the legal Delta, as defined in section 12220 of the California Water Code (USFWS 1994).

The primary objective in designating critical habitat was to identify the key components of Delta Smelt habitat that support successful completion of the life cycle, including spawning, larval and juvenile transport, rearing, and adult migration back to spawning sites. Delta Smelt are endemic to the San Francisco Bay/Sacramento–San Joaquin Delta (Bay-Delta) and the vast majority only live 1 year. Thus, regardless of annual hydrology, the estuary must provide suitable habitat all year, every year. The primary constituent elements essential to the conservation of the Delta smelt are physical habitat, water, river flow, and salinity concentrations required to maintain Delta Smelt habitat for spawning, larval and juvenile transport, rearing, and adult migration (USFWS 1994). The USFWS recommended in its designation of critical habitat for the Delta Smelt that salinity in Suisun Bay should vary according to water year type. For the months of February through June, this element was codified by the State Water Resources Control Board's (Water Board) "X2 standard" described in D-1641 and the Water Board's current Water Quality Control Plan.

Table 9-7 compares the 1994 USFWS rule to the current state of scientific understanding for each primary constituent element.

The Proposed action area encompasses the entire range wide critical habitat primary constituent element for Delta smelt. Each of the features of the critical habitat designation for Delta smelt, and potential effects associated with the Proposed Action, is described in subsections below.

Table 9-7 Comparison of delta smelt primary constituent elements of critical habitat between the 1994 publication of the rule and the present.

| **Primary Constituent Element** | **1994 critical habitat rule** | **2023 state of scientific understanding** |
|---|---|---|
| Spawning Habitat | Shallow fresh or slightly brackish edge-waters | No change |
| | Backwater sloughs | Possible, never confirmed. Potentially spawning sites have sandy substrates (Bennett 2005) and need not occur in sloughs. Backwater sloughs in particular tend to have silty substrates that would suffocate the eggs. |
| | Low concentrations of pollutants | No change |
| | Submerged tree roots, branches, emergent vegetation (tules) | Not likely. Unpublished observations of spawning by captive Delta smelt suggest spawning on substrates oriented horizontally and a preference for gravel or sand that is more consistent with observations of other fishes in the family Osmeridae. |
| | Key spawning locations: Sacramento River "in the Delta", Barker Slough, Lindsey Slough, Cache Slough, Prospect Slough, Georgiana Slough, Beaver Slough, Hog Slough, Sycamore Slough, Suisun Marsh | All of the locations listed in 1994 may be suitable for spawning, but based on better monitoring from the Spring Kodiak Trawl Survey, most adult fish have since been observed to aggregate around Grizzly Island, Sherman Island, and in the Cache Slough complex including the subsequently flooded Liberty Island (Polansky et al. 2018). |
| | Adults could spawn from December-July. | Adults are virtually never fully ripe and ready to spawn before February and most spawning is completed by May (Damon et al. 2016). |
| Larval and juvenile transport | Larvae require adequate river flows to transport them from spawning habitats in backwater sloughs to rearing habitats in the open waters of the low-salinity zone | Not likely. Most Delta smelt that survive to the juvenile life stage do eventually inhabit water that is in the 0.5 to 6 ppt range, due to downstream movement and/or decreasing outflow (Bush 2017). However, Delta smelt larvae can feed in the same habitats in which they hatched, and both larval and juvenile fish can rear in water with a salinity lower than 0.5 ppt (Nobriga 2002; Hammock et al. 2017). |
| | Larvae require adequate flow to prevent entrainment | No change, but turbidity has been shown to be an important variable for predicting entrainment of larvae and interacts with flow (Smith et al. 2021). |

| Primary Constituent Element | 1994 critical habitat rule | 2023 state of scientific understanding |
|---|---|---|
| | Larval and juvenile transport needs to be protected from physical disturbances like sand and gravel mining, diking, dredging, rip-rapping | No change, but seems likely to have more impact on spawning habitat than larval transport, which was subsequently shown to be related to swimming behavior timed to tidal flows (Bennett et al. 2002). |
| | 2 ppt isohaline (X2) must be west of the Sacramento-San Joaquin River confluence to support sufficient larval and juvenile transport | Subsequent research showed the larvae distribute similarly relative to X2 regardless of where it resides (Dege and Brown 2004). X2 is generally west of the river confluence during February-June due to State Water Resources Control Board X2 standard; however, the standard does have a drought off-ramp. |
| | Maturation must not be impaired by pollutant concentrations | No change |
| | Additional flows might be required in the July- August period to protect Delta smelt that were present in the south and central Delta from being entrained in export pumps. | July-August outflow augmentations may be helpful, but not to mitigate entrainment because Delta smelt were subsequently shown to no longer occupy the south Delta during July-August (Kimmerer 2008). Habitat changes in the central and south Delta have rendered it seasonally unsuitable to Delta smelt during the summer (Nobriga et al. 2008);<br>entrainment is seldom observed past June and the 2008 Service BiOp RPA has a 25 degree Celsius off-ramp that usually triggers in June. |
| Rearing habitat | 2 ppt isohaline (X2) should remain between Carquinez Strait in the west, Three-Mile Slough on the Sacramento River and Big Break on the San Joaquin River in the east. This was determined to be a historical range for 2 ppt salinity (including its tidal time scale excursion into the Delta). | Recent research has suggested that the 1994 description of seasonal X2 movement is considerably less than what occurred pre- development (Gross et al. 2018). That said, X2 is generally in the specified region during February-June due to the State Water Resources Control Board X2 standard; however, the standard does have a drought off-ramp. Most juvenile Delta smelt still rear in the low-salinity zone in the summer and fall, but it is now recognized that a few remain in the Cache Slough complex as well (Sommer and Mejia 2013; Hobbs et al. 2019). |
| Adult migration | Adults require unrestricted access to spawning habitat from December-July | Adults disperse faster than was recognized in 1994; most of it is finished by the time Spring Kodiak Trawls start in January (Polansky et al. 2018), though local movements and possibly rapid longer distance dispersal occurs throughout the spawning season, which as mentioned above is usually February-May. The only known 'barriers' to adult dispersal are water diversions. |

