Long-Term Operation – Biological Assessment

Appendix J – Winter and Spring Pulses and Delta Outflow–Smelt, Chinook Salmon, and Steelhead Migration and Survival

October 2024

Contents

Tables

Figures

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Appendix J Winter and Spring Pulses and Delta Outflow–Smelt, Chinook Salmon, and Steelhead Migration and Survival

J.1 Introduction

Outflow from the Sacramento–San Joaquin Delta (Delta) integrates the effects of runoff, storage, releases, and diversions. In the spring months, native and other fish complete their most sensitive life stages. Juvenile Chinook salmon migrate from natal tributaries through the Delta and rear along the way to the ocean. Winter and spring flows provide outmigration cues for juvenile Chinook salmon and help to enhance likelihood of Central Valley steelhead anadromy. Portions of the Delta smelt and longfin smelt populations spawn in the freshwater area of the Delta and their larvae and juveniles migrate toward Suisun Marsh and Bay. State Water Resources Control Board (Water Board) Decision 1641 (D-1641) implemented the water quality objectives from the 1995 San Francisco Bay/Sacramento–San Joaquin Delta Estuary (Bay-Delta) Plan and assigned certain responsibilities to the Central Valley Project (CVP) and State Water Project (SWP).

Delta outflow is influenced by CVP and SWP storage, releases, and diversions as well as uncontrolled runoff and diversion by non-project water users. Recent efforts to balance the need to build a coldwater pool through storing water in reservoirs with the needs for instream flows and Delta outflow require a more detailed understanding of how different actions might perform.

J.2 Initial Alternatives Report

J.2.1 Management Questions

United States Department of the Interior, Bureau of Reclamation's (Reclamation) management questions for the formulation of an alternative include the following:

- During the spring, what is the proportion of primary and secondary productivity supplied to the Delta from tributary inflows, Yolo Bypass, and other floodplain inundation versus productivity within the Delta?
- Does the inundation of Yolo Bypass and other floodplain areas change the productivity compared to in-channel and shallow tidal habitat within the Delta?
- What is the proportion of spring primary and secondary productivity passed to Suisun Marsh and Bay versus removed by CVP and SWP exports versus captured; e.g., clams?

- Can spring exports and tributary releases stimulate phytoplankton blooms and/or disperse central Delta phytoplankton biomass to habitats that are likely occupied by Delta smelt and longfin smelt?
- Can spring exports and tributary releases stimulate detrital-based zooplankton production and/or disperse central Delta food resources to habitats that are likely occupied by Delta smelt and longfin smelt?
- Does maintenance of low-salinity zone connectivity to Suisun Marsh and San Pablo Bay for Delta smelt and longfin smelt bolster spring survival?
- How much does spring export reductions, tributary releases, and/or both improve migratory conditions for Chinook salmon and steelhead?
- Do spring Delta outflows driven by tributary releases reduce the need for Old and Middle River management?
- What are the costs of Delta outflow actions to the current year's water supply, storage, water quality, and/or hydropower?

J.2.2 Initial Analyses

Reclamation solicited input for the knowledge base paper, *Delta Spring Outflow Management Smelt Growth and Survival Knowledge Base Document*.

Reclamation completed a literature review.

Reclamation reviewed physical and biological modeling developed by the Upper Sacramento Scheduling Team during the real-time pulse flow planning process in 2020–2023.

J.2.3 Initial Findings

Spring Delta outflow can affect numerous attributes of water quality. There is a well-established relationship between outflow and salinity incursion into the Delta, with increasing outflow leading to decreased salinity. Increasing riverine inflow to meet outflow may decrease Delta water temperatures indirectly, though atmospheric influences predominate. Reducing exports to meet outflow are likely to result in longer residence times, which are likely to result in warmer water temperatures. There remains uncertainty about sources of spring outflow and oxygen, contaminants, and sediment.

Changes in spring Delta outflow due to changes in river inflow can increase primary productivity and fish growth in migratory habitats by inundating seasonal floodplain habitat like the Yolo Bypass. Changes in spring Delta outflow due to exports have not been shown to have similar effects. Effects of spring Delta outflow on ecosystem productivity in the tidally-influenced estuarine Delta regions are less clear. Modifying spring Delta outflow may affect productivity primarily by changing the volume and distribution of low-salinity habitat as well as changing water residence time.

Changes in spring Delta outflow through increased riverine inflow increases survival of juvenile salmonids through the Delta.

J.2.4 Subsequent Considerations

Reclamation solicited input for the knowledge base paper, *Delta Spring Outflow Management-Smelt Growth and Survival*.

Reclamation completed a literature review.

Reclamation reviewed physical and biological modeling developed as part of Upper Sacramento Scheduling Team process for spring pulse flows in 2020–2023.

J.3 Public Draft Environmental Impact Statement Scenarios

Under the National Environmental Policy Act (NEPA), Reclamation compares action alternatives to a “no action” alternative. Under the Endangered Species Act, Reclamation’s discretionary actions over an environmental baseline determine the effects on listed species. No single environmental baseline to evaluate the effects under the Endangered Species Act (ESA) or impacts under NEPA. ESA requires a comparison to the environmental baseline which is informed by ROR and Alternative 1. NEPA requires a comparison to No Action alternative.

J.3.1 Run of River

[Placeholder]

J.3.2 No Action

[Placeholder]

J.3.3 Alternative 1 – Water Quality Control Plans

[Placeholder]

J.3.4 Alternative 2 – Multi-Agency Consensus

[Placeholder]

J.3.5 Alternative 3 – Modified Natural Flow Hydrograph

[Placeholder]

J.3.6 Alternative 4 – Reservoir Flexibility

[Placeholder]

J.4 Performance Metrics

J.4.1 Biological

Biological metrics consider direct observations and environmental surrogates as follows.

- **Smelt Metrics (Delta and Longfin):**
    - Survival and
    - Physical habitat quality and quantity
- **Food Web Metrics:**
    - Zooplankton (prey availability)
- **Salmon Metrics:**
    - Juvenile salmonid survival and travel time in Sacramento River
    - Juvenile survival probability to Chipps Island
    - Juvenile physical habitat quality and quantity

J.4.2 Water Supply

Water supply metrics consider the multipurpose beneficial uses of CVP reservoirs including:

- North-of-Delta agricultural deliveries (average and critical/dry years)
- South-of-Delta agricultural deliveries (average and critical/dry years)
- Bay-Delta Water Quality Control Plan (D-1641) Standards

J.4.3 National Environmental Policy Act Resource Areas

Major considerations under NEPA will include changes in multiple resource areas. Key resources are anticipated to include: surface water supply, water quality, groundwater resources, power, aquatic resources, terrestrial biological resources, regional economics, land use and agricultural resources, recreation, cultural resources, socioeconomics, environmental justice, and climate change.

J.5 Methods Selection

Reclamation solicited input for the knowledge-based paper *Spring Pulse and Delta Outflow-Smelt, Chinook Salmon, and Steelhead Migration and Survival*. Knowledge-based papers compile potential datasets, literature, and models for analyzing potential effects from the operation of the CVP and SWP on species, water supply, and power generation. From the knowledge-based papers, Reclamation and California Department of Water Resources (DWR) organized the best available information for evaluating the impacts of spring pulse and Delta outflow as described below.

J.5.1 Literature

J.5.1.1 History of Spring Outflow Effects by Regulatory Regime

1950s–Early 1970s: Onset of Central Valley Project Operations

The C.W. "Bill" Jones Pumping Plant was constructed from 1947 to 1951. During this era, there were no Water Right Decisions that provided recommendations or regulatory requirements for Delta outflow.

D-1275: Water Right Decision 1275 (D-1275) was adopted in May of 1967. At this point this Water Right Decision did not provide recommendations or requirements for Delta outflow. Presented in D-1275 is DWR's plan of Delta outflow at 1,800 cfs and Reclamation's plan of Delta outflow at 1,500 cfs.

1978: Water Right Decision D-1485

Unlike the 1960s, during the 1970s exports began to occur year-round and were increasing in volume. Water Right Decision 1485 (D-1485) marked the beginning of environmental protections and management to outflow requiring standards for the protection of fish and wildlife.

D-1485 was adopted in 1978 to establish water quality standards, including flows to be maintained for the protection of fish and wildlife, imposed as a condition to all of the CVP and SWP permits. The two documents adopted by the Water Board (a water quality control plan and a water right decision) represent a unified effort by the Water Board to develop and implement under its full authority a single comprehensive set of water quality standards to protect beneficial uses of Delta water supplies (D-1485:6). D-1485 was the first Water Right Decision to consider monthly Delta outflow, pumping, and protections for listed fish. D-1485 additionally calls for research studies to determine "outflow needs in San Francisco Bay, including ecological benefits of unregulated outflows and salinity gradients established by them." This Water Right Decision outlined Delta outflow and net stream flow values for striped bass and salmonid protection by month for varying water year types.

1990s and Early 2000s: Central Valley Project Improvement Act, D-1641, CALFED

By the early 1990s, agreements were in place allowing the California Department of Fish and Wildlife to monitor salvage operations providing further benefits to protected fish. During this era there were requirements set in place to address standards for fish and wildlife protection with written intent to restore the Bay-Delta ecosystem and improve water management. Among these requirements was consideration of the export rate restriction standard (export/inflow ratio). The Central Valley Project Improvement Act (CVPIA) passed mandating changes in CVP management specifically for "protection, restoration, and enhancement of fish and wildlife" (Section [b][4] of CVPIA). There was organization of federal and state agencies through

CALFED. D-1641 outlined a long-term plan to limit pumping to protect juvenile Chinook salmonids.

- **CALFED:** CALFED was organized in 1994, a partnership between federal and state agencies with management and regulatory responsibilities in the Delta. The lead CALFED agencies released a Final Programmatic Environmental Impact Statement/Environmental Impact Report and the Preferred Alternative on July 21, 2000. This was followed by the signing of the Record of Decision on August 28, 2000, which formally approved a long-term plan to restore the Bay-Delta ecosystem and improve water management.
- **D-1641:** In 2000, through adoption of D-1641, the SWP and CVP were mandated to comply with the objectives in the 1995 Bay-Delta Plan. The requirements in D-1641 address standards for fish and wildlife protection, municipal and industrial water quality, agricultural water quality, and Suisun Marsh salinity. D-1641 also authorizes SWP and CVP to jointly use each other's points of diversion in the southern Delta, with conditional limitations and required response coordination plans. Objectives include outflow requirements and specific spring export restraints. Important Bay-Delta Standards in D-1641 include habitat protection outflow and salinity starting conditions (hereafter "Spring X2"), export/inflow ratio, minimum Delta outflow, Sacramento River Rio Vita flow standards.

  D-1641 additionally established a systematic approach for operations' effects on the geographical position of X2. The compliance location and number of X2 days a month between February and June is defined by regulatory standard tables. Additionally, there is a salinity starting gate requirement condition that must be met in all by very dry January conditions.

Late 2000s and 2010s: 2008/2009 Reasonable and Prudent Alternative

U.S. Fish and Wildlife Service and National Marine Fisheries Service (NMFS) issued Biological Opinions in 2008 and 2009, respectively recognized operations of the CVP and SWP were likely to adversely modify critical habitat for listed species and jeopardize some species' continued existence. Protections were put in place including management actions for listed fish protections.

- **2008 Biological Opinion:** The 2008 U.S. Fish and Wildlife Service Biological Opinion suggests a reasonable and prudent alternative to 2009 Biological Opinion: There are no reasonable and prudent measures in the 2009 NMFS Biological Opinion for spring outflow actions. 2009 NMFS Biological Opinion recommends Action I.2.2. – November through February Keswick Release Schedule (Fall Actions). If operations to meet Delta outflow conditions occur, Action I.2.2. (Action I.2.2.C. Implementation and Exception Procedures for EOS Storage of 1.9 MAF or below) recommends CVP/SWP Delta combined exports decrease to 2,000 cfs or more restrictive to meet legal requirements while maintaining a 3,250 cfs Keswick release (p. 596).

Present Day: 2019 Reasonable and Prudent Measures, 2020 Record of Decision and 2020 Incidental Take Permit

Currently there are measures in place to provide continued protections for listed fish within Reclamation's 2020 Proposed Action via the 2020 Record of Decision and DWR's 2020 Incidental Take Permit.

- **2019 Biological Opinion:** The 2019 NMFS Biological Opinion does not have any reasonable and prudent measures or reasonable and prudent alternatives associated with spring Delta outflow.
- **2020 Record of Decision/Proposed Action and 2020 Incidental Take Permit:** 3.17.1 Spring Outflow Action (2020 Incidental Take Permit:42) may include export reductions to maintain CVP and SWP's contribution towards spring Delta outflow. 4.10.1.2 Spring Pulse Flows (2020 Proposed Action:4-28) allow for the implementation of a spring pulse action from Shasta Reservoir if specific environmental conditions are met.

J.5.1.2 Effects on Listed Native Fish Species

CVP and SWP operations can potentially influence the growth and survival of foraging and migrating smelts and salmonids in Delta habitats by modifying hydrology and diversions. Conceptual models for salmonids (Windell et al. 2017) and smelts (Interagency Ecological Program 2015; Rosenfield 2010) describe some of the effects that flow and related parameters can have on these species.

Juvenile winter-run Chinook salmon are generally rearing and outmigrating through the Bay-Delta between November and April (Appendix C, *Species Spatial-Temporal Domains*). Habitat quality plays an important role in migration, growth, and survival of juvenile Chinook salmon outmigrants (Windell et al. 2017). Studies have shown that juvenile outmigrants from the Sacramento River experience higher survival when riverine inflows are higher (Kjelson et al. 1982; Buchanan et al. 2021, 2017). Pulse flows can increase instream flow, creating outmigration cues and affecting numerous habitat attributes, which can result in changes in juvenile salmonid survival (Windell et al. 2017). Higher flows can also inundate floodplains and increase connectivity, allowing juvenile salmonids access to refuge habitat and higher quality food habitat (Windell et al. 2017; Sommer et al. 2001).

Delta smelt is primarily an annual species with spawning occurring in springtime within the freshwater portion of the Bay-Delta. By March, most adult Delta smelt that reared in the low-salinity habitat would have made their migration into freshwater (Interagency Ecological Program 2015). Note that a subset of the Delta smelt population appear to reside in freshwater year-round, mostly within the Cache Slough Complex region (Sommer et al. 2011; Hobbs et al. 2019). Delta smelt have a protracted spawning season given their life span. Spawning can occur from late January through June, while larvae can be seen from late February through early May (Moyle et al. 2016). Food availability, predation risk associated with turbidity, entrainment risk, and temperatures associated with the spawning window have all been considered as factors that can affect spawning and larval recruitment success (Interagency Ecological Program 2015; Brown et al. 2016). There has been less emphasis on the positive impacts of high spring outflow on Delta smelt relative to the summer-fall period. However, low outflow years are generally associated with a decline in Delta smelt abundance (Interagency Ecological Program 2015; Mahardja et al. 2021) and there is some evidence that higher spring outflow can improve recruitment for Delta smelt (Polansky et al. 2020).

Longfin smelt are a small, euryhaline, anadromous, pelagic fish species that typically reach maturity at the end of their second year (Dryfoos 1965; Merz et al. 2013). Spawning can occur between January and May, and larvae are typically detected between February and May (Merz et al. 2013). Longfin smelt larvae are most frequently detected from the confluence west to San Pablo Bay, with distribution extending upstream of the Confluence through the northern and eastern part of the Delta earlier in their development (Merz et al. 2013). Several studies have found a positive relationship between freshwater flow and longfin smelt abundance (Jassby et al. 1995; Kimmerer 2002; Rosenfield and Baxter 2007). The mechanism is not well understood, but may be related to increased spawning habitat, decreased predation, and increased food resources, leading to faster growth (Rosenfield 2010).

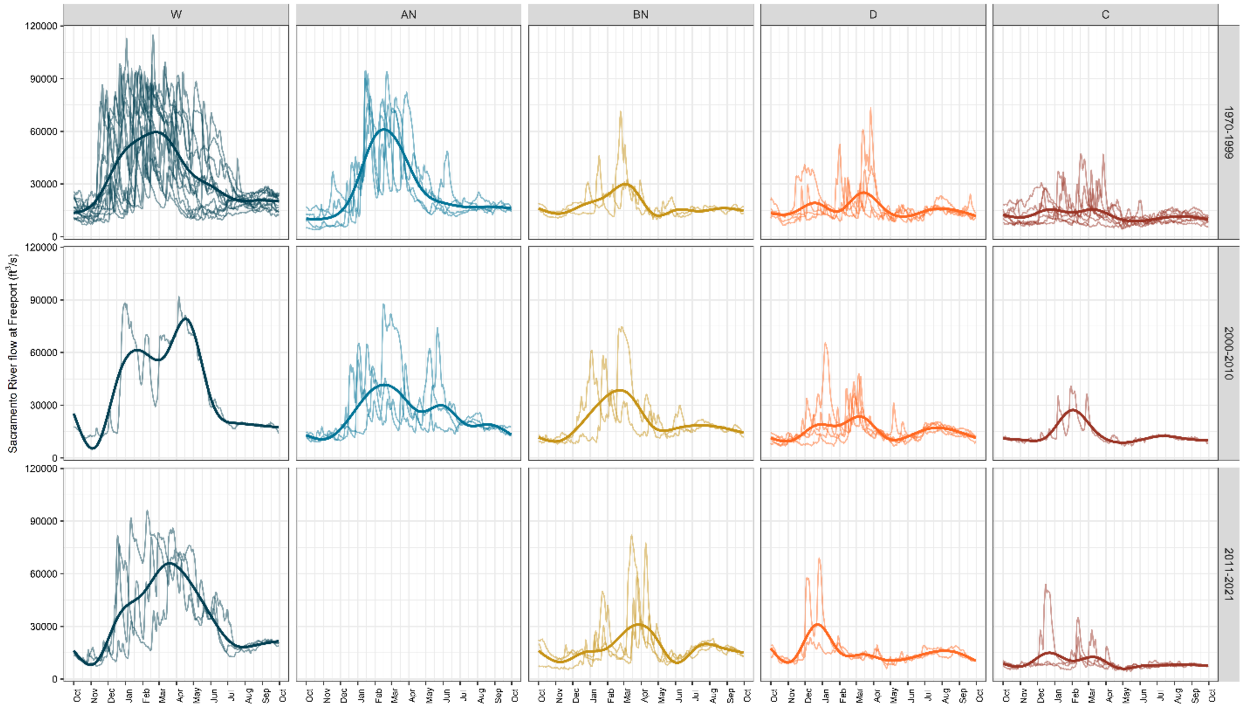
J.5.2 Datasets

The impacts of spring pulses on the Sacramento River and Delta outflow on federally listed native fish species are influenced by multiple factors including hydrology, water quality, and fish population abundance and distribution. Monitoring of hydrodynamics, water quality, and fish populations has been ongoing for over forty years, for some datasets, and covers the full spatial extent of the upper Sacramento River and Bay-Delta. These data and the following plots serve as the foundation and to illustrate patterns of interannual variability in historical hydrology and trends in water quality. They also provide data and visualizations of trends in federally listed native fish population abundances and distribution through the Sacramento River and Bay-Delta.