| Primary Constituent Element | 1994 critical habitat rule | 2023 state of scientific understanding |
|---|---|---|
|  | Unrestricted access results from adequate flow, suitable water quality, and protection from physical disturbance | No change |

## 9.3.1 Physical Habitat

### 9.3.1.1 Delta

*Physical habitat* is defined as the structural components of habitat (USFWS 1994). The ancestral Delta was a large tidal marsh–floodplain habitat totaling approximately 300,000 acres. During the late 1800s and early 1900s, most of the wetlands were diked and reclaimed for agriculture or other human use. The physical habitat modifications of the Delta and Suisun Bay were mostly due to land reclamation and urbanization. Water conveyance projects and river channelization have had some influence on the regional physical habitat by armoring levees with riprap, building conveyance channels like the Delta Cross Channel (DCC), storage reservoirs like Clifton Court Forebay, and by building and operating temporary barriers in the south Delta and permanent gates and water distribution systems in Suisun Marsh.

Between the 1930s to 1960s, the shipping channels were dredged deeper (about 12 meters) to accommodate shipping traffic from the Pacific Ocean and San Francisco Bay to ports in Sacramento and Stockton. These changes left Suisun Bay and the Sacramento–San Joaquin River confluence region as the largest places with the greatest depth variation in the typical range of the low-salinity zone. This region remained a highly productive nursery for many decades (Stevens and Miller 1983; Moyle et al. 1992; Jassby et al. 1995). However, the deeper landscape created to support shipping and flood control requires more freshwater outflow to maintain the low-salinity zone in the large Suisun Bay/river confluence region than was once required. The shipping itself has historically provided a source of nonnative organisms, that, along with lower Delta outflow and deep channelization, have contributed to the changing ecology of the upper estuary (Winder and Jassby 2011; Kratina et al. 2014; Andrews et al. 2017).

Although the Delta smelt is a generally pelagic or open-water fish, depth variation of open-water habitats is an important habitat attribute (Moyle et al. 1992; Hobbs et al. 2006). In the wild, Delta smelt are most frequently collected in water that is somewhat shallow (4 to 15 feet deep) where turbidity is often elevated and tidal currents exist but are not excessive (Moyle et al. 1992; Bever et al. 2016). In Suisun Bay, the deep shipping channels are poor quality habitat because tidal velocity is very high (Bever et al. 2016), but in the north Delta where tidal velocity is slower, the Sacramento Deepwater Shipping Channel is used to a greater extent. Adult Delta smelt also use edge habitats as tidal current refuges and corridors to spawning habitats (Bennett and Burau 2015).

As identified in is section 9.2, Effects Analysis, there are no stressors associated with the Proposed Action that are anticipated to affect the structural components of habitat.

## 9.3.2 Water Quality

### *9.3.2.1 Delta*

*Water* is defined as water of suitable quality to support various Delta Smelt life stages that allow for survival and reproduction (USFWS 1994). Certain conditions of temperature, turbidity, and food availability characterize suitable pelagic habitat for Delta smelt and are discussed in detail below. Contaminant exposure can degrade this primary constituent element even when the basic habitat components of water quality are otherwise suitable (Hammock et al. 2015).

*Turbidity* is required by Delta smelt. Even in captivity, clear water is a source of physiological stress (Lindberg et al. 2013; Hasenbein et al. 2016). The small plankton that Delta smelt larvae eat are nearly invisible in clear water. The sediment (or algal) particles that make turbid water turbid, provide a dark background that helps Delta smelt larvae see their translucent prey (Baskerville-Bridges et al. 2004). Older Delta smelt are less reliant on turbidity to see their prey, but juvenile fish still feed more effectively in water of moderate turbidity (Hasenbein et al. 2016) and probably need turbid water to help disguise themselves from predators (Ferrari et al. 2014). The turbidity of the Delta and Suisun Bay has been declining for a long time due to dams and riprapped levees, both of which cut off sources of sediment from rivers flowing into the estuary (Arthur et al. 1996; Wright and Schoellhamer 2004), and due to the spread of Brazilian waterweed (Hestir et al. 2015) which filters the water, increasing clarity. Water exports from the south Delta may also have contributed to the trend toward clearer water by removing resuspended sediment in the exported water (Arthur et al. 1996), but the contribution of diversions, via reduced outflow, to reducing the total suspended sediment budget in the estuary is small (Schoellhamer et al. 2012). The primary turbid areas that remain in the upper estuary are the semi-shallow embayments in northern Suisun Bay (Bever et al. 2016) and the lower Yolo Bypass region that includes Liberty Island and the upper reach of the Sacramento Deepwater Shipping Channel (Morgan-King and Schoellhamer 2013). Both tidal and river flows, as well as wind speed, affect turbidity in these locations (Bever et al. 2018). Many of the estuary's deeper channels tend to have somewhat lower turbidity because water velocity and wind cannot resuspend sediment that sinks into deep water (Ruhl and Schoellhamer 2004).

*Water temperature* is the primary driver of the timing and duration of the Delta smelt spawning season (Bennett 2005). Water temperature also affects Delta Smelt's growth rate which in turn can affect their readiness to spawn (Rose et al. 2013a). Water temperature is not strongly affected by variation in Delta outflow; the primary driver of water temperature variation in the Delta Smelt critical habitat is air temperature (Wagner et al. 2011). Very high flows can transiently cool the upper estuary (e.g., flows in the upper 10th percentile, Kimmerer 2004) during the early part of the year, but the system rapidly re-equilibrates once air temperatures begin to warm.

Older laboratory-based research suggested an upper water temperature limit for Delta smelt of about 25°C, or 77°F (Swanson et al. 2000). Newer laboratory research suggests Delta smelt temperature tolerance decreases as the fish age, but is a little higher than previously reported, up to 28°C or 82°F in the juvenile life stage (Komoroske et al. 2014). It should be kept in mind that these are upper acute water temperature limits, meaning temperatures in this range will kill, on the average, one of every two fish.

In the laboratory and the wild, Delta smelt appear to have a physiological optimum temperature near 20°C or 68°F (Nobriga et al. 2008; Rose et al. 2013a; Jeffries et al. 2016). Multiple measures show declines in Delta Smelt physiological and ecological performance at temperatures great than 21-22°C or 70-71.5°F, including genetic indicators of stress (Komoroske et al. 2015; Koromoske et al. 2021), growth rates (Lewis et al. 2021), and behavioral energetic demands (Davis et al. 2019). Performance temperature thresholds for adult Delta Smelt based on a review of multiple studies appear to be 19-22°C or 66-71.5°F for adults and 20-22°C or 68-71.5°F for juveniles (Davis et al. 2022). Most of the upper estuary exceeds this water temperature from June through September (Wagner et al. 2011). Thus, many parts of the estuary are energetically costly and stress Delta smelt. Spring and summer water temperatures are generally cooler to the west and warmer to the east due to the differences in overlying air temperatures between the Bay Area and the warmer Central Valley (Kimmerer 2004). In addition, there is a strong water temperature gradient across the Delta with cooler water in the north and warmer water in the south. The higher flows from the Sacramento River probably explain this north-south gradient. Note that water temperatures in the north Delta near Liberty Island and the lower Yolo Bypass are also typically warmer than they are along the Sacramento River (Sommer et al. 2001; Nobriga et al. 2005).

Food and water temperature are strongly interacting components of Delta smelt health and habitat because the warmer the water, the more food Delta Smelt require (Rose et al. 2013a). If the water gets too warm, then no amount of food is sufficient. The more food Delta smelt eat (or must try to eat) the more they will be exposed to predators and contaminants. Water exports can limit the flux of phytoplankton production from the Delta into Suisun Bay (Jassby and Cloern 2000), but the effect of water exports on phytoplankton production appears to be lower than grazing by clams (Jassby et al. 2002) and ammonium inhibition of phytoplankton growth from Sacramento's urban wastewater inputs (Dugdale et al. 2007).

Historically, prey production peaked when the low-salinity zone was positioned over the shoals of Suisun Bay during late spring through the summer, but this function has been depleted due to grazing by overbite clams (Kimmerer and Thompson 2014), high ammonium concentrations in critical habitat (Dugdale et al. 2012; Dugdale et al. 2016), and water diversions (Jassby and Cloern 2000). Recent research suggests Delta smelt occupying Suisun Bay may experience poor nutritional health (Hammock et al. 2015). Delta Smelt occupying the Cache Slough region in the north Delta are in better nutritional health, but have shown evidence of relatively high contaminant impacts. The southern Delta is among the more productive areas remaining in the upper estuary (Nobriga et al. 2005), but Delta Smelt cannot remain in this habitat during the warmer months of the year (Nobriga et al. 2008) and may face a high risk of entrainment when they occupy it during cooler months (Kimmerer 2008; Grimaldo et al. 2009). Extensive blooms of the toxin producing cyanobacteria Microcystis in the central and southern Delta became abundant around 1999 which, depending on flow and temperature, can extend westward into the low-salinity zone where Delta Smelt are rearing (Brooks et al. 2012). In one recent study, Delta Smelt that occupied Suisun Marsh fared better both in terms of nutrition and in experiencing a lower level of contaminant impacts (Hammock et al. 2015).

This primary constituent element (PCE; water quality) is comprised of three components (turbidity, water temperature and food) that cumulatively determine the value of this element.

The components of the PCE are independently assessed in this section and then they are combined to determine the cumulative impact on the overall PCE.