Presented in this section are three themes of empirical data: hydrodynamics, water quality parameters, and biological datasets. Hydrodynamics datasets (Section J.5.2.1, *Hydrodynamics*) include five decades of flows on the Sacramento and San Joaquin rivers, X2 location, Delta inflow, and SWP and CVP exports, 1970–2021. Water quality parameters (Section J.5.2.2, *Water Quality Parameters*) include turbidity, salinity, temperature, and chlorophyll a. Fish and other biological datasets (Section J.5.2.2) include Chinook salmon catch per unit effort (CPUE), zooplankton abundance, benthos abundance by taxonomic group, and invasive clam abundance.

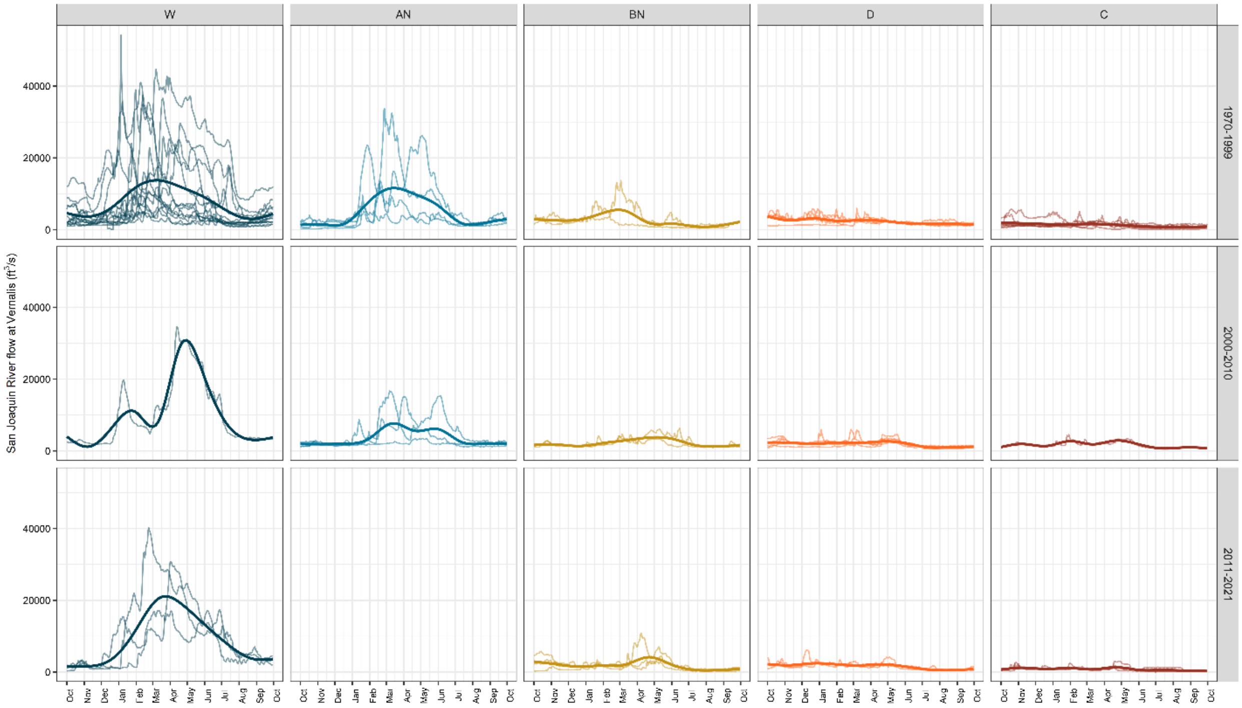
While some datasets include data gaps or shorter sampling efforts than others, overall, a large body of historic monitoring data within the Sacramento River and Bay-Delta is available. These data sets, in conjunction with modeled data (i.e., CalSim 3, Delta Simulation Model II [DSM2], USRDOM), serve as inputs for models that can be used to understand and predict the effects of CVP and SWP operations on environmental conditions and fish distribution and loss. Each data set is incorporated into one of multiple lines of evidence used to inform conclusions about both the magnitude and direction of differences among alternatives regarding hydrology and listed native fish populations abundance and distribution.

J.5.2.1 Hydrodynamics



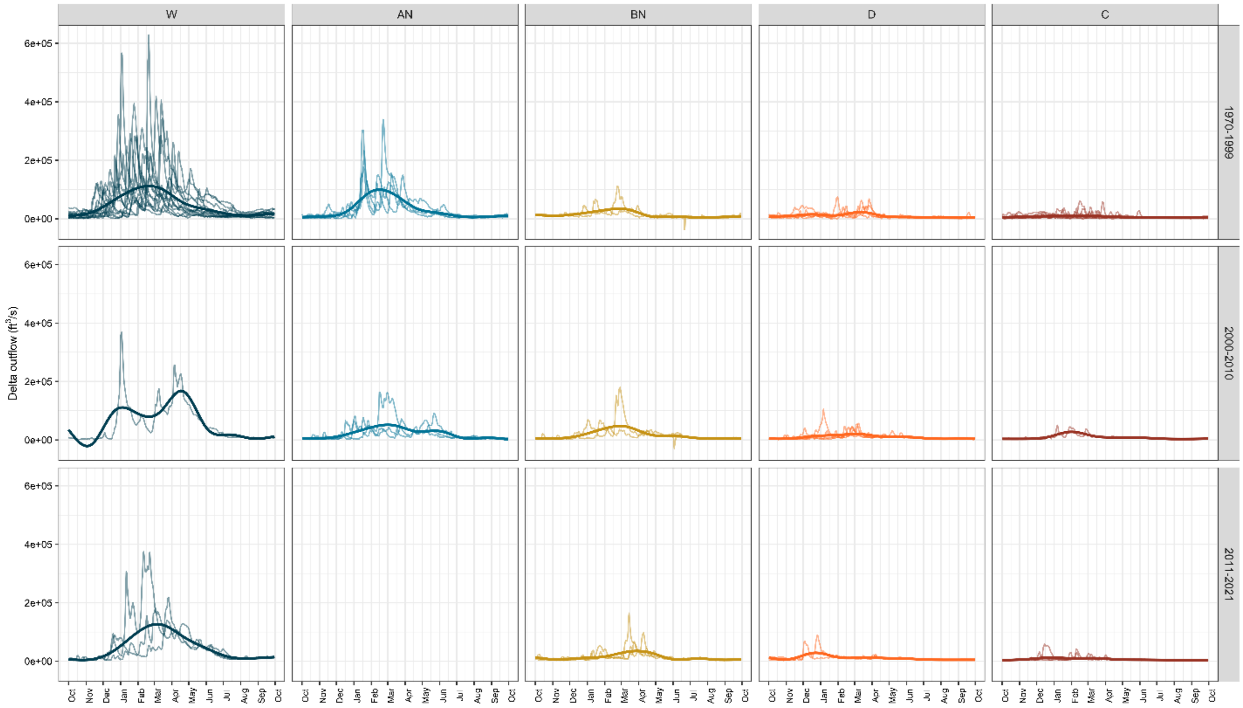
Source: DAYFLOW Model (https://data.cnra.ca.gov/dataset/dayflow).
ft^3/s = cubic foot per second;
W = wet; AN = above normal; BN = below normal; D = dry; C = critical;
1970–1999 = pre-D-1641 and CALFED era;
2000–2010 = D-1641 and CALFED era;
2011–2021 = post-2008/2009 Biological Opinions.
Each thin line represents a water year within a category and bolded line represents the LOESS smoothed trend line in each category’s dataset (which may include multiple water years).

Figure J-1. Estimated Sacramento River Flow at Freeport, 1970–2021, by Water Year Type



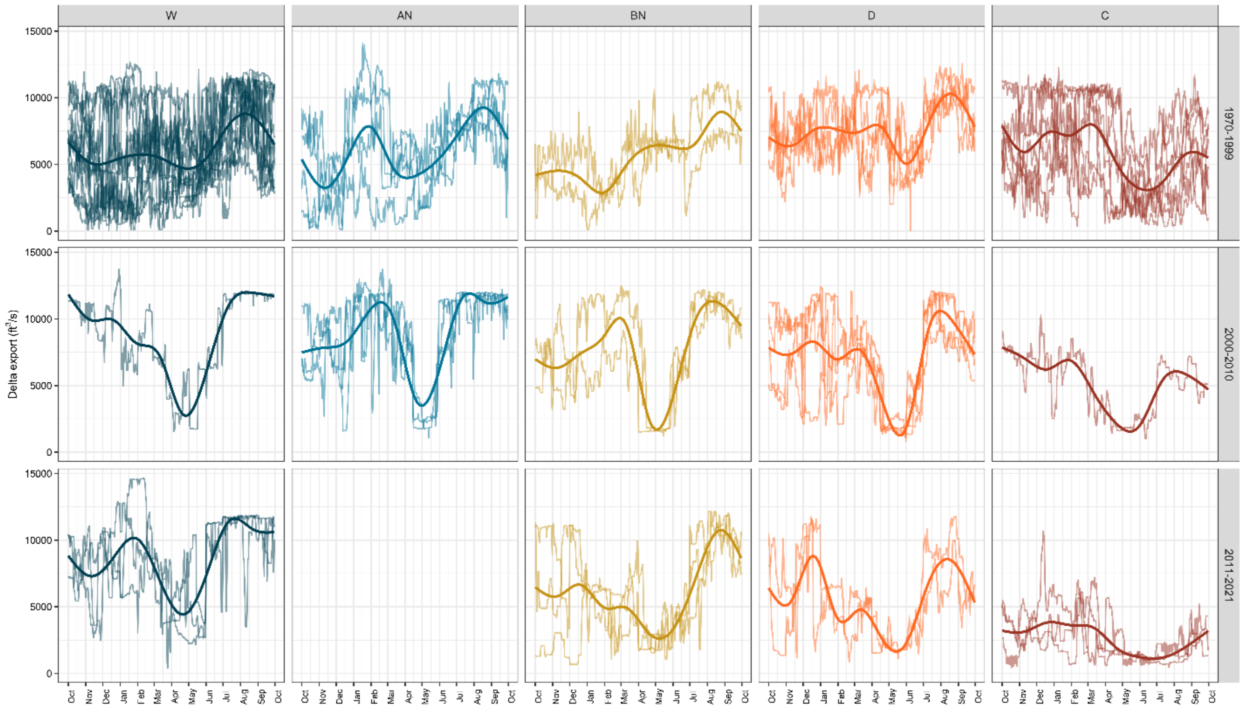
Source: DAYFLOW Model (https://data.cnra.ca.gov/dataset/dayflow).
ft^3/s = cubic foot per second;
W = wet; AN = above normal; BN = below normal; D = dry; C = critical;
1970–1999 = pre-D-1641 and CALFED era;
2000–2010 = D-1641 and CALFED era;
2011–2021 = post-2008/2009 Biological Opinions.
Each thin line represents a water year within a category and bolded line represents the LOESS smoothed trend line in each category's dataset (which may include multiple water years).

Figure J-2. Estimated San Joaquin River Flow at Vernalis, 1970–2021, by Water Year Type



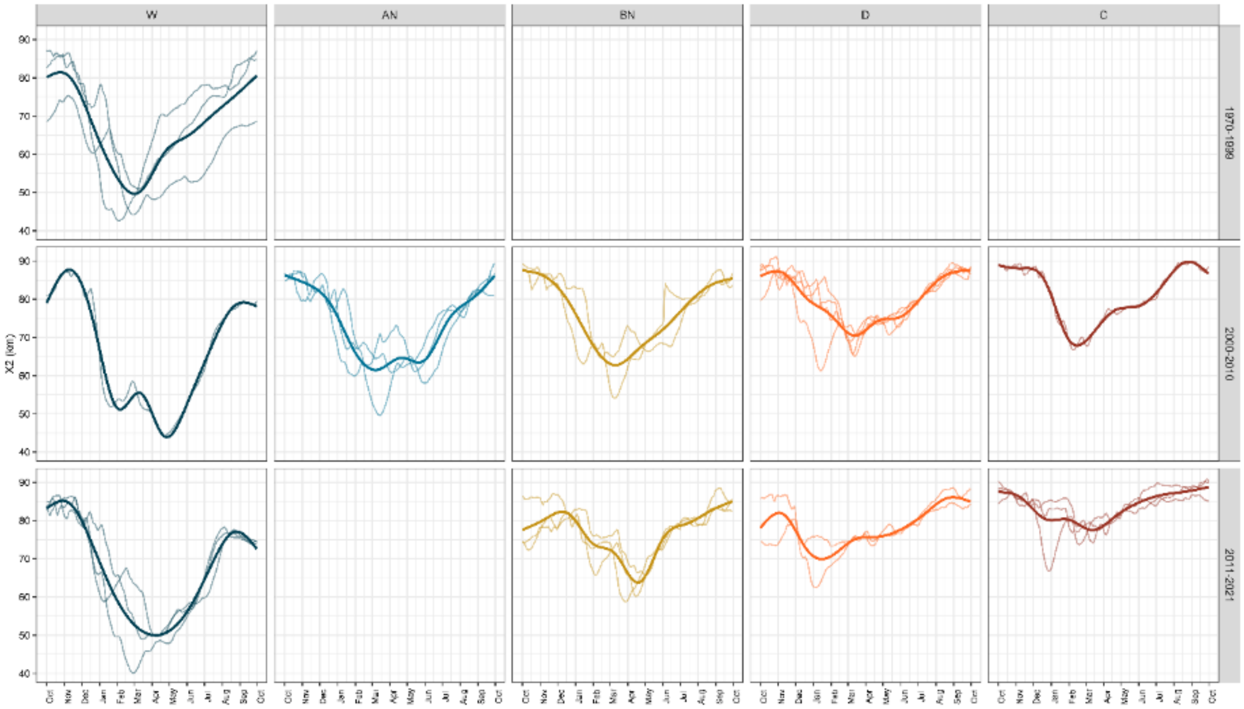
Source: DAYFLOW Model (https://data.cnra.ca.gov/dataset/dayflow).
ft^3/s = cubic foot per second;
W = wet; AN = above normal; BN = below normal; D = dry; C = critical;
1970–1999 = pre-D-1641 and CALFED era;
2000–2010 = D-1641 and CALFED era;
2011–2021 = post-2008/2009 Biological Opinions.
Each thin line represents a water year within a category and bolded line represents the LOESS smoothed trend line in each category's dataset (which may include multiple water years).

Figure J-3. Delta Outflow, 1970–2021, by Water Year Type



Source: DAYFLOW Model (https://data.cnra.ca.gov/dataset/dayflow).
ft^3/s = cubic foot per second;
W = wet; AN = above normal; BN = below normal; D = dry; C = critical;
1970–1999 = pre-D-1641 and CALFED era;
2000–2010 = D-1641 and CALFED era;
2011–2021 = post-2008/2009 Biological Opinions.
Each thin line represents a water year within a category and bolded line represents the LOESS smoothed trend line in each category's dataset (which may include multiple water years).