The relevant stressors that are impacted by *turbidity* are food visibility and predation. The predation stressor impacts all relevant life stages while the food visibility stressor only applies to the adult and eggs/larvae life stages. As identified in *Section 9.2*, the Proposed Action will reduce inflow and outflow in the Delta which may reduce the turbidity levels in the Delta. The reduced turbidity levels are thought to result in higher potential rates of predation for all life stages. The reduced turbidity levels will decrease the food visibility stressor for adults who feed optimally in clearer water while increasing the food visibility stressor for larvae that feed optimally in water with turbidity levels greater than 25 NTU. The impacts of the reduced turbidity levels are negligible/discountable for the relevant stressors listed above.

As identified in *Section 9.2,* the Proposed Action will result in the storage and diversion of water which will reduce Delta inflows and outflows. *Water temperature* will increase for all life stages as the Delta inflow is negatively correlated with the water temperature in spring. The water stressor will decrease for the juvenile and sub-adult life stage as the Delta inflow is positively correlated with water temperature for the months of July through September. The impact of the change in the water temperature stressor are negligible for all life stages associated with this stressor.

As identified in Section *9.2.1.1, Food Availability Stressor,* Section *9.2.2.1, Food Availability Stressor, and* Section *9.2.3.1, Food Availability and Quality Stressor*, the food availability stressor will increase due to the storage and diversion of water which will reduce Delta inflows and outflows. The abundance of historically important Delta smelt zooplankton prey taxa in the LSZ, including *Eurytemora affinis*, generally exhibit a positive correlation with Delta outflow in the spring. This stressor is thought to result in adverse effects on all applicable stages associated with the potential reduction in food availability.

The spring Delta outflow and tidal habitat restoration are conservation measures that could result in greater abundance of important zooplankton prey taxa in the LSZ through increased available habitat for food production and Delta outflow.

The water quality PCE has negative effects on all life stages associated with the reduction in historically important food for Delta smelt that are positively correlated with Delta outflow in the spring. All other applicable impacts on components of this PCE are negligible and discountable.

### 9.3.3 River Flow

"River flow" was originally defined as transport flow to facilitate spawning migrations and transport offspring to low-salinity zone rearing habitats (USFWS 1994), currently called tidal surfing (Bennett and Burau 2015). Both the flood and ebb tide influence the Delta smelt distribution and dispersal.

The spawning microhabitats of Delta smelt are not known, but it is likely there is more available suitable spawning habitat when Delta outflow is high during spawning than when it is low because more of the estuary is covered in fresh- and low-salinity water when outflow is high (Jassby et al. 1995). An examination of the adults found that a majority were using fresh to low salinity water. Most spawning occurs between February and May. Delta outflow during February through May is mainly driven by the climatic effect on the amount and form of precipitation in the watershed, the storage and diversion of water upstream of the Delta, and CVP and SWP water operations in the Delta (Jassby et al. 1995; Kimmerer 2002b). Thus far, the 21st Century has tended to be pretty dry and warm and that could have resulted in some chronic reduction in spawning habitat availability or suitability.

As identified in Section *9.2.1.2*, *Entrainment Stressor,* Section *9.2.2.2, Entrainment Stressor, and* Section *9.2.3.2. Entrainment Stressor*, the Proposed Action will result in the diversion of water that may increase the entrainment risk stressor. The risk of entrainment is reduced and minimized through the implementation of OMR export restrictions and reductions during specific time frames, in response to specific abiotic factors and associated with the salvage of Delta smelt. The impacts of the Proposed Action will result in adverse effects on this PCE.

### 9.3.4 Salinity

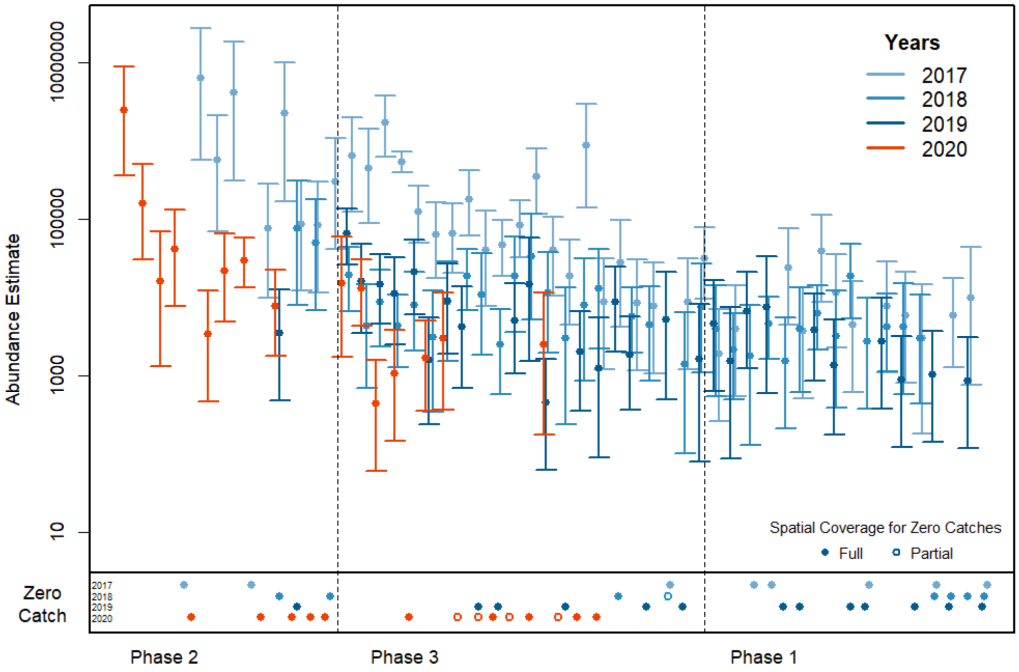
Older laboratory research suggested that Delta smelt have an upper acute salinity tolerance of about 20 ppt (Swanson et al. 2000) which is about 60 percent of seawater's salt concentration of 32 to 33 ppt. Newer laboratory-based research suggests that some individuals can acclimate to seawater, but that comes at a high energetic cost that is lethal to about one in four individuals (Komoroske et al. 2014, 2016). In the wild, Delta Smelt are nearly always collected at very low salinities. Research has suggested prey may be more readily captured at low salinities; stomach fullness in Delta smelt was higher in brackish regions during the spring and fall (Hammock et al. 2017) which may be why Delta smelt are collected at very low salinities. Few individuals are collected at salinities higher than 6 ppt (about 20 percent of seawater salt concentration) and very few are collected at salinities higher than 10 ppt (about 30 percent of seawater salt concentration) (Bennett 2005). This well documented association with fresh to low salinity water is a reason for the scientific emphasis on X2 as a Delta smelt habitat indicator (Dege and Brown 2004; Feyrer et al. 2011). Recent research combining long-term monitoring data with three-dimensional hydrodynamic modeling shows that the spatial overlap of several of the key habitat attributes increases as Delta outflow increases (Bever et al. 2016), salinity being one (but not the only) key attribute.