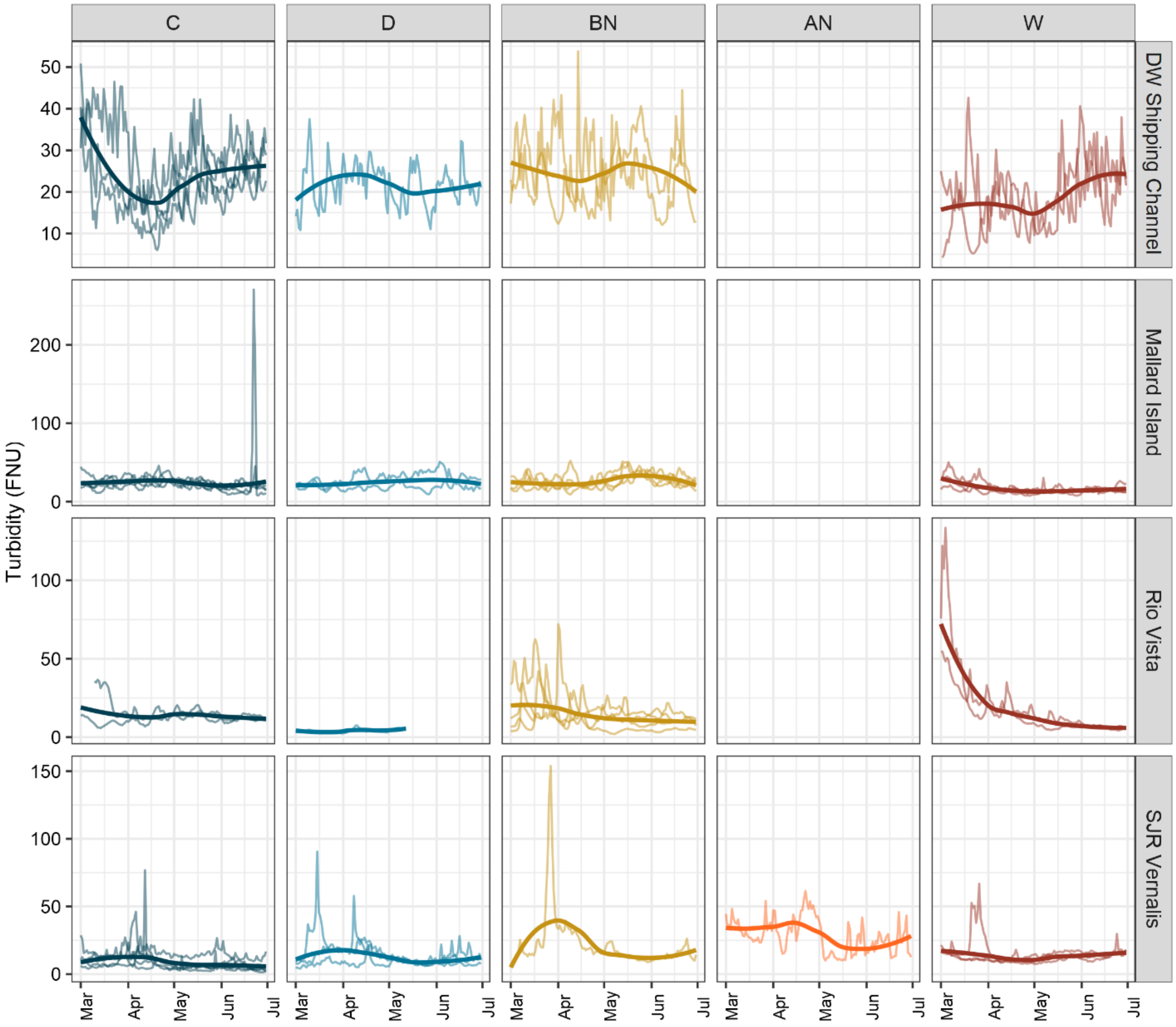
Figure J-4. Combined Delta Exports, 1970–2021, by Water Year Type



Source: DAYFLOW Model (https://data.cnra.ca.gov/dataset/dayflow).
ft^3/s = cubic foot per second;
W = wet; AN = above normal; BN = below normal; D = dry; C = critical;
1970–1999 = pre-D-1641 and CALFED era;
2000–2010 = D-1641 and CALFED era;
2011–2021 = post-2008/2009 Biological Opinions.
Each thin line represents a water year within a category and bolded line represents the LOESS smoothed trend line in each category’s dataset (which may include multiple water years).

Figure J-5. X2 Data, 1997–2021, by Water Year Type

J.5.2.2 Water Quality Parameters

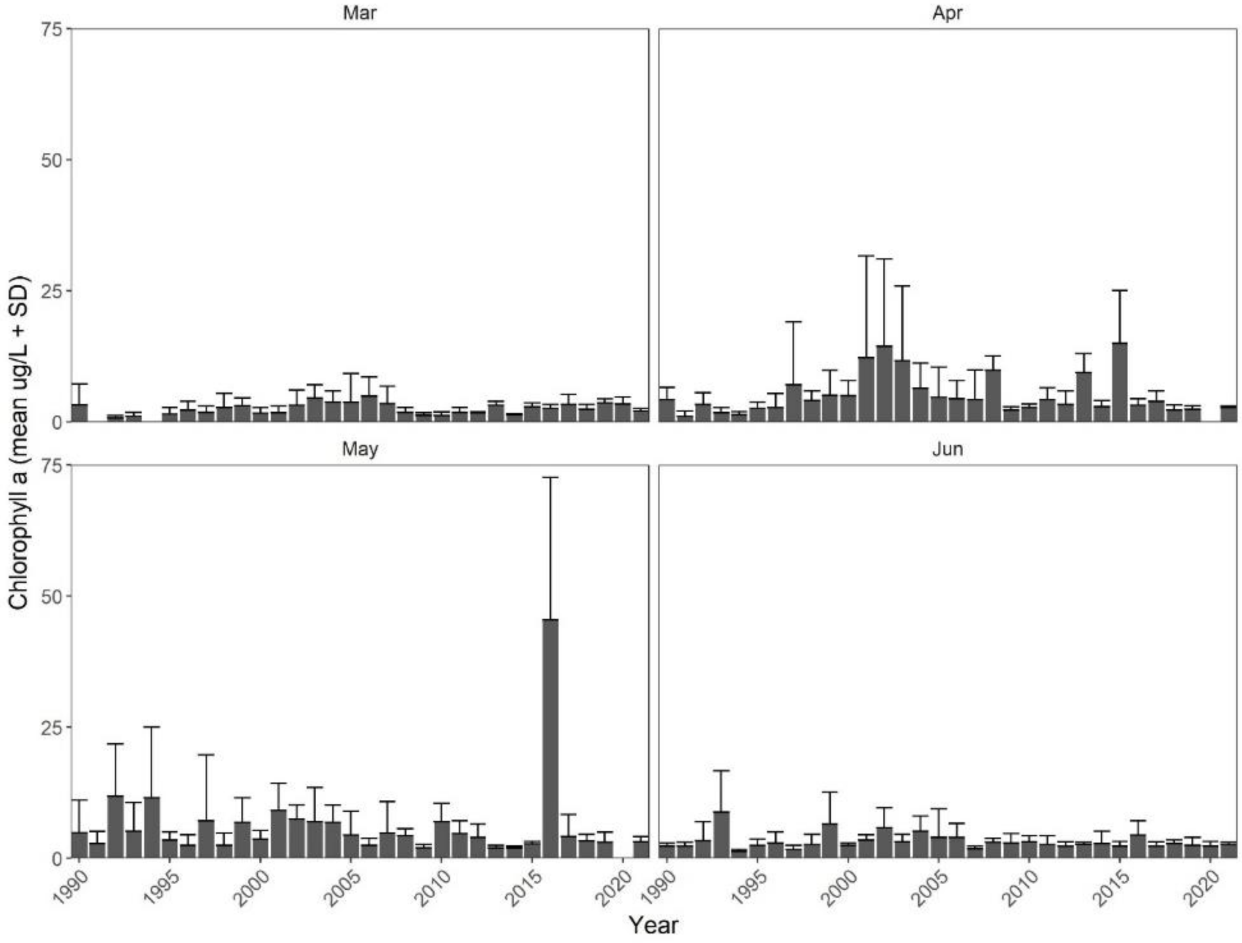


Sources: Mallard Island (MAL) and SJR Vernalis (SJR) event data downloaded from the California Data Exchange Center (https://cdec.water.ca.gov/); DW Shipping Channel (DWC) and Rio Vista (SRV) data downloaded from the National Water Information System (https://waterdata.usgs.gov/nwis?).

FNU = Formazin Nephelometric Unit; W = wet; AN = above normal; BN = below normal; D = dry; C = critical.

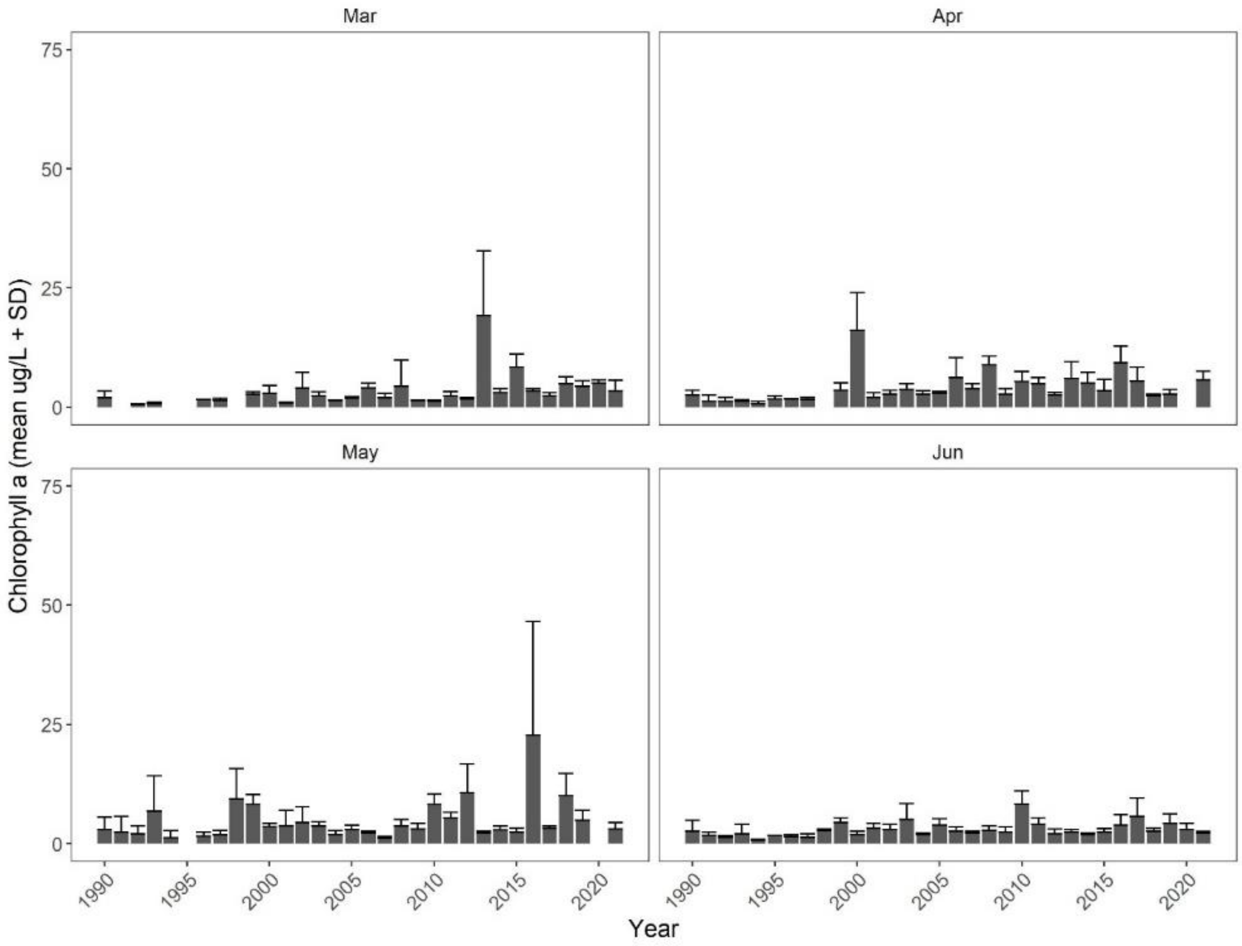
Raw data were filtered to values greater than 0, and dates with less than 20 hours out of 24 hours per day were removed. Mean turbidity values that appeared to deviate drastically from the surrounding values were plotted against flow as a check, and removed if deemed to be erroneous. Data were then averaged on a daily timestep. Each thin line represents a water year within a category and bolded line represents the LOESS smoothed trend line in each category’s dataset (which may include multiple water years). Note scales on the y-axis differ for each station. Start date differs for each station based on data availability: SRV, SJR and MAL (2010), DWC (2014).

Figure J-6. Daily Average Turbidity through Water Year 2022, by Water Year Type



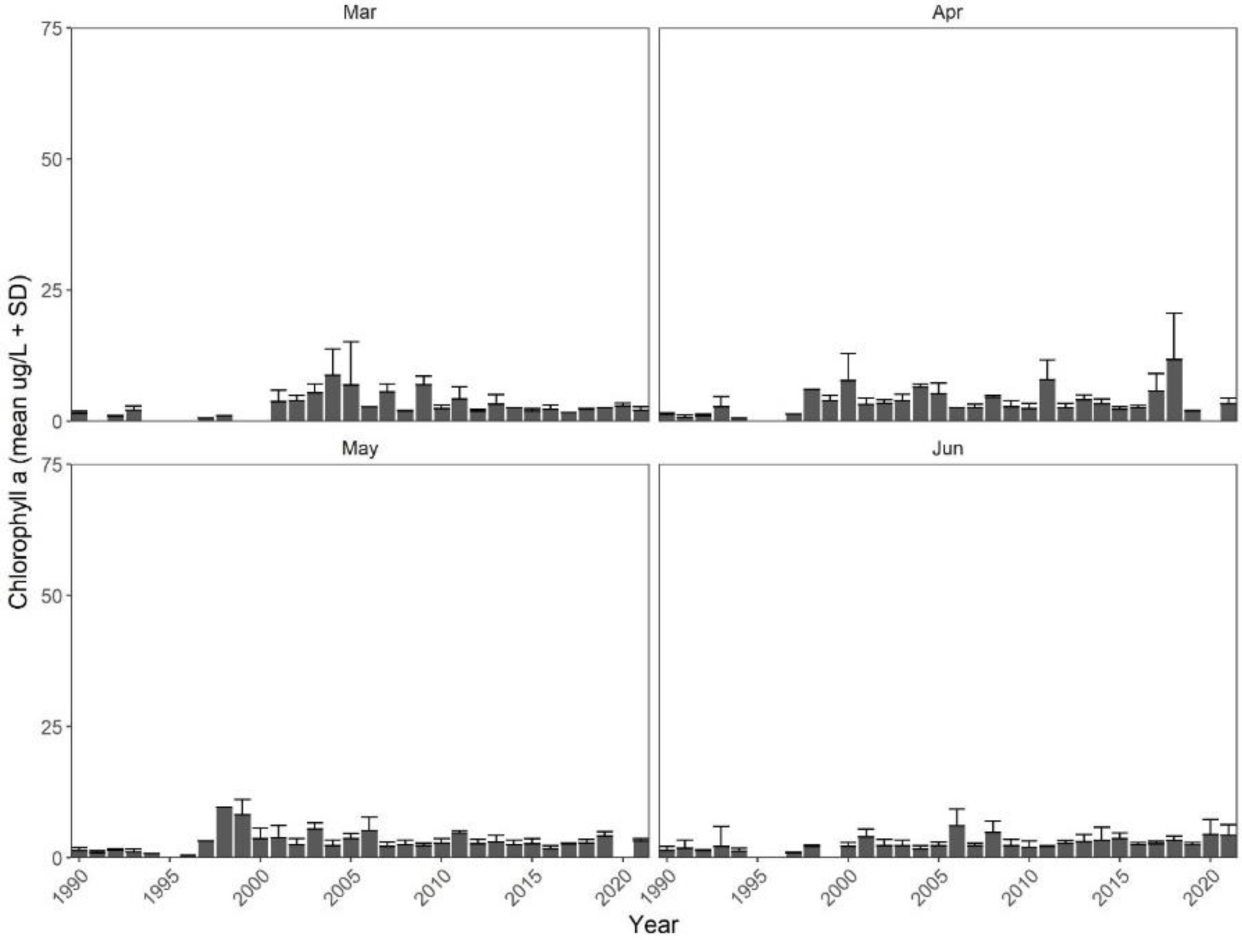
Source: Data downloaded and plotted using Zooper package in R.
ug/L = micrograms per liter; SD = standard deviation; psu = practical salinity unit.
Salinity zones are defined as follows, based on surface salinity:
<0.5 psu, freshwater;
0.5–6.0 psu, low salinity zone;
>6.0 psu, high salinity zone.

Figure J-7. Freshwater Zone Chlorophyll a Mean Monthly Concentration Measured by the Environmental Monitoring Program from March through June of Each Year, 1990–2021



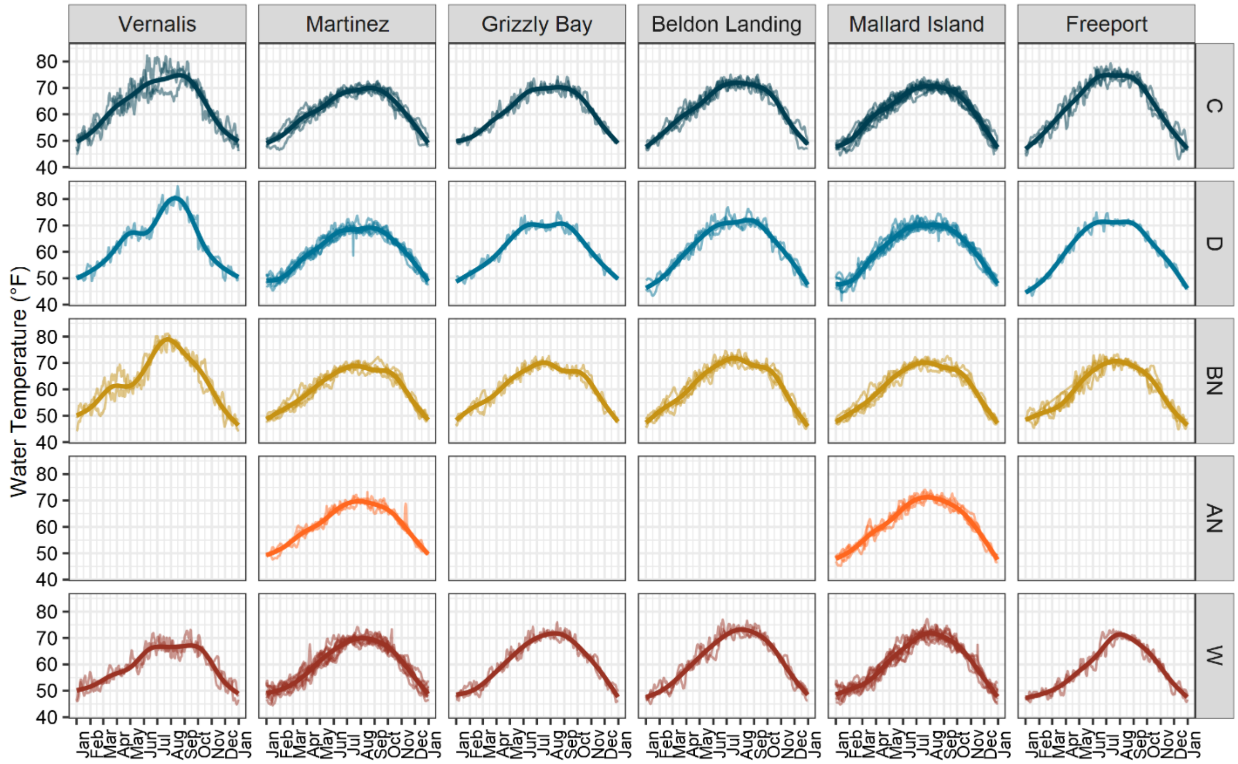
Source: Data downloaded and plotted using Zooper package in R.
ug/L = micrograms per liter; SD = standard deviation; psu = practical salinity unit.
Salinity zones are defined as follows, based on surface salinity:
<0.5 psu, freshwater;
0.5–6.0 psu, low salinity zone;
>6.0 psu, high salinity zone.

Figure J-8. Low Salinity Zone Chlorophyll a Mean Monthly Concentration Measured by the Environmental Monitoring Program from March through June of Each Year, 1990–2021



Source: Data downloaded and plotted using Zooper package in R.
ug/L = micrograms per liter; SD = standard deviation; psu = practical salinity unit.
Salinity zones are defined as follows, based on surface salinity:
<0.5 psu, freshwater;
0.5–6.0 psu, low salinity zone;
>6.0 psu, high salinity zone.

Figure J-9. High Salinity Zone Chlorophyll a Mean Monthly Concentration Measured by the Environmental Monitoring Program from March through June of Each Year, 1990–2021

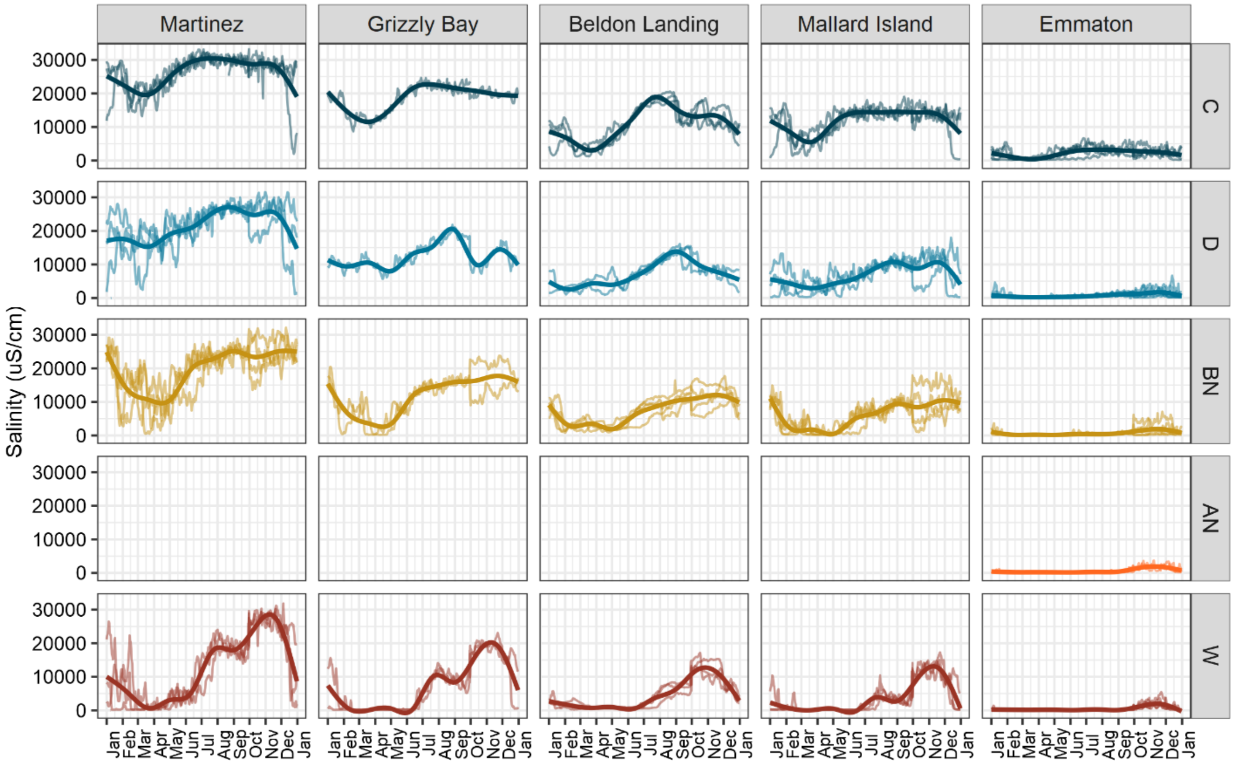


Source: California Data Exchange Center (https://cdec.water.ca.gov/).

°F = degrees Fahrenheit; W = wet; AN = above normal; BN = below normal; D = dry; C = critical.

Event data downloaded from the California Data Exchange Center, converted to hourly data, and averaged on a daily time step. QA/QC were applied to data prior to averaging (see https://portal.edirepository.org/nis/mapbrowse?packageid=edi.591.2 for description of QA/QC methods). Each thin line represents a water year within a category and bolded line represents the LOESS smoothed trend line in each category's dataset (which may include multiple water years). Start date differs for each station based on data availability: Vernalis (2014), Martinez (1994), Mallard Island (1987), Grizzly Bay (2015), Beldon Landing (2008), Freeport (2009).

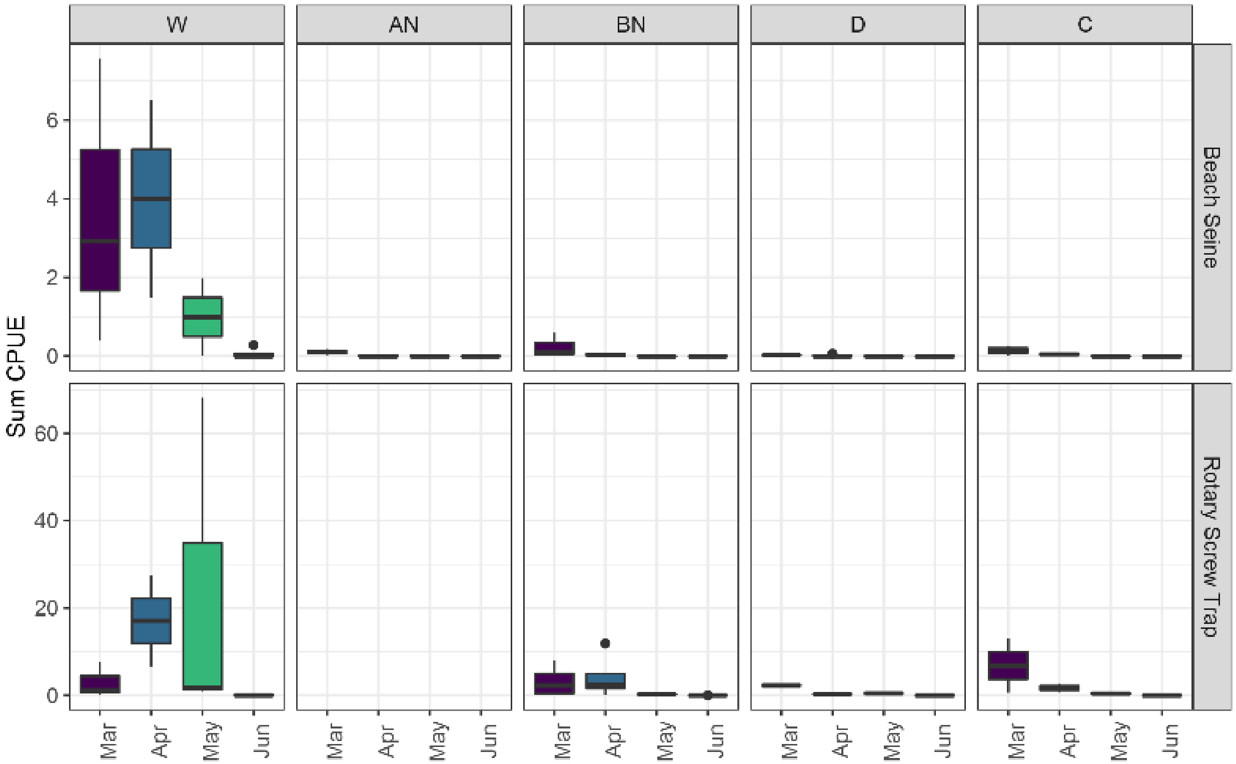
Figure J-10. Daily Average Water Temperature through Water Year 2022, by Water Year Type



Source: California Data Exchange Center (https://cdec.water.ca.gov/).
uS/cm = microsiemens per centimeter; W = wet; AN = above normal; BN = below normal; D = dry; C = critical.
Event data downloaded from the California Data Exchange Center then averaged. Minor QA/QC applied (Filtered between 0 and 50,000 µS/cm; minor outlier removal). Each thin line represents a water year within a category and bolded line represents the LOESS smoothed trend line in each category's dataset (which may include multiple water years). Start data differs for each station: Martinez and Mallard Island (2002), Emmaton (2000), Grizzly Bay (2015), Beldon Landing (2009).

Figure J-11. Daily Average Salinity through Water Year 2022, by Water Year Type

J.5.2.3 Biological Observations

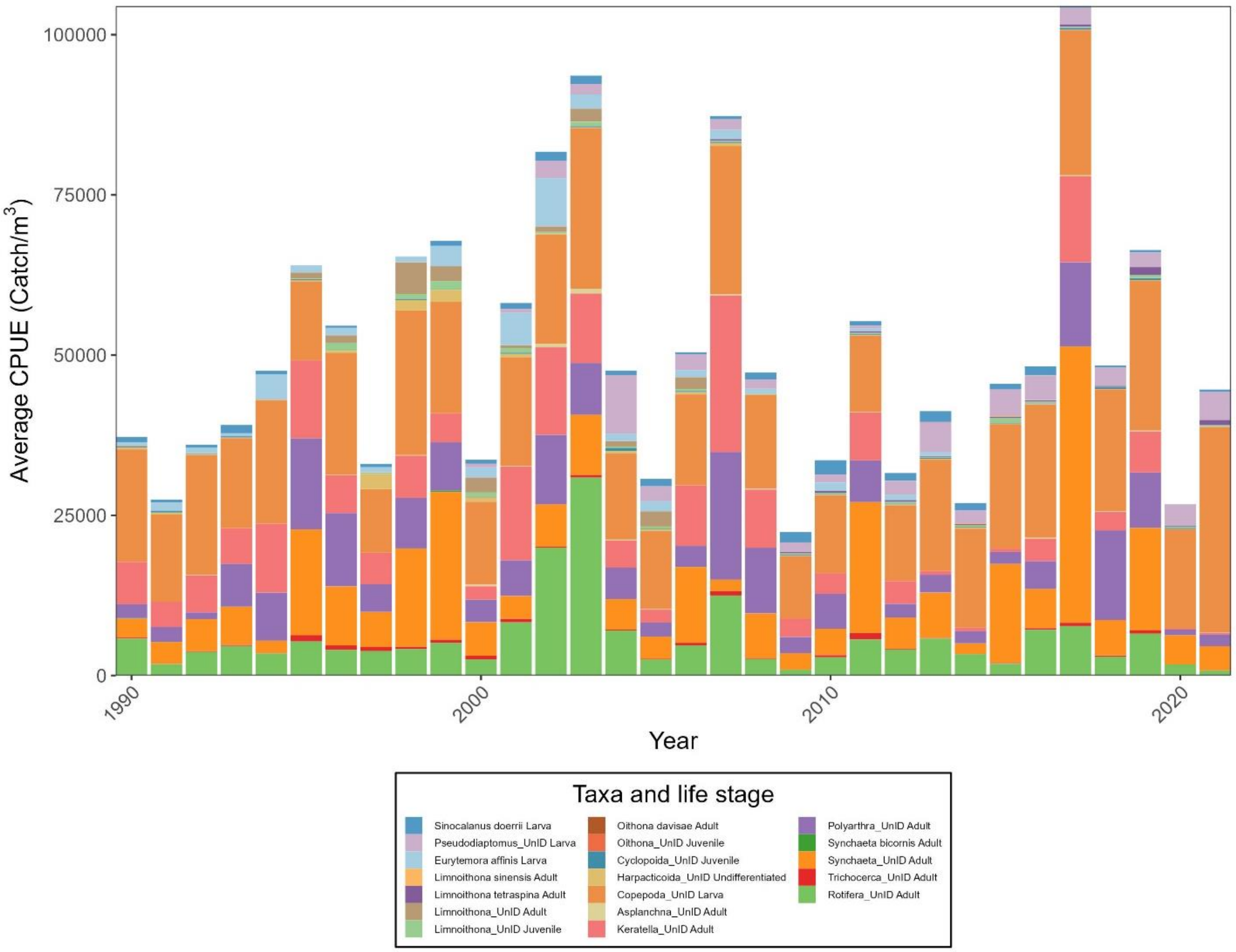


Sources: Yolo data are from Interagency Ecological Program et al. 2022; water year classifications are from the California Data Exchange Center (https://cdec.water.ca.gov/reportapp/javareports?name=WSIHIST).

CPUE = catch per unit effort; count/m^3 = number of individuals per cubic meter.

Beach seine data are between Water Years 2000–2019, Rotary screw trap data are between Water Years 2010–2019 due to lack of accurate effort data prior to 2010 for rotary screw trap. Beach seine CPUE is calculated by volume (count/m^3) while rotary screw trap data CPUE is calculated by hours (count/hours of effort). CPUE values are summed by month and method and boxplots represent CPUE over different water years.

Figure J-12. Juvenile Chinook Salmon Catch per Unit Effort in Yolo Bypass



Sources: Data collected by the Environmental Monitoring Program; data downloaded and plotted using Zooper package in R.

CPUE = catch per unit effort; catch/m^3 = number of individuals per cubic meter; psu = practical salinity unit.

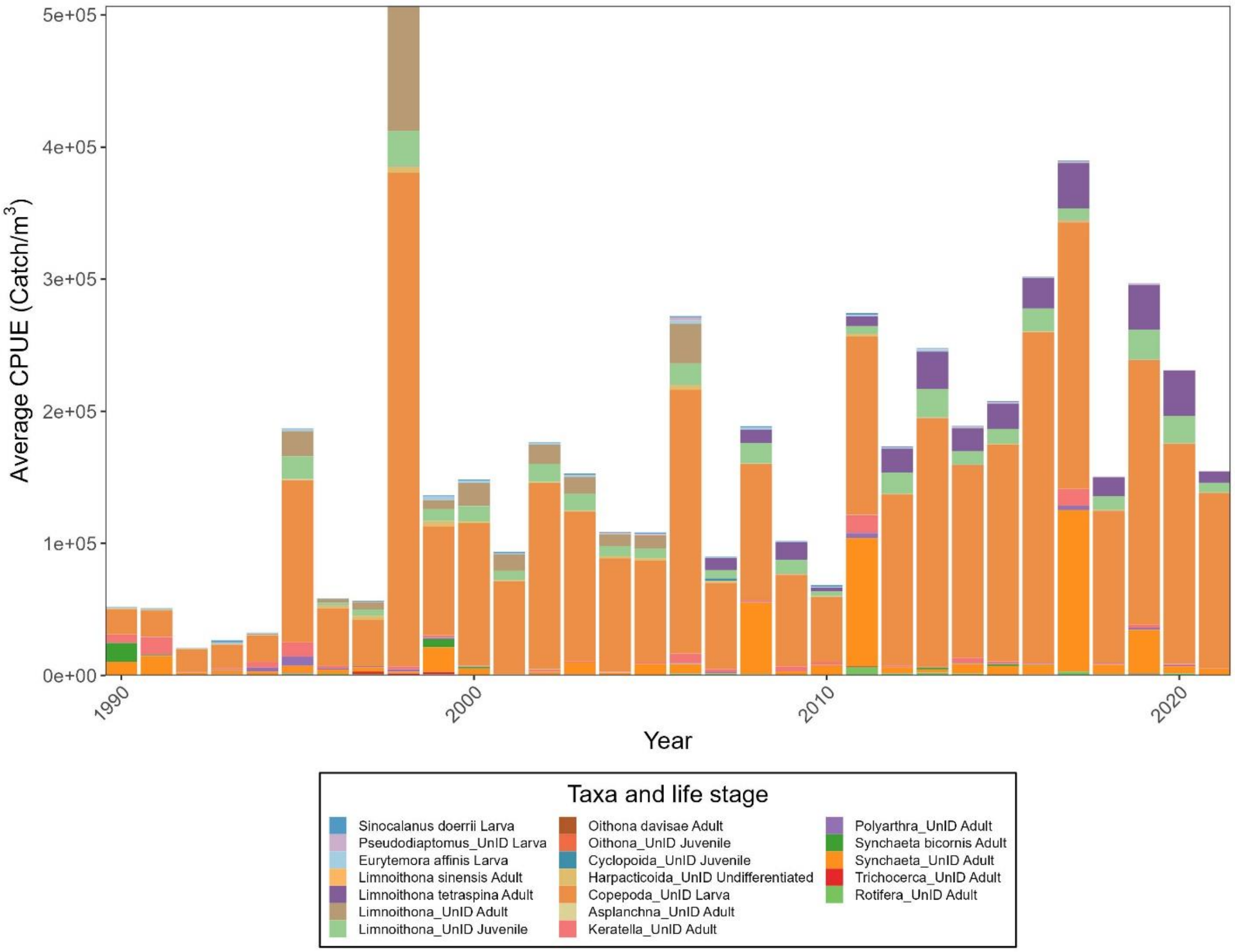
Salinity zones are defined as follows, based on surface salinity:

<0.5 psu, freshwater;

0.5–6.0 psu, low salinity zone;

>6.0 psu, high salinity zone.

Figure J-13. Freshwater Zone Micro-Zooplankton Mean Annual Relative Abundance from March through June of Each Year, 1990–2021



Sources: Data collected by the Environmental Monitoring Program; data downloaded and plotted using Zooper package in R.

CPUE = catch per unit effort; catch/m^3 = number of individuals per cubic meter; psu = practical salinity unit.