As identified in *Section 9.2.3.3, Size and Location of LSZ Stressor*, the Proposed Action will store and divert water that may result in position of the LSZ being further landward which would reduce the size of the LSZ and, thus, available habitat for juvenile Delta smelt. The impact of this stressor is reduced through the implementation of the Delta Smelt Summer and Fall Habitat Action which results in additional SMSCG operation in certain year types to reduce the salinity of portions of the Suisun Marsh. The impacts of the Proposed Action will result in negative effects on this PCE.

## 9.4 Lifecycle Analysis

### 9.4.1 Life Stage Transitions in the Literature

Delta smelt typically experience the highest mortality rate during the early life stage and lower mortality rate during the juvenile/sub-adult life stage before spawning occurs in the following spring and essentially all adults die off (Figure 26 and Figure 27). No direct measurements of life stage survival are made, although this pattern is observable in data from the EDSM surveys over a cohorts life cycle. The probability of survival of different life stages of Delta smelt has been explored using nonlinear state-space modeling (Polansky et al. 2021). Survival is influenced by covariates related to abiotic habitat conditions (e.g., temperature, X2 position, outflow, turbidity) and biological factors (e.g., prey availability, competitors, predators; Polansky et al. 2021, Web Appendix C Table C.1). Post-larval survival was influenced by outflow and turbidity; juvenile survival by turbidity and temperature; and sub-adult survival by turbidity in the south Delta, OMR, and adult striped bass (Morone saxatilis, Polansky et al. 2021). Delta smelt adult equivalent units were used to estimate the percent mortality of eggs, larvae, and juveniles (Table 9-8., Figure 9-27). It is unclear what life stage proportional improvement in survival would yield the highest population growth rate, as such analysis has yet to be done. However, Smith et al. (2021) found substantial variation in fall mortality in years 1995–2015, which suggests that management actions to reduce Delta smelt demographic bottlenecks during the part of the year may be worth pursuing. Using a state state-space life cycle model, Smith et al. (2021) found natural mortality in the fall season was negatively associated with turbidity and natural mortality of late sub-adult and adult stages was negatively associated with food. In a similar analysis, Maunder and Deriso (2011) found food abundance, water temperature, predator abundance and density dependence were the most important factors affecting population dynamics. Density dependence was most evident in survival of juveniles to adults but is probably not having a significant impact at recent levels of abundance.



Weekly Delta Smelt Abundance Estimates from Enhanced Delta Smelt Monitoring Program (EDSM) between 2017 and 2020. Years indicates the years in which each Delta smelt cohort was born. Phase 1 of EDSM runs from December through March and focuses on adult Delta smelt. Phase 2 sampling takes place from April through June and targets post-larval and juvenile Delta smelt. Phase 3 runs from July through November and targets juvenile and sub-adult Delta smelt. Closed circles indicate normal sampling effort for the week and open circles indicate a reduced sampling effort. Summer and Fall of 2020 (Phase 2) had multiple weeks with incomplete spatial coverage due to wildfire smoke/hazardous air quality.

Figure 9-26. Weekly Delta Smelt Abundance Estimates from Enhanced Delta Smelt Monitoring Program (EDSM) between 2017 and 2020.