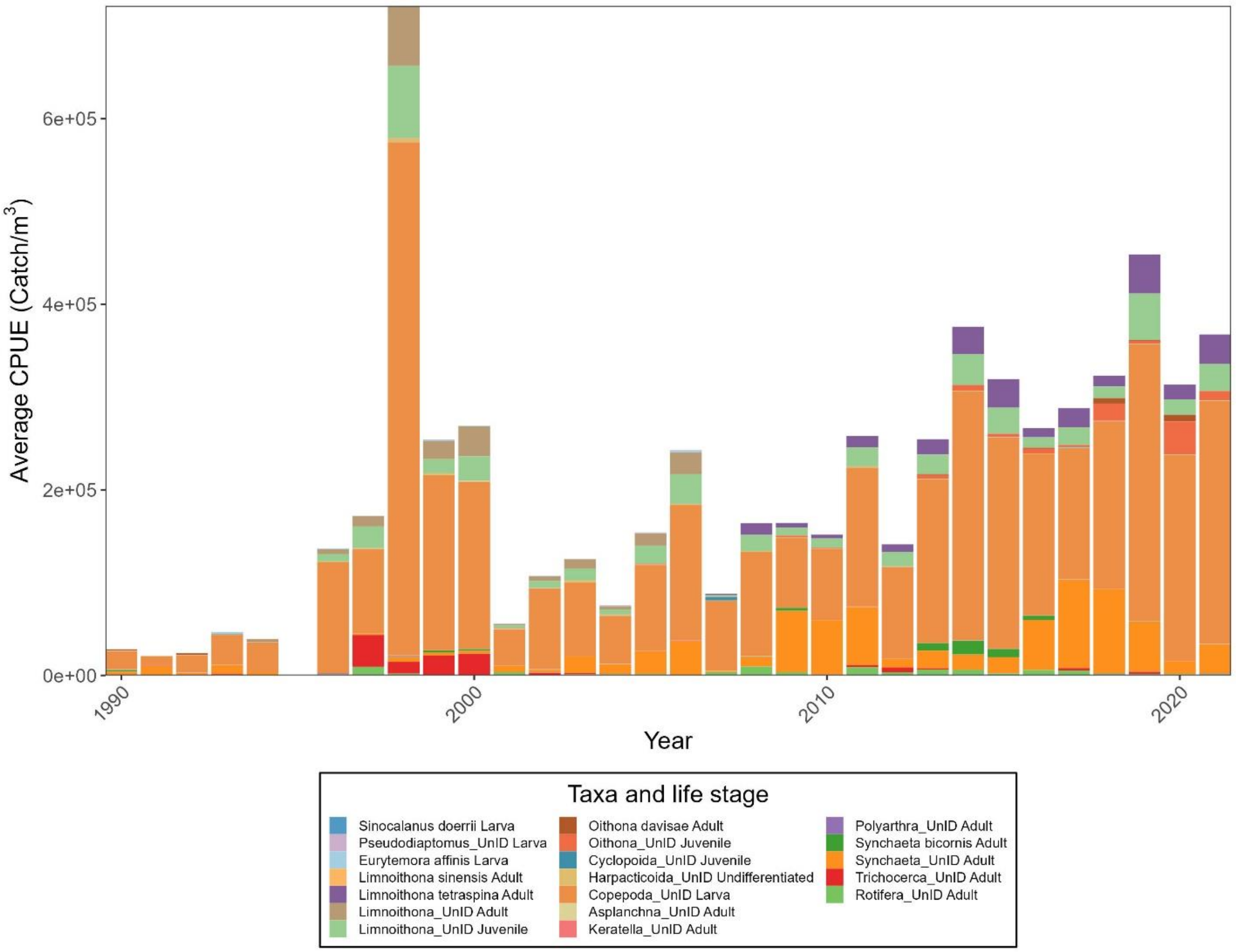
Salinity zones are defined as follows, based on surface salinity:

<0.5 psu, freshwater;

0.5–6.0 psu, low salinity zone;

>6.0 psu, high salinity zone.

Figure J-14. Low Salinity Zone Micro-Zooplankton Mean Annual Relative Abundance from March through June of Each Year, 1990–2021



Sources: Data collected by the Environmental Monitoring Program; data downloaded and plotted using Zooper package in R.

CPUE = catch per unit effort; catch/m^3 = number of individuals per cubic meter; psu = practical salinity unit.

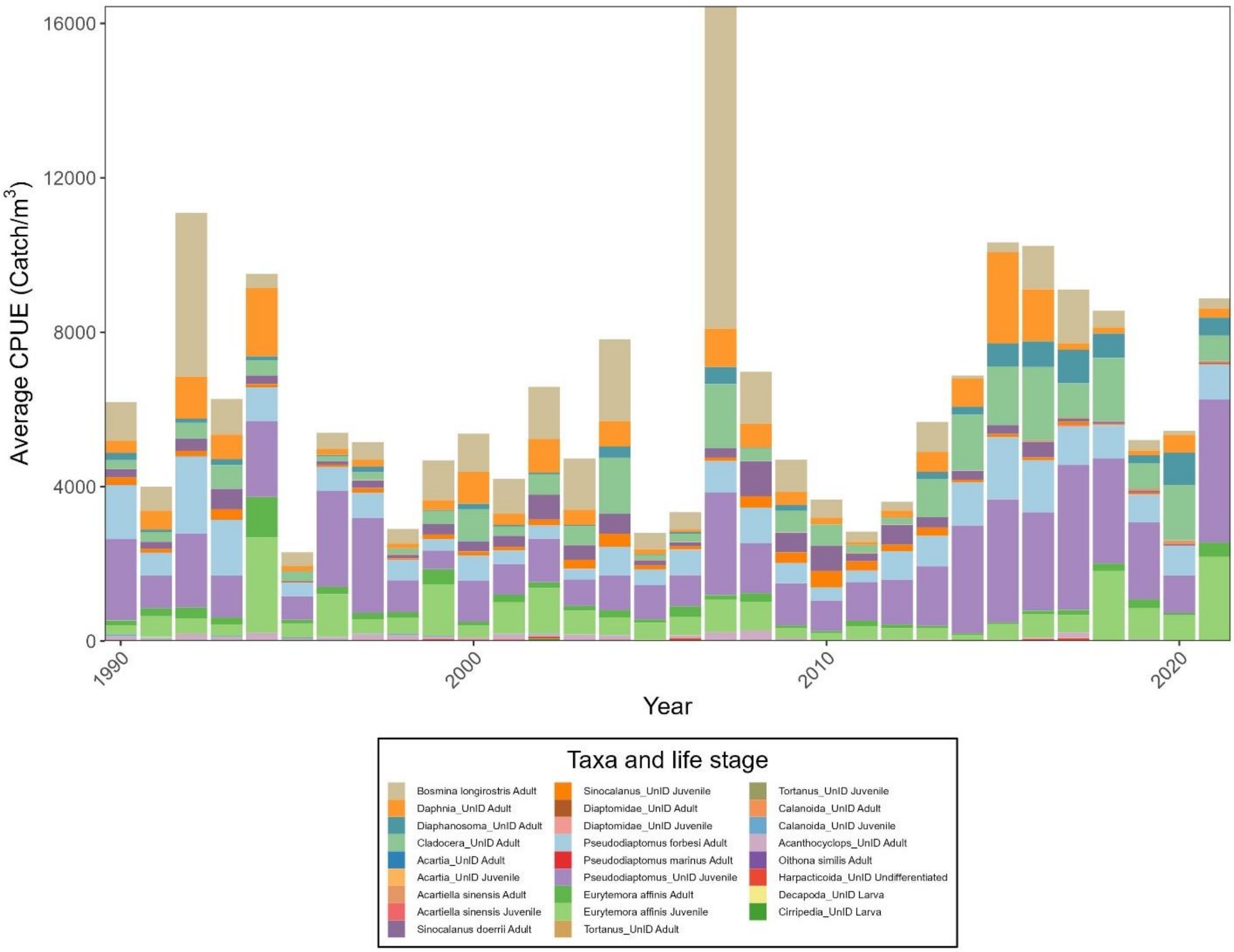
Salinity zones are defined as follows, based on surface salinity:

<0.5 psu, freshwater;

0.5–6.0 psu, low salinity zone;

>6.0 psu, high salinity zone.

Figure J-15. High Salinity Zone Micro-Zooplankton Mean Annual Relative Abundance from March through June of Each Year, 1990–2021

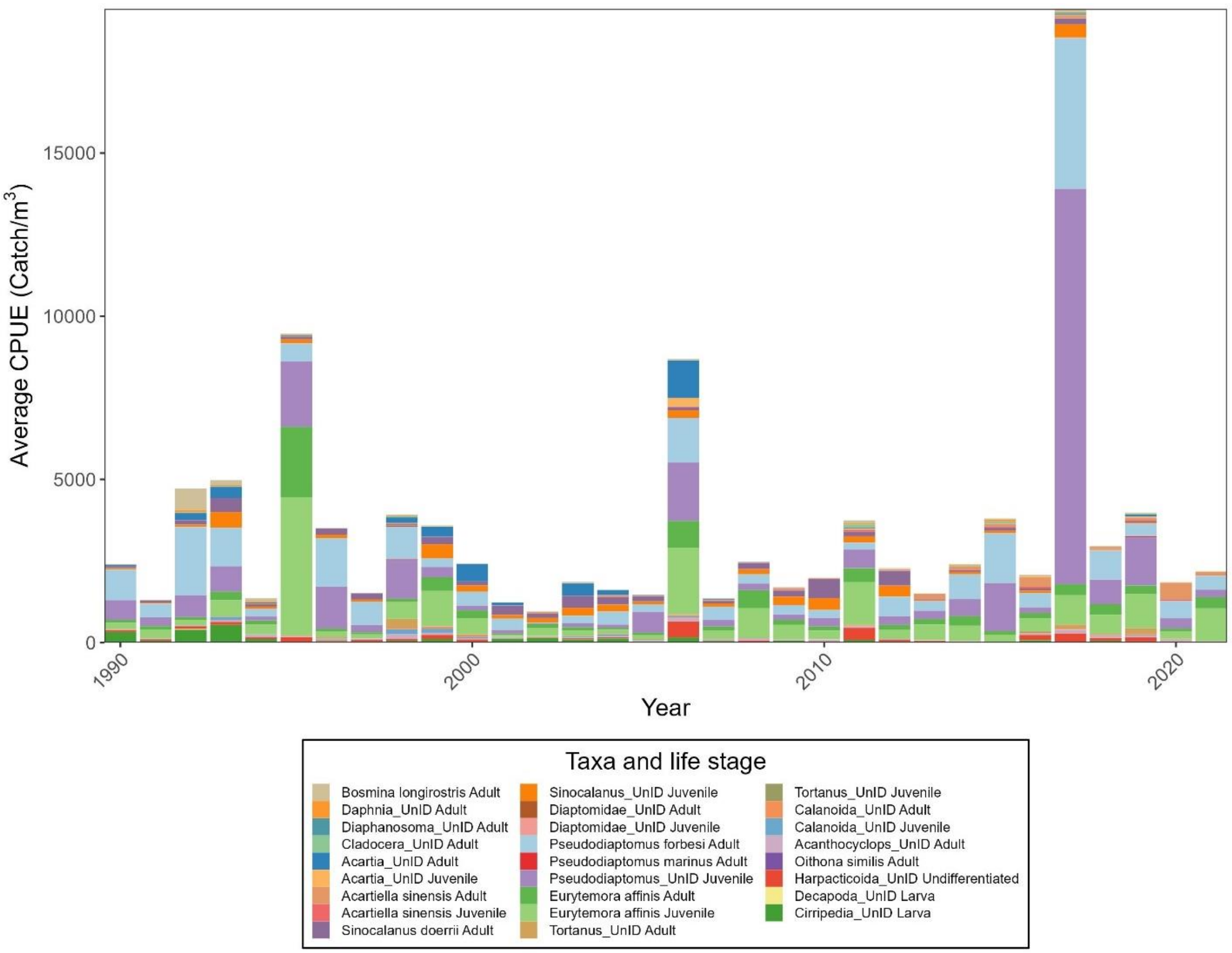


Sources: Data collected by the Environmental Monitoring Program; data downloaded and plotted using Zooper package in R.

CPUE = catch per unit effort; catch/m^3 = number of individuals per cubic meter; psu = practical salinity unit.

Salinity zones are defined as follows, based on surface salinity:
<0.5 psu, freshwater;
0.5–6.0 psu, low salinity zone;
>6.0 psu, high salinity zone.

Figure J-16. Freshwater Zone Meso-Zooplankton Mean Annual Relative Abundance from March through June of Each Year, 1990–2021



Sources: Data collected by the Environmental Monitoring Program; data downloaded and plotted using Zooper package in R.

CPUE = catch per unit effort; catch/m^3 = number of individuals per cubic meter; psu = practical salinity unit.

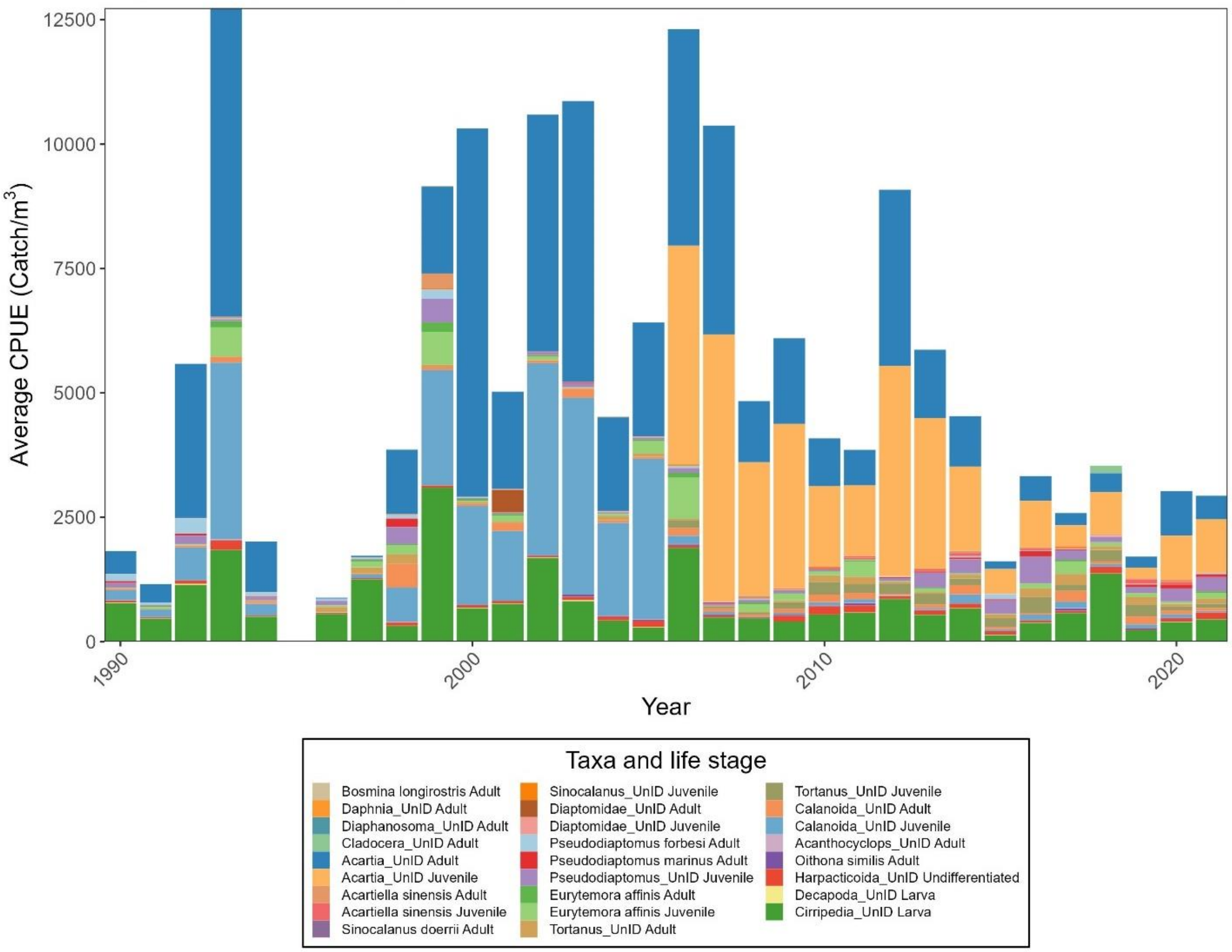
Salinity zones are defined as follows, based on surface salinity:

<0.5 psu, freshwater;

0.5–6.0 psu, low salinity zone;

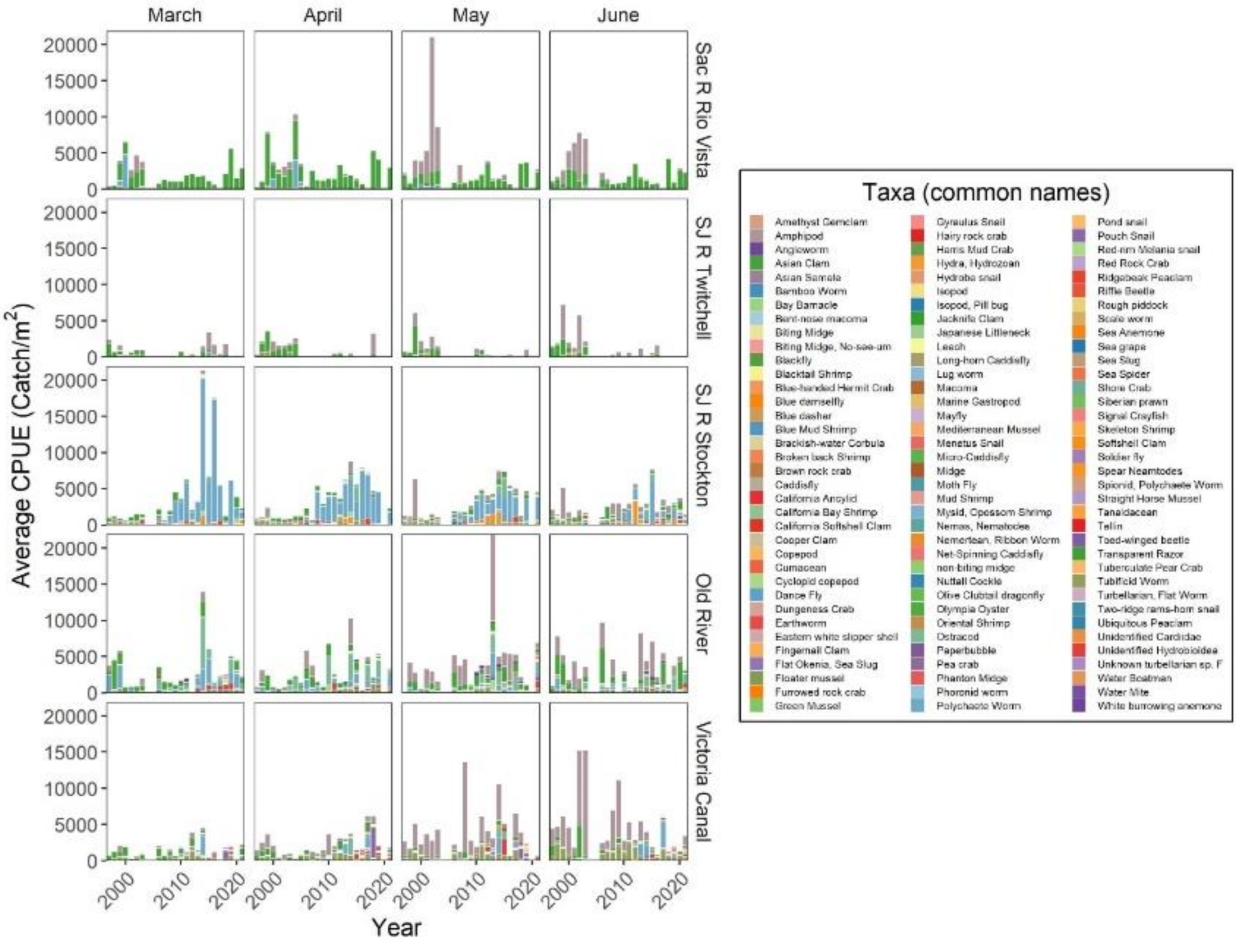
>6.0 psu, high salinity zone.

Figure J-17. Low Salinity Zone Meso-Zooplankton Mean Annual Relative Abundance from March through June of Each Year, 1990–2021



Sources: Data collected by the Environmental Monitoring Program; data downloaded and plotted using Zooper package in R.
CPUE = catch per unit effort; catch/m^3 = number of individuals per cubic meter; psu = practical salinity unit.
Salinity zones are defined as follows, based on surface salinity:
<0.5 psu, freshwater;
0.5–6.0 psu, low salinity zone;
>6.0 psu, high salinity zone.

Figure J-18. High Salinity Zone Meso-Zooplankton Mean Annual Relative Abundance (from March through June of Each Year, 1990–2021

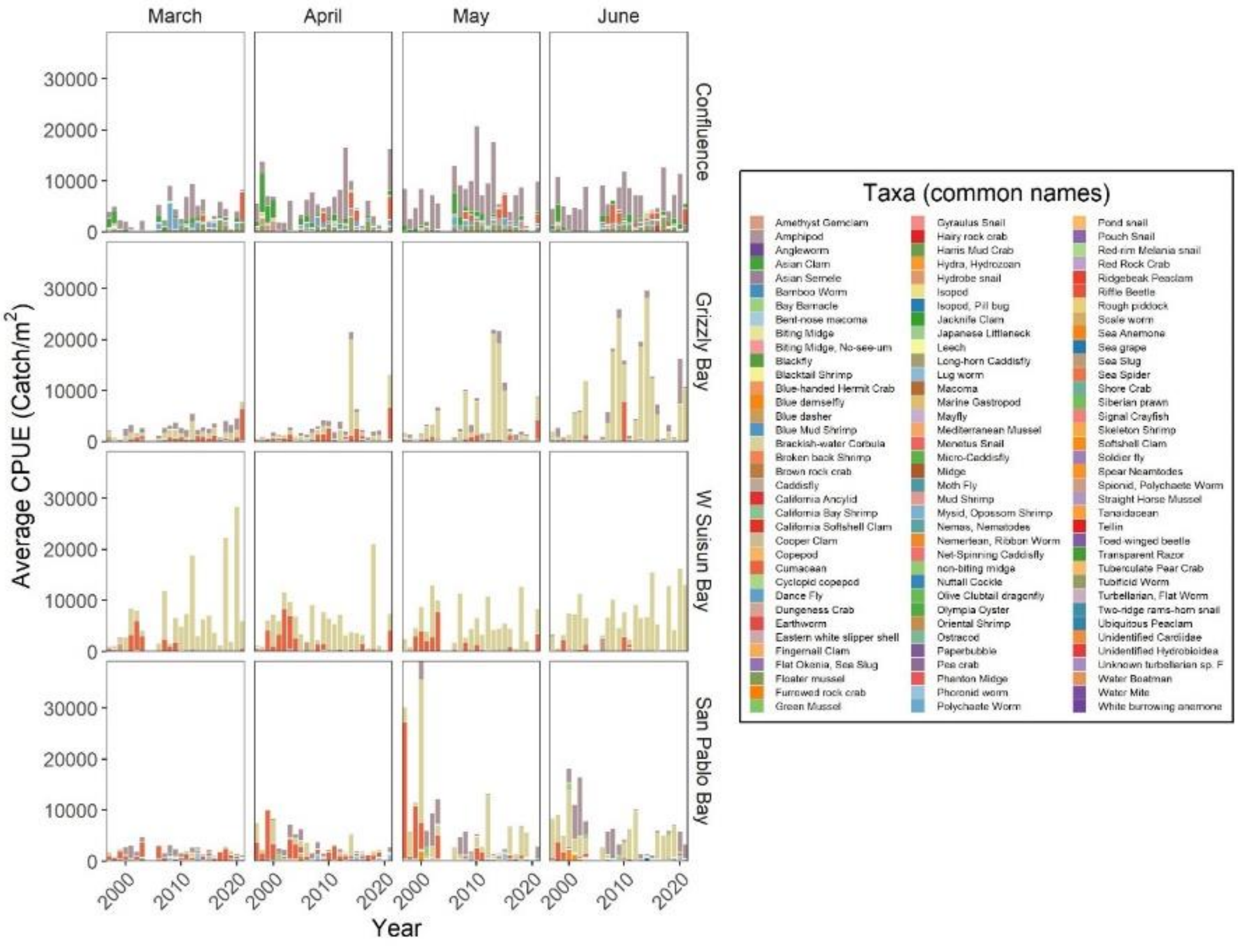


Source: Samples were collected by the Environmental Monitoring Program. Data were downloaded from the Environmental Data Initiative on December 23, 2022.

CPUE = catch per unit effort; catch/m^2 = number of individuals per square meter; Sac R = Sacramento River; SJR = San Joaquin River.

Taxonomic groups provided as common names. Note the y-axis scales differ between the plot for the fresher regions and the brackish regions.

Figure J-19. Benthos Mean Monthly Relative Abundance by Enhanced Delta Smelt Monitoring Program Region: Fresher Regions, from March through June of Each Year, 1996–2021

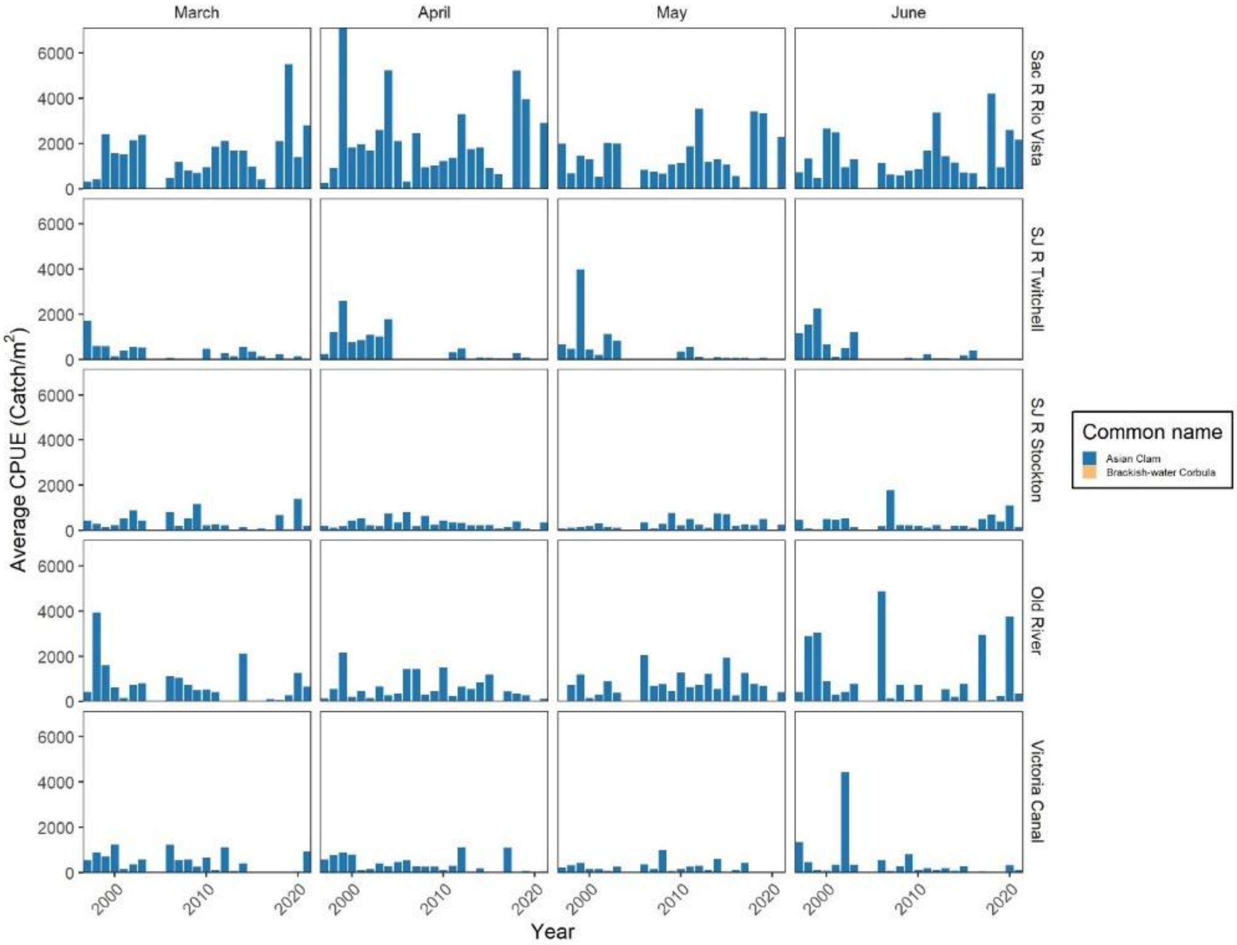


Source: Samples were collected by the Environmental Monitoring Program. Data were downloaded from the Environmental Data Initiative on December 23, 2022.

CPUE = catch per unit effort; catch/m^2 = number of individuals per square meter.

Taxonomic groups provided as common names. Note the y-axis scales differ between the plot for the fresher regions and the brackish regions.

Figure J-20. Benthos Mean Monthly Relative Abundance by Enhanced Delta Smelt Monitoring Program Region: Brackish Regions, from March through June of Each Year, 1996–2021

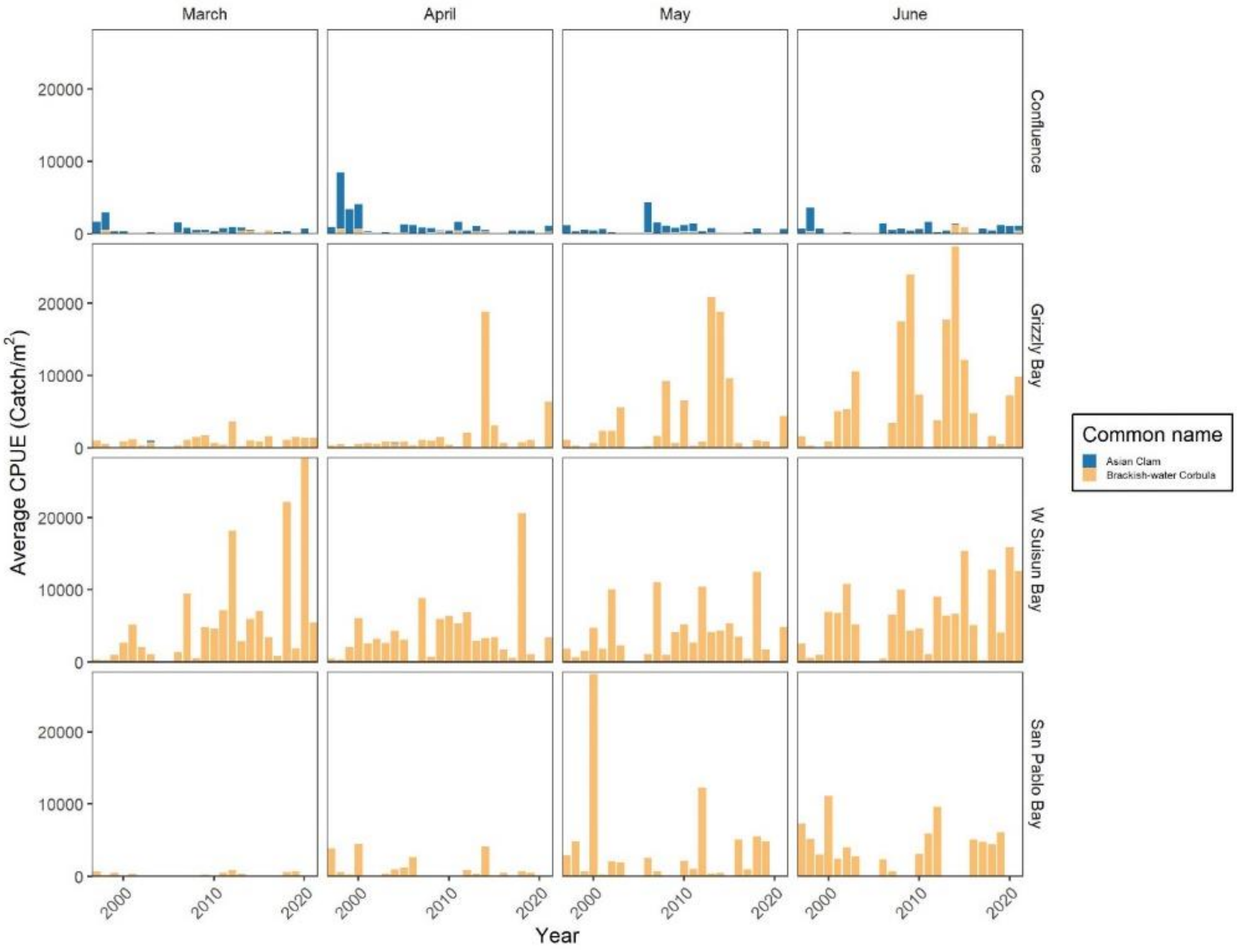


Source: Samples were collected by the Environmental Monitoring Program. Data were downloaded from the Environmental Data Initiative on December 23, 2022.

CPUE = catch per unit effort; catch/m^2 = number of individuals per square meter; Sac R = Sacramento River; SJR = San Joaquin River.

Taxonomic groups provided as common names.

Figure J-21. Invasive Clam Mean Monthly Relative Abundance by Enhanced Delta Smelt Monitoring Program Region: Fresher Regions, from March through June of Each Year, 1996–2021



Source: Samples were collected by the Environmental Monitoring Program. Data were downloaded from the Environmental Data Initiative on December 23, 2022.
CPUE = catch per unit effort; catch/m^2 = number of individuals per square meter.
Taxonomic groups provided as common names.

Figure J-22. Invasive Clam Mean Monthly Relative Abundance by Enhanced Delta Smelt Monitoring Program Region: Brackish Regions, from March through June of Each Year, 1996–2021

J.5.3 Models

J.5.3.1 Hydrodynamics

Particle Tracking Model

The Particle Tracking Model (PTM) is a component of the Delta Simulation Model II to simulate the particle movement throughout the Bay-Delta network. The PTM model uses the hydrodynamics calculated from the DSM2-HYDRO model and extrapolates the one dimension average velocity in a channel to a pseudo three dimension velocity with assumed certain cross-sectional velocity profiles. The velocity profiles assume faster velocity at channel center and slower velocity near the channel bank and bottom. Field data are used to guide the selection of the velocity profiles and to calibrate the PTM.

Currently, two applications are commonly used with PTM. One is to estimate the particle residence time. When a certain number of particles (e.g., 1,000) are inserted at a certain location, the time for 25%, 50% and 75% of the particles to exit the system is estimated. The other is to estimate particle traces. For example, the percentage of particles released at Vernalis into the San Joaquin River and diverted into the SWP and CVP after 90 days can be used to represent the likelihood of fish entrainment.

Applications are available at: https://water.ca.gov/Library/Modeling-and-Analysis/Bay-Delta-Region-models-and-tools/Delta-Simulation-Model-II. PTM can be used to evaluate the movement and distribution of smelt larvae performance metric.

Bay-Delta SCHISM

The Bay-Delta Semi-implicit Cross-scale Hydroscience Integrated System Model (SCHISM) model is a three-dimensional numerical modeling system for the San Francisco Bay Delta estuary that is based on an unstructured grid numerical model known as SCHISM (Ateljevich et al. 2014; Chao et al. 2017a, 2017b; Zhang et al. 2008, 2016, 2019). The model can predict salinity and temperature in the Bay-Delta. Bay-Delta SCHISM can be used along with Bever et al. (2016) to evaluate physical habitat quality and suitability for Delta and longfin smelt. These quality and suitability criteria are for older life stages, and is not useful for evaluating spring Delta smelt habitats.