Table 9-8. Delta smelt adult equivalent units for different life stages (L. He, USFWS, personal communication).

| Life Stage | Size Range (mm FL) | Adult Equivalent |
|---|---|---|
| Eggs | ~1 | 5824 |
| Larvae | < 20 | 116 |
| Juvenile | 20-58 | 10 |
| Adult | > 58 | 1 |

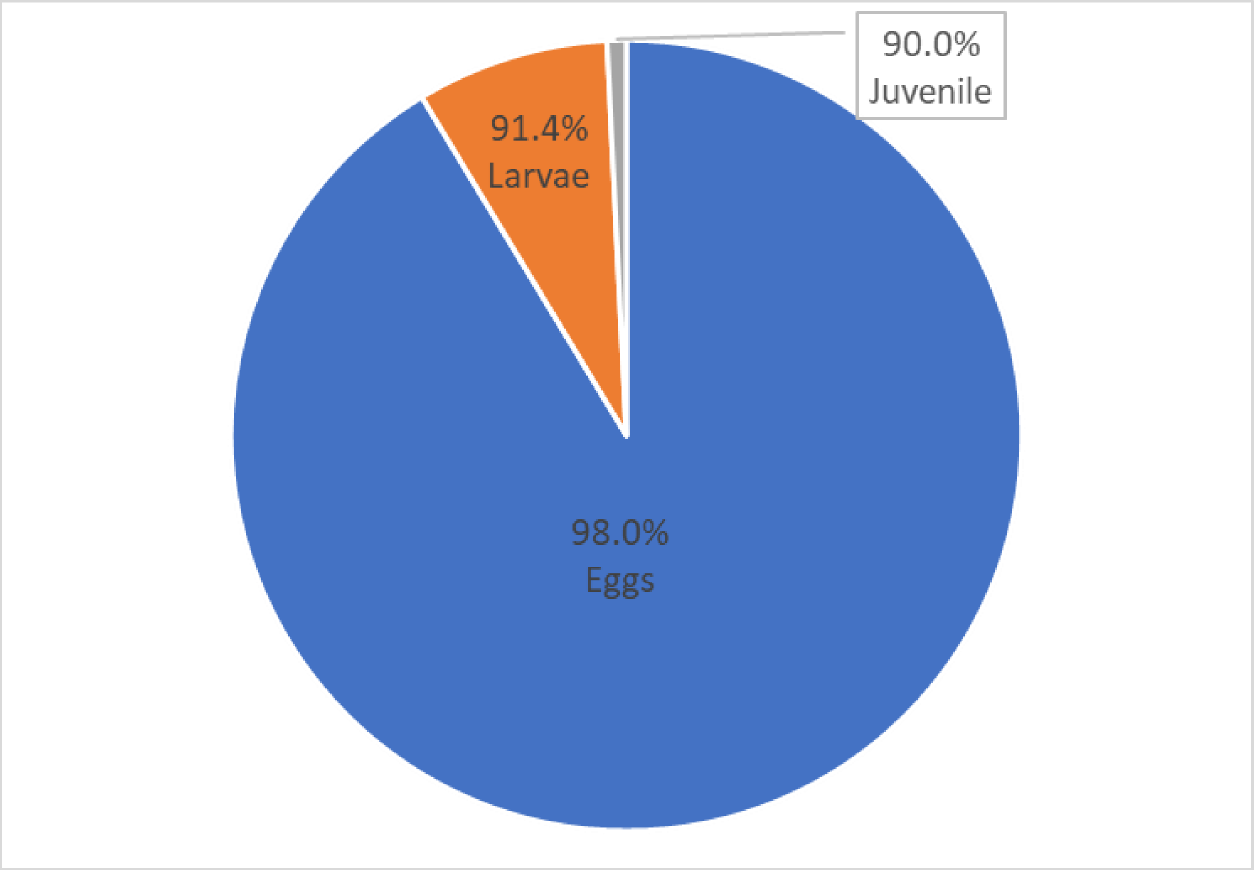


Figure 9-27. Delta Smelt Mortality by Life Stage Based on the USFWS Adult Equivalents for Each Life Stage

### 9.4.2 Delta Smelt Life Cycle Model with Entrainment

The Delta Smelt Life Cycle Model with Entrainment Analysis (LCME), Appendix F, Attachment X produces estimates values for larval recruitment and survival at the subsequent life stages (Smith et al. 2021). The most statistically supported model used means of December-June OMR values, June-August outflow aggregated from monthly values or longer timescales, and aggregated food/prey metric from January to March. The model is used to calculate expected annual population growth rate ($\lambda$; the abundance of current year divided by abundance from previous year) as a performance measure of Delta seasonal flow operations influence on OMR and outflow over a twenty-year time period (1995-2015) (Figure 9-28).

The geometric mean of the expected population growth across years (1995-2015), λ, for the Proposed Action components ranged from 0.95 to 0.98 (Table 9-9). The means of the expected population growth rate varied more widely across water year types, and showed positive growth rates under wetter meteorology and negative growth rates under drier meteorology. Note that wetter years also occurred with greater frequency at the beginning of the time series (1995-1999) compared to the end of the time series (2006-2015). The various phases of Proposed Action produced geometric mean λ similar to the empirical data (0.95-0.98 vs. 0.96). While the various phases of of the Proposed Action resulted in higher λ than the empirical data during drier years, they also resulted in lower λ than the empirical data during wetter years (Table 9-9).

The various phases of the Proposed Action may have produced higher λ during drier years due to the more positive OMR values for multiple months and higher zooplankton estimates in February. Meanwhile, the Proposed Action components may have produced lower λ than the empirical data during wetter years because of the lower June-August Delta Outflow values and more negative OMR values for some months. The Proposed Action phases did not produce higher λ despite OMR restrictions that should reduce entrainment of Delta smelt. This may be due to the apparent trade-off between OMR flow and summer Delta outflow that somehow occurred between Proposed Action phases and the empirical data.