Water Temperature (HEC-5Q)

Over the past 15 years, various temperature models were developed to simulate temperature conditions on the rivers affected by CVP and SWP operations (Sacramento River Water Quality Model, San Joaquin River HEC-5Q model) (Bureau of Reclamation 2008). Recently, these models were compiled and updated into a single modeling package called the HEC-5Q model. Further updates were performed under the Long-Term Operation Environmental Impact Statement modeling that included improved meteorological data and subsequent validation of the Sacramento and American River models, implementation of the Folsom Temperature Control Devices and low-level outlet, implementation of the Trinity auxiliary outlet, improved temperature targeting for Shasta and Folsom Dams, improved documentation and streamlining of the models, and improved integration with the CalSim II model (Bureau of Reclamation 2015). A summary of previous model calibration and validation details can be found at the following link: https://www.waterboards.ca.gov/waterrights/water_issues/programs/bay_delta/california_waterfix/exhibits/docs/petitioners_exhibit/dwr/part2/DWR-1084%20RMA%202003%20SRWQM.pdf.

HEC-5Q can inform juvenile salmonid survival as a function of river temperature. These models are useful for riverine temperature models, but do not apply to the Delta.

J.5.3.2 Food Web

Several models are available for assessment of food web performance metrics.

Effects on Zooplankton: Greenwood (2018)

The density of the key smelt zooplankton prey *Eurytemora affinis* (*E. affinis*) is significantly negatively related to mean March through May X2 and a general linear model to analyze this for different outflow scenarios is available from Greenwood (2018). X2 is the distance, expressed in kilometers from the Golden Gate Bridge, at which channel bottom water salinity (isohaline) is 2 parts per thousand. Greenwood's method (2018) can be used to evaluate potential effects on *E. affinis* and *Crangon* as a result of spring Delta outflow operations. Kimmerer (2002a) found statistically significant negative relationships between mean spring (March–May) X2 and the relative abundance (CPUE) of *E. affinis* and *Crangon* (Bay Shrimp); Kimmerer et al. (2009) updated the latter relationship with additional years of data. Application of the Kimmerer et al. (2009) Bay Shrimp X2-abundance relationship can show the relationship between spring X2 and relative abundance of Bay Shrimp. Kimmerer's (2002a) method was followed to conduct an analysis for the period from 1980 to 2017 (Greenwood 2018).

Effects on Zooplankton: Hennessy and Burris (2017)

Regression equations from Hennessy and Burris (2017) are available that predict *E. affinis* density and mysid shrimp *Neomysis mercedis* density in the low-salinity zone as a function of March through May Delta outflow as well as an equation predicting the density of the smelt zooplankton prey *Pseudodiaptomus forbesi* in Suisun Bay as a function of mean June through September Delta outflow, although this is minimally overlapping the spring Delta outflow period).

The equations outlined in the Hennessy and Burris (2017) memo were examined and it was decided these regressions are too geographically simplistic and temporally broad as currently developed to add value to evaluating effects of operations on the zooplankton community.

J.5.3.3 Smelt

Delta Smelt Individual-Based Model

For Delta smelt, an Individual-Based Model was developed by Rose et al. (2013a, 2013b) and updated in 2022. This model simulates reproduction, movement, growth, and mortality of Delta smelt based on a combination of the approaches described by Rose et al. (2013a). It was calibrated to entrainment mortality, abundances, and growth rates estimated from the wild Delta smelt population between 1995 and 2015.

Delta smelt Individual-Based Model can be used to evaluate the movement and distribution and survival probability performance metrics for Delta smelt. This model can combine Delta Simulation Model II flow data from the Sacramento and San Joaquin Rivers with export level values from the pumping facilities. This model's inputs are different than the numeric modeling developed for the Biological Assessment, and is not being used.

Delta Smelt Life Cycle Model (2021 version)

Polansky et al. (2020) developed a stage-structured state-space life cycle model for Delta smelt. State-space models are useful as ecological modeling tool because they allow separate descriptions of state and observation processes and because they permit integration of disparate data sets. This Delta smelt life cycle model was later expanded from four to seven different life stages and to include a component that describes the entrainment process into the Delta export facilities (Smith et al. 2021). This model produces expected values for larval recruitment and survival at the subsequent life stages. The best model in Smith et al. (2021) did not include spring outflow as a variable influencing abundance and survival, so it will not be used to examine spring outflow.

Delta Smelt Maunder and Deriso (2011) State-Space Model

Maunder and Deriso (2011) developed a state-space multistage life cycle model for delta smelt that allows for density dependence and environmental factors to impact the different life stages. This model may be applicable to scenario data given assumptions regarding covariates for which the effects of management actions are not predictable.

Longfin Smelt Outflow-Abundance Model

Various statistical models are available linking to longfin smelt abundance indices to winter-spring Delta outflow. A recently developed model uses a Bayesian model-stacking approach to predict the longfin smelt Fall Midwater Trawl (FMWT) abundance index as a function of Delta outflow during March through May and December through May; the FMWT abundance index two years prior (as an index of parental stock size); and a term indicating ecological regime (i.e., *Potamocorbula amurensis* (*P. amurensis*) invasion and pelagic organism decline). This modeling approach was developed to address concerns such as lack of parental stock terms in simpler X2-abundance approaches (Kimmerer 2002a) or uncertainty in density-dependence and use of models for predictions rather than to test hypotheses (Nobriga and Rosenfield 2016). The model is described by DWR (California Department of Water Resources 2022: Appendix 12B).

The potential effect of the alternatives on longfin smelt can be investigated through development of a statistical model relating the longfin smelt FMWT abundance index to Delta outflow, the FMWT abundance index 2 years earlier (as a representation of parental stock size), and ecological regime (i.e., 1967–1987, pre-*P. amurensis* invasion; 1988–2002, post-*P. amurensis* invasion; and 2003–2020, Pelagic Organism Decline; to represent major ecological changepoints in the Bay-Delta, e.g., Nobriga and Rosenfield 2016). Assess total Delta outflow (summed, thousand acre-feet) for March through May and December through May, similar time periods to previous work by Mount et al. (2013) and Nobriga and Rosenfield (2016).

J.5.3.4 Chinook Salmon

SacPAS Fish Migration Model

The SacPAS fish model allows estimation of juvenile Chinook salmon survival in Sacramento reaches downstream of the Red Bluff Diversion Dam (http://www.cbr.washington.edu/sacramento/fishmodel/). Survival, passage time, and estimated counts of juvenile passage at reference sites between the Red Bluff Diversion Dam and Freeport is based on the mean free-path length model (i.e., XT model), in which juvenile survival in the Sacramento River reaches is modeled as a function of reach length, passage time, and flow rate based on expected interactions with predators (Anderson et al. 2005). Parameters for the XT model were estimated using acoustic telemetry data from releases of juvenile late fall-run Chinook salmon, obtained from the Coleman National Fish Hatchery, in water years 2013 and 2014 (Steel et al. 2020).

Flow Threshold Survival Model (Michel et al 2021)

The flow threshold survival model (Michel et al. 2021) methods were applied to assess potential effects of spring pulse and Delta outflow effects on juvenile Chinook salmon riverine survival in the Sacramento River as a function of flow. To assess potential effects of Project operations on juvenile Chinook salmon as a result of flow-survival relationships, the flow thresholds and survival estimates from Michel et al. (2021) were applied to Sacramento River at Wilkins Slough flow. The models were fit and validated using acoustic telemetry Chinook salmon smolts released between 2013 and 2019. These flow thresholds and corresponding assumptions are well described and clear from the published paper. This model has recently been used to update survival results for the CVPIA Science Integration Team Decision Support Models for Chinook salmon.

STARS Models

The Survival, Travel time, and Routing Simulation (STARS) model is an individual-based simulation that predicts fish parameters (survival, travel time, entrainment) of juvenile salmonids migrating through the Delta. The fish parameters are related to movement of individual acoustically tagged late-fall and winter-run Chinook salmon connected to daily data (Delta Cross Channel gate status and Sacramento River flow at Freeport). The implementation of the simulation model currently available for use is calibrated to acoustically tagged late-fall fish released from 2007 to 2011. Data inputs to the model can be obtained by assigning monthly CalSim output to daily values within each month. Results are for individuals in cohorts, or fish who enter the model's "system" daily at Freeport. The use of the STARS model can inform the migrating behavior of juvenile salmonids (i.e., route selection) and total survival in the Delta. It is constructed to understand the space outside the interior Delta, but interpolation could be used to identify possible behavior of fish once they take a specific route away from the Sacramento River (i.e., Delta Cross Channel or Georgiana Slough). STARS provides overall survival and travel time, route-specific survival and travel time, and proportion of fish on a daily timestep that would use individual migration pathways or routes. An application of the STARS models run in real time is available here: https://oceanview.pfeg.noaa.gov/shiny/FED/CalFishTrack/. The code and supporting document are available from the U.S. Geological Survey (USGS) (Perry pers.

comm.). The model structure and assumptions are documented in peer-reviewed literature (Perry et al. 2018). Model development is not currently open and participatory.

The STARS model can be applied to assess the performance metric of routing probability for winter-run Chinook salmon and possibly also spring-run Chinook salmon. The STARS model was applied to the 2019 NMFS Biological Opinion.

J.5.3.5 Other Species

A number of general linear models are available which link spring Delta outflow or X2 to abundance or survival of fish and shrimp species occurring within the Delta. Relationships predicting abundance or survival were developed by Kimmerer et al. (2009) and recently applied by DWR (California Department of Water Resources 2022: Appendix 12B) for the following species:

- Striped bass (separate models based on Bay Otter Trawl Abundance Index, Bay Midwater Trawl Abundance Index, FMWT Abundance Index, Summer Townet Abundance Index, and Summer Townet Survival Index).
- American shad (separate models for Bay Midwater Trawl Abundance Index and FMWT Abundance Index).
- Starry flounder and California bay shrimp (models based on Bay Otter Trawl Abundance Indices).
- General linear models are also available linking white sturgeon year class strength (based on capture by otter trawls by the San Francisco Bay Study) to March through July and April through May Delta outflow. This can be used as a surrogate for inflow and outflow effects on green sturgeon year class strength.

J.6 Lines of Evidence

During alternative development, rationales behind different concepts and approaches to species-specific spring outflow management strategies were documented. These concepts are described here as lines of evidence. From the full list of quantitative models outlined above (Section J.5.3, *Models*), a subset of tools was selected to evaluate the environmental impacts of the CVP and SWP operations on listed fishes. These tools are included as lines of evidence.

J.6.1 Effect of Spring Outflow on Water Quality

Spring outflows have varying effects on important aspects of water quality in the Delta, including temperature, salinity, turbidity or sedimentation, oxygen, nutrients, contaminants, and organic and inorganic particle load (Schoellhamer et al. 2016).

Freshwater inflow into the Delta has limited direct effects on temperatures in the Delta after winter storms and runoff events cease by the end of February (Wagner et al. 2011). Water temperatures in the Delta are usually driven by surface heat fluxes, and any effects of altered spring freshwater inflow will diminish rapidly (i.e., in less than a month) (Monismith et al. 2009; Wagner et al. 2011). However, outflow-based effects on Delta hydrology may have indirect effects on temperature patterns throughout the Delta (Gleichauf 2015) as springtime surface water temperature is typically colder when inflow is higher (Bashevkin and Mahardja 2022).

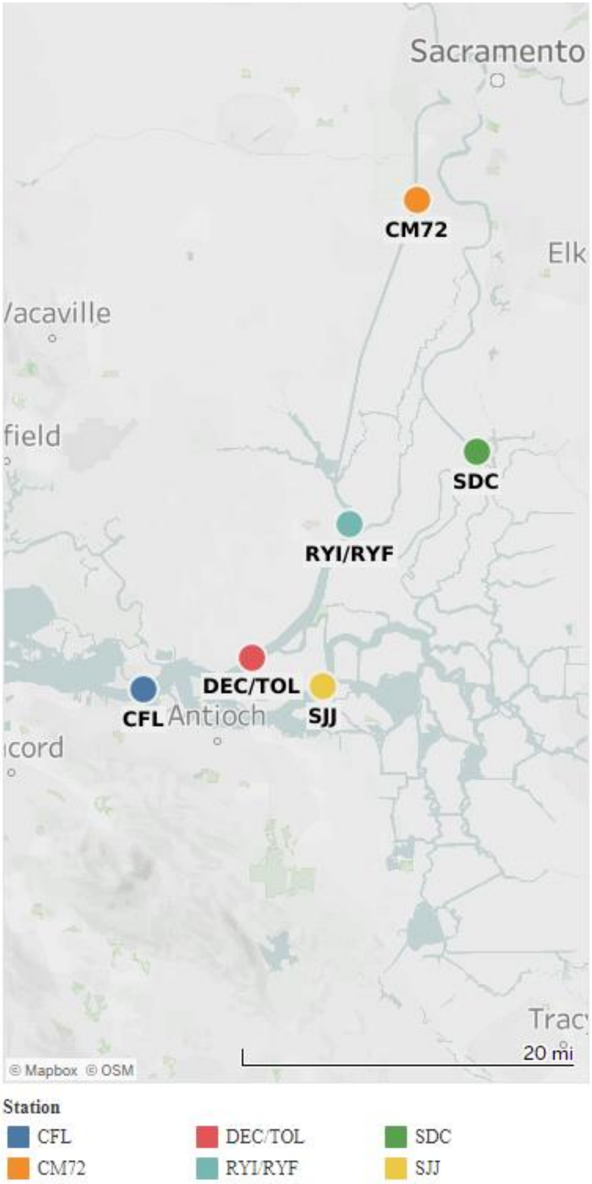
Modeling efforts have observed that X2 responds more rapidly to increases in flow than decreases (Chen et al. 2015), and that the response of X2 is fast when flow is large (MacWilliams et al. 2015), which supports the value of spring outflow pulses for improving Delta habitat as it relates to salinity. However, pulse flows are expected to require a larger total volume of flow to maintain a given X2 than a steady flow corresponding to the same X2 (Monismith 2017).

Turbidity levels in the upper Delta respond strongly to high winter and spring river inflows associated with storm runoff, with winter "first flush" typically exhibiting the highest suspended sediment concentrations in a given year (Schoellhamer et al. 2012). However, the effects of spring outflow pulses from reservoirs appear to be poorly understood. Releases from reservoirs are relatively clear and are not expected to contribute substantial suspended sediment loads to downstream reaches. Sedimentation patterns throughout the Delta may be affected indirectly by flows as changing salinity levels in the Delta can alter hydrology and sediment transport (Shellenbarger et al. 2013).

Effects of spring river inflow and exports (which result in outflow) on oxygen, nutrients, contaminants, and particle load are less understood. Spring river inflow may indirectly maintain sufficient oxygen levels for normal ecosystem function by decreasing residence time and reducing occurrences of high biological oxygen demand (i.e., large phytoplankton blooms) (Monsen et al. 2007; Baxter et al. 2008). Spring outflow may reduce the effect of contaminants on ecosystems by reducing water residence time (Schoellhamer et al. 2016). In this case, the operations to improve outflows may affect water residence time differently. Reducing exports to increase outflow may not reduce residence times similar to how greater inflows reduce water residence times. Direct effects of river inflow on concentrations of contaminants are incompletely understood. For example, Kimmerer et al. (2002b) reports competing hypotheses that increased river flows either dilute existing contaminants or increase loading of contaminants, potentially through increased terrestrial habitat connections and runoff.

J.6.2 Historical Biogeochemical Fluxes from the U.S. Geological Survey Seasonal Analyses, Biomass Flux between Regions

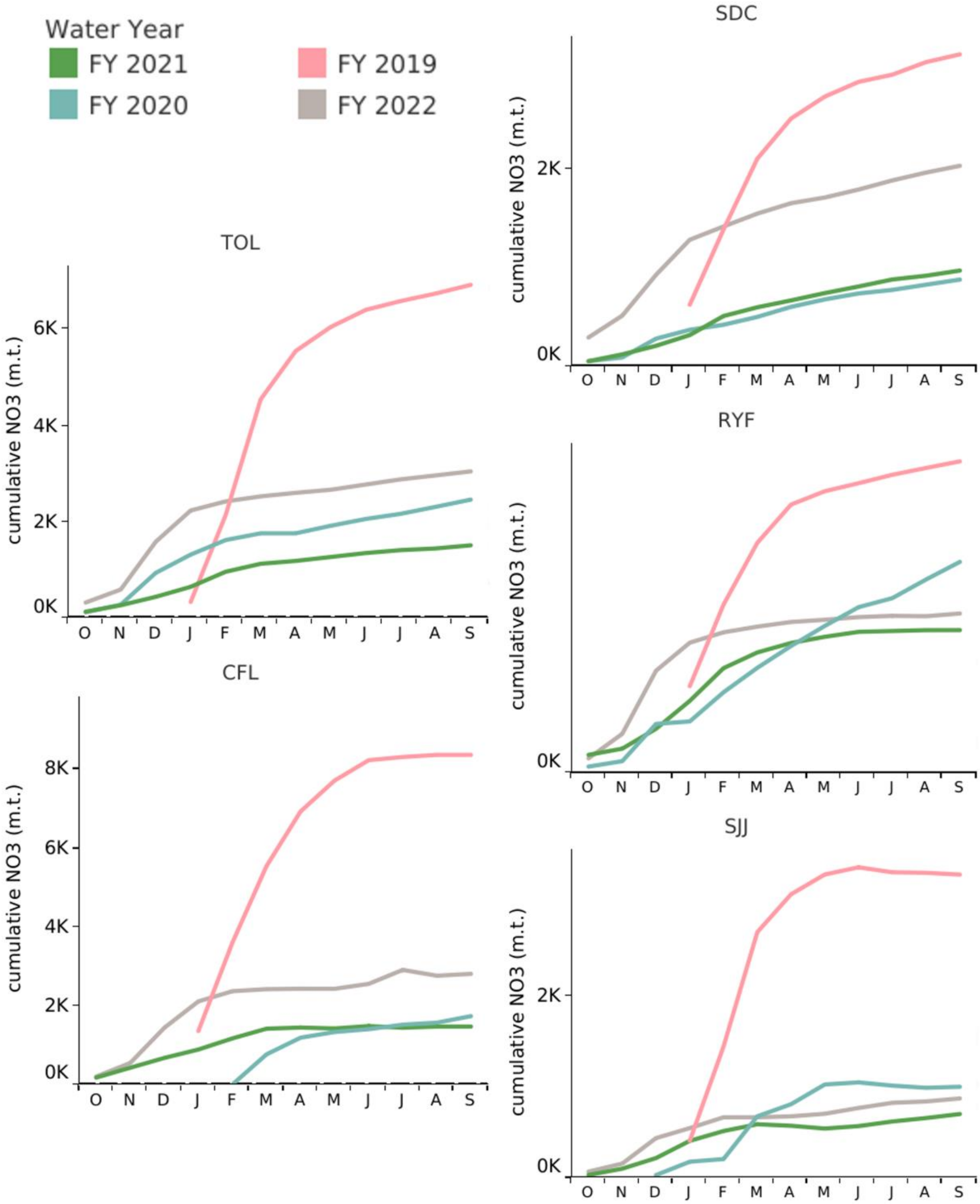
Biogeochemical flux, in the context of the Bay-Delta, is a representation of biomass cycling through lower trophic levels in the riverine and estuarine environment. Trends in water quality parameters (e.g., nitrates [NO3], chlorophyll a) have been measured in the Bay-Delta for water years 2014 through the present and are available online at the USGS's webpages (https://tableau.usgs.gov/views/BOR_reporting_test_May-July_2023/Fig_2Totalfluxtidefltrd?%3Aembed=y&%3Aiid=1&%3AisGuestRedirectFromVizportal=y; https://tableau.usgs.gov/views/BOR_reporting_test_v2/Totalfluxandtidefilteredconcentrations?%3Adevice=desktop&%3Aembed=y&%3AisGuestRedirectFromVizportal=y). Interpretations are based on preliminary, curated data summaries provide by USGS. Data have been sampled at six stations (Figure J-23): Confluence (CFL), Decker Island/Toland (DEC/TOL), San Joaquin River at Jersey Point (SJJ), Cache Slough at Ryer Island (RYI/RYF), Sacramento River at Walnut Grove (SDC), and Sacramento Deep Water Ship Channel at Channel Marker 72 (CM72). Positive flux values and positive slopes of NO3s and chlorophyll a represent seaward transport of the constituent; negative flux values and negative slopes represent landward transport.