Table 9-9. Geometric mean of predicted population growth rate (λ) across all years and binned into wetter and drier years for all alternatives.

| **Category** | **EXP1** | **EXP3** | **NAA** | **PA without TUCP without VA** | **PA without TUCP Delta VA** | **PA without TUCP Systemwide VA** | **Empirical** |
|---|---|---|---|---|---|---|---|
| 1995-2015 | 1.01 | 1.41 | 0.97 | 0.95 | 0.98 | 0.98 | 0.96 |
| Below Normal, Dry, or Critically Dry years | 0.57 | 0.90 | 0.74 | 0.75 | 0.77 | 0.77 | 0.58 |
| Wet and Above Normal years | 1.91 | 2.32 | 1.32 | 1.24 | 1.27 | 1.28 | 1.68 |

Empirical scenario indicates the LCME fit to observed data, while all alternative models represent simulations using CalSim output.

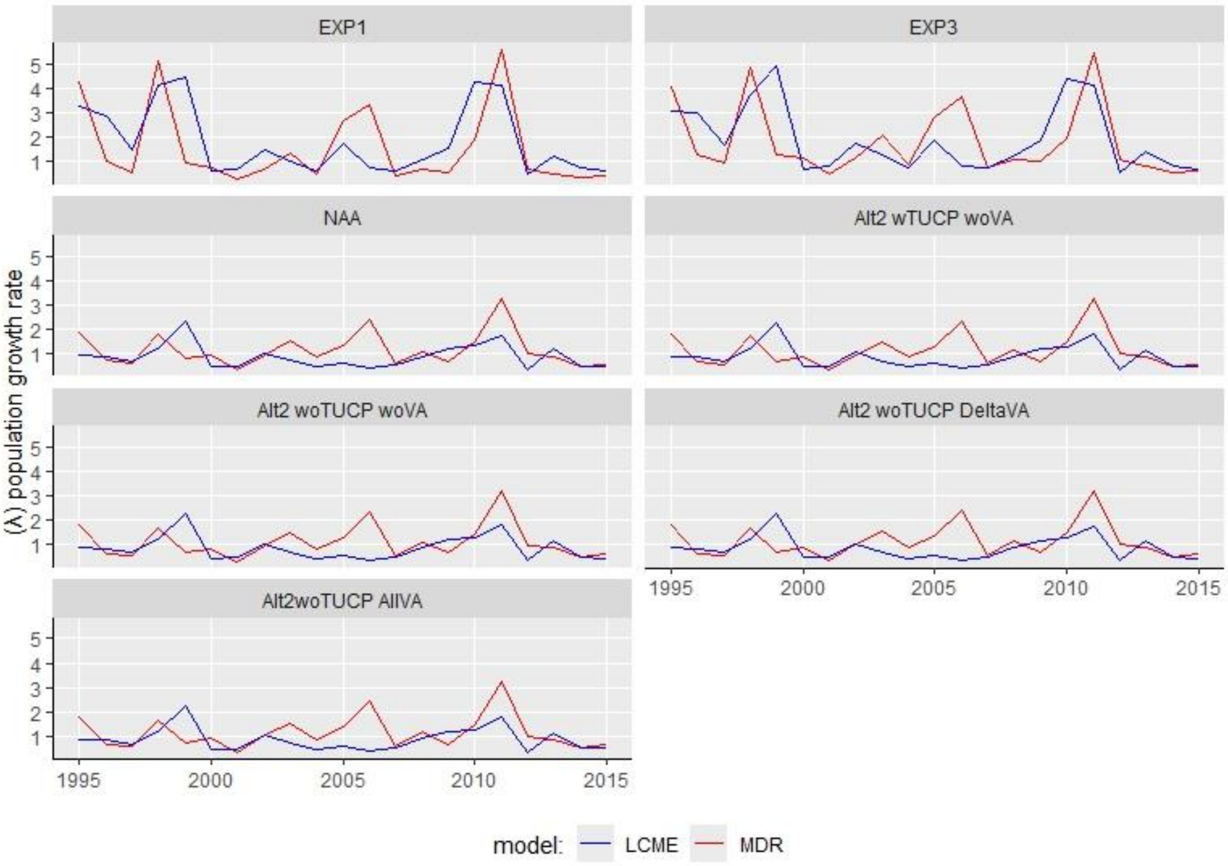


Figure 9-28: Predicted population growth rate (λ) for each proposed alternative across all years from the Delta Smelt Lifecycle Model with Entrainment (LCME) in blue and the Maunder and Deriso in R (MDR) in red.

### 9.4.3 Maunder and Deriso in R

The Delta smelt life cycle model published by Maunder and Deriso (2011) was updated in 2021 following the approach of Polansky et al. (2021) as far as practical, by modifying and generalizing the originally published model. The updated model is now known as the Maunder and Deriso Model in R (MDR) and is detailed in Appendix F and Attachment F. This state-space life cycle was fitted to Delta smelt abundance indices at four life stages and covariate data from the 1995-2015 period. As with the LMCE, the MDR is useful for comparing expected population growth rate ($\lambda$; the abundance of current year divided by abundance from previous year) as a performance measure of Delta seasonal flow operations influence on OMR and outflow over a twenty-year time period (1995-2015) (Figure 9-29). The model with strongest statistical support included December-February OMR values and June-August outflow aggregated from monthly values along with temperature and turbidity in multiple seasons, but these additional covariates were not modified for evaluation of Proposed Action phases.

Across the complete projection period (1995-2015 covariate values, projected forward from the observed 2015 adult abundance index) the geometric mean of the expected population growth, λ, did not exceed 1 (i.e., positive population growth) and did not differ between Proposed Action phases (λ = 0.91 for all; Table 9-10). However, each Proposed Action phase did result in improvement relative to the baseline projection (λ = 0.82). When separated into wetter (wet/above normal) and drier (below normal/dry/critically dry) year groups the geometric mean of projected λ values remained below 1 for all Proposed Action phases and groups, though in wetter years the values approached 1. Overall, the MDR projection results suggest on average negative population growth, regardless of water year type (Figure 9-25). Differences between the Proposed Action phases were driven primarily by December-February OMR, with relatively minor influence from June-August outflow. The lack of difference in projected population growth between the Proposed Action phases, therefore, results from the very similar OMR values during this period across each of the CalSim outputs.

Table 9-10. Geometric mean of predicted population growth rate (λ) across all years and binned into wetter and drier years for all alternatives.

| **Category** | **EXP1** | **EXP3** | **NAA** | **PA without TUCP without VA** | **PA without TUCP Delta VA** | **PA without TUCP Systemwide VA** |
|---|---|---|---|---|---|---|
| 1995-2015 | 1.60 | 1.88 | 0.91 | 0.91 | 0.91 | 0.91 |
| Below Normal, Dry, or Critically Dry years | 0.94 | 1.18 | 0.79 | 0.81 | 0.80 | 0.82 |
| Wet and Above Normal years | 1.99 | 2.27 | 0.96 | 0.96 | 0.95 | 0.95 |

Proposed Action phases modeled represent forward projections using CalSim output to modify June-August outflow and December-February OMR.

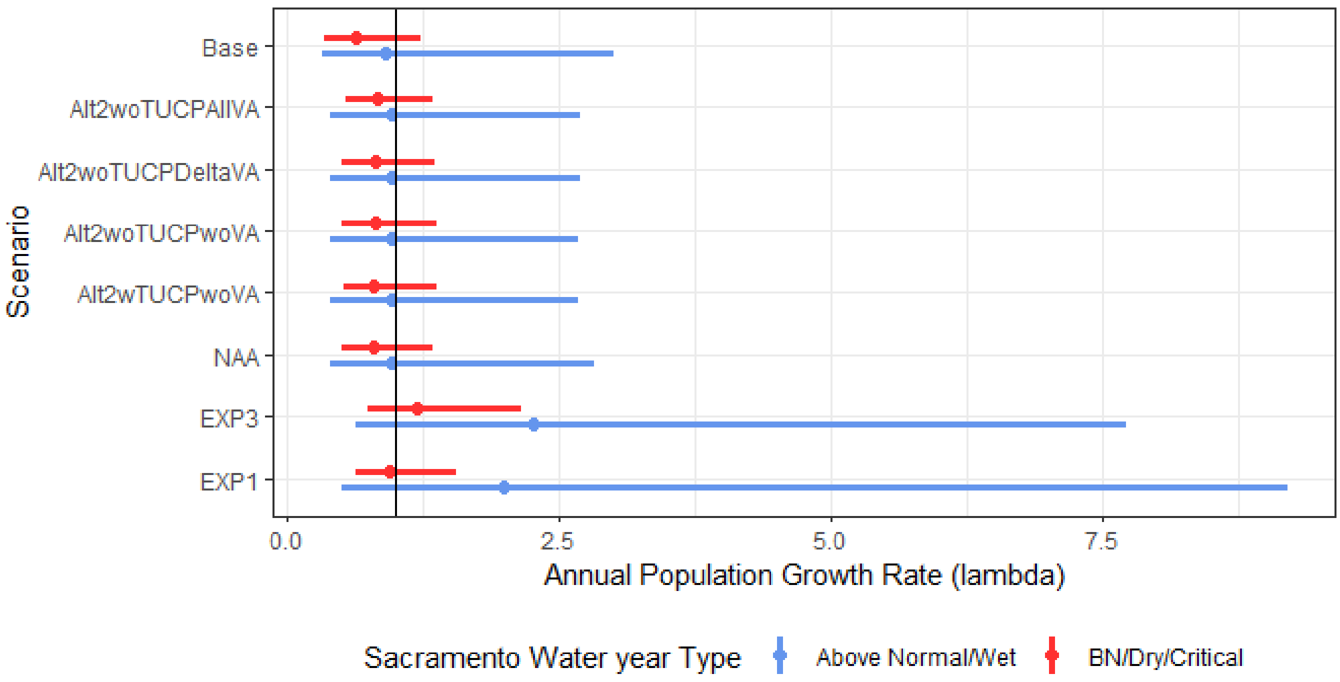


Figure 9-29. Geometric means (points) and full ranges (lines) of projected population growth rate (λ) by hydrology and covariate scenario (1995-2015; note that projection is initiated from the 2015 adult abundance index).

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### 9.5.2 Personal Communications

L. He, USFWS, personal communication