Source: U.S. Geological Survey (https://tableau.usgs.gov/views/BOR_reporting_test/Fig_4WYcumulativeflux?%3Aembed=y&%3AisGuestRedirectFromVizportal=y).

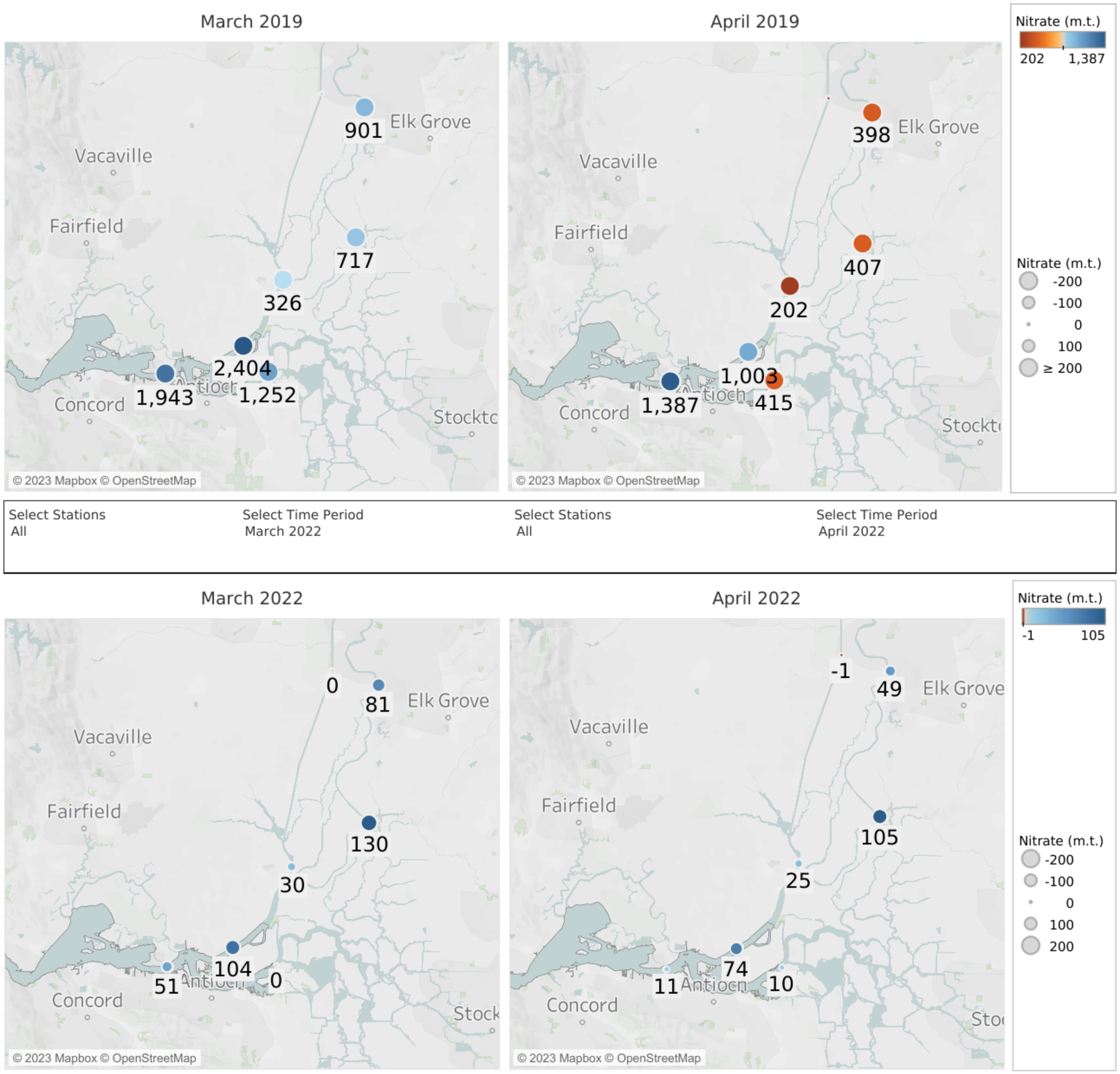
Figure J-23. Bay-Delta U.S. Geological Survey Stations Sampling Biogeochemical Variables: Nitrate and Chlorophyll

A qualitative comparison of cumulative flux of NO3 across Water Years 2019–2022 shows similar trends for dry years (2020–2022) based on the similar slopes (Figure J-24). Exceptions include a relatively large flux at SDC in October and December of Water Year 2022, due to heavy rain events. Cumulative fluxes were noticeably steeper and positive slopes extended further into the year during Water Year 2019, an above normal year type, mostly due to a series of large fall and winter storms. Monthly, seaward NO3 flux was higher in March and April of 2019 compared to 2022, respectively (Figure J-25).



FY = fiscal year; NO3 = nitrate; m.t. = metric tons.

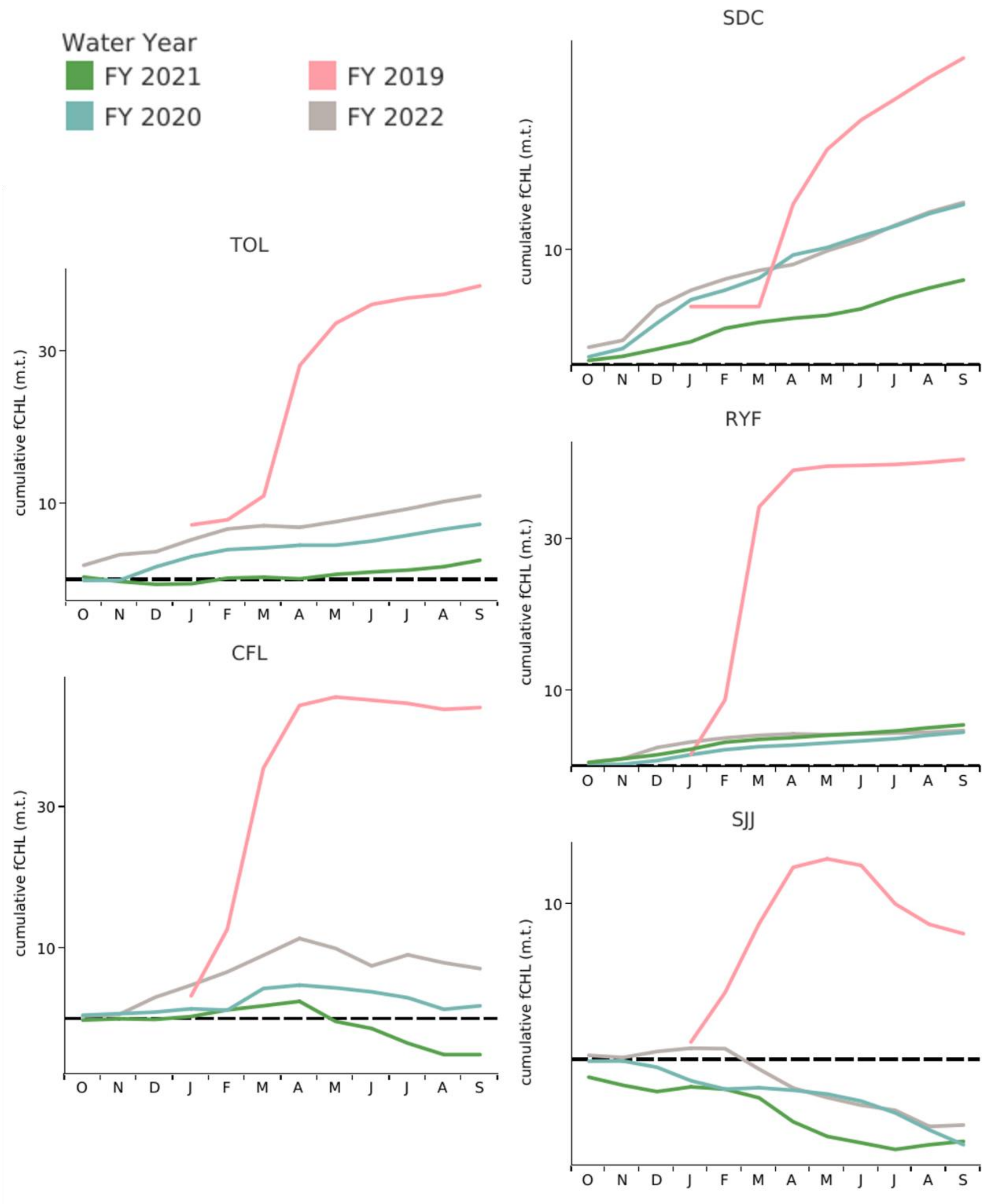
Figure J-24. Cumulative Nitrate Flux by Site, Water Years 2019–2022



m.t. = megatonnes.

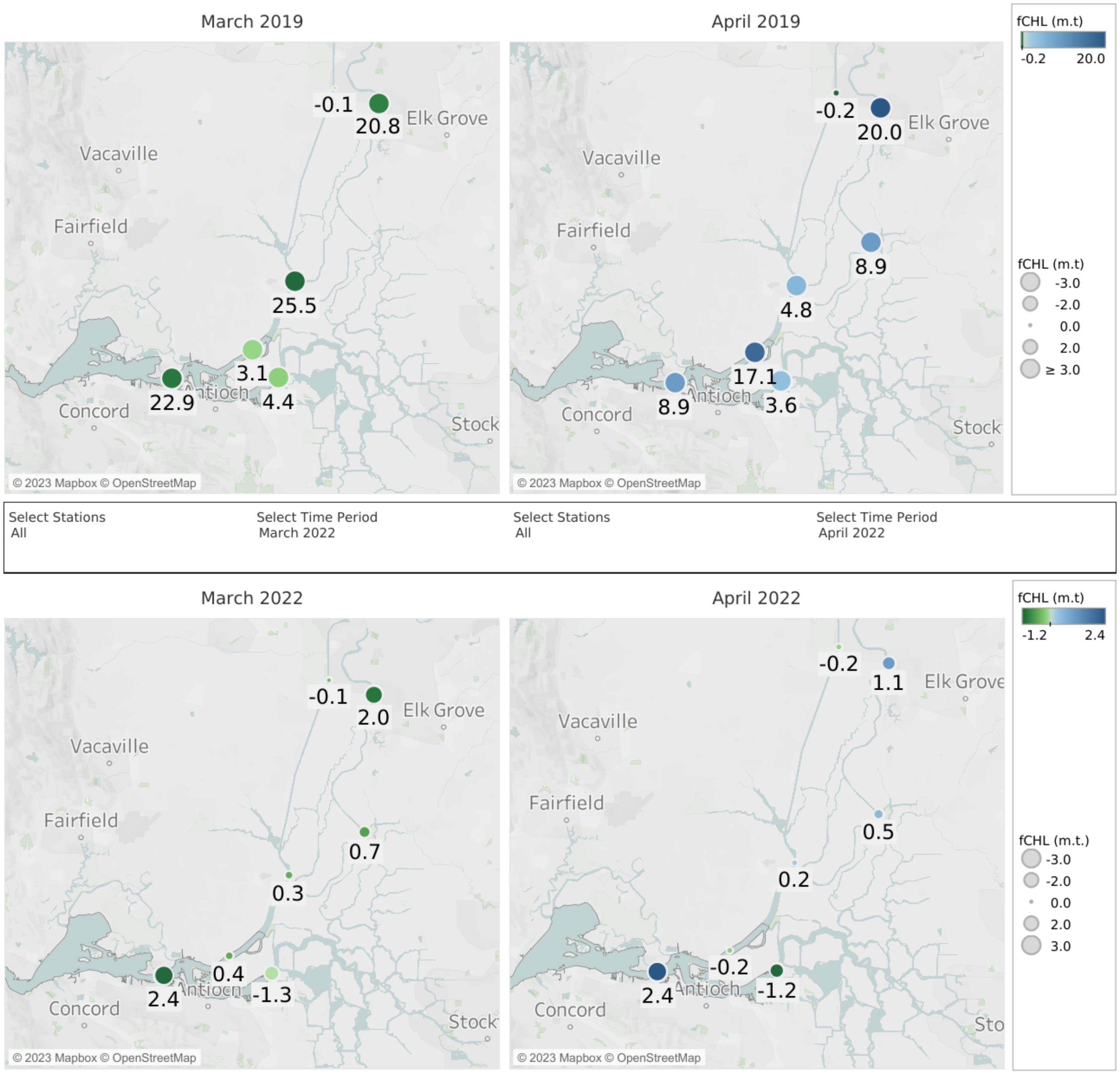
Figure J-25. Nitrate Flux in March 2019, March 2022, April 2019, and April 2022

A qualitative comparison of cumulative flux of chlorophyll a across Water Years 2019–2022 shows similar trends for dry years (2020–2022) based on the similar slopes for each site (Figure J-26). Flux was generally seaward (positive slopes) at SDC, RYF, and TOL throughout the year and at CFL during winter months. A switch to negative (landward) flux after winter is consistent with net cumulative transport of chlorophyll from Suisun Bay into the Confluence region. Consistently negative flux at SJJ is due to net cumulative transport of chlorophyll from the Confluence region into the Central Delta. The positive (seaward) slopes in total cumulative flux at RYF, TOL, and CFL in 2019 were primarily due to series of large fall and winter storms. The steep rises in slopes at these sites in March coincided with the recessional phase of the Yolo Bypass flooding. Monthly, seaward chlorophyll flux in March and April 2019 was higher than in March and April of 2022, respectively (Figure J-27).



FY = fiscal year; m.t. = metric tons.

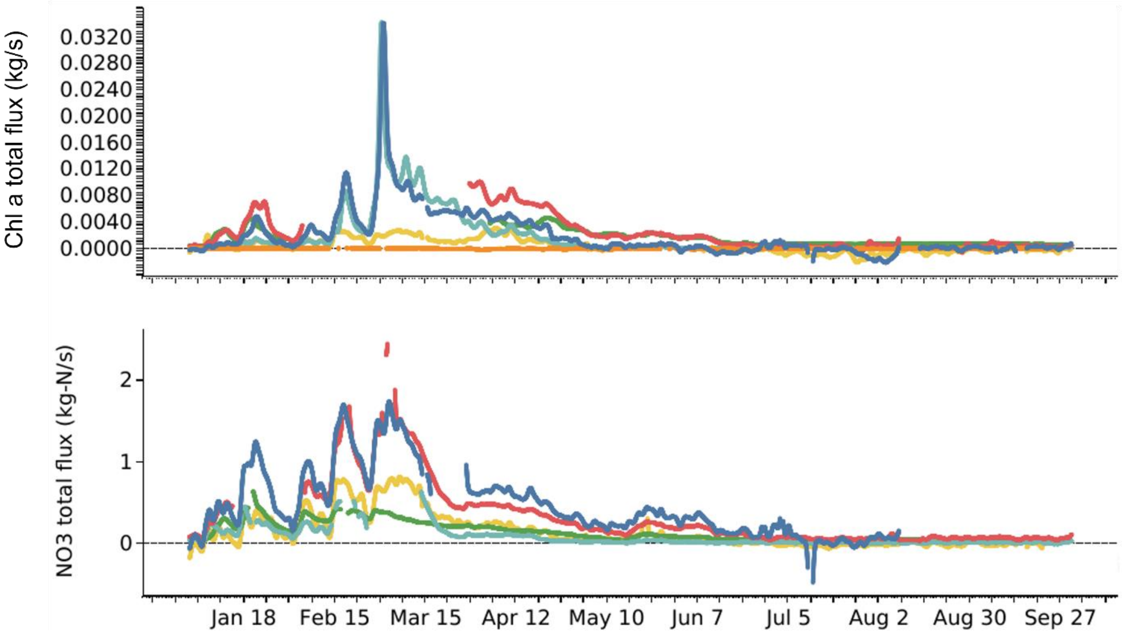
Figure J-26. Cumulative Chlorophyll a Flux by Site, Water Years 2019–2022



FY = fiscal year; m.t. = megatonnes.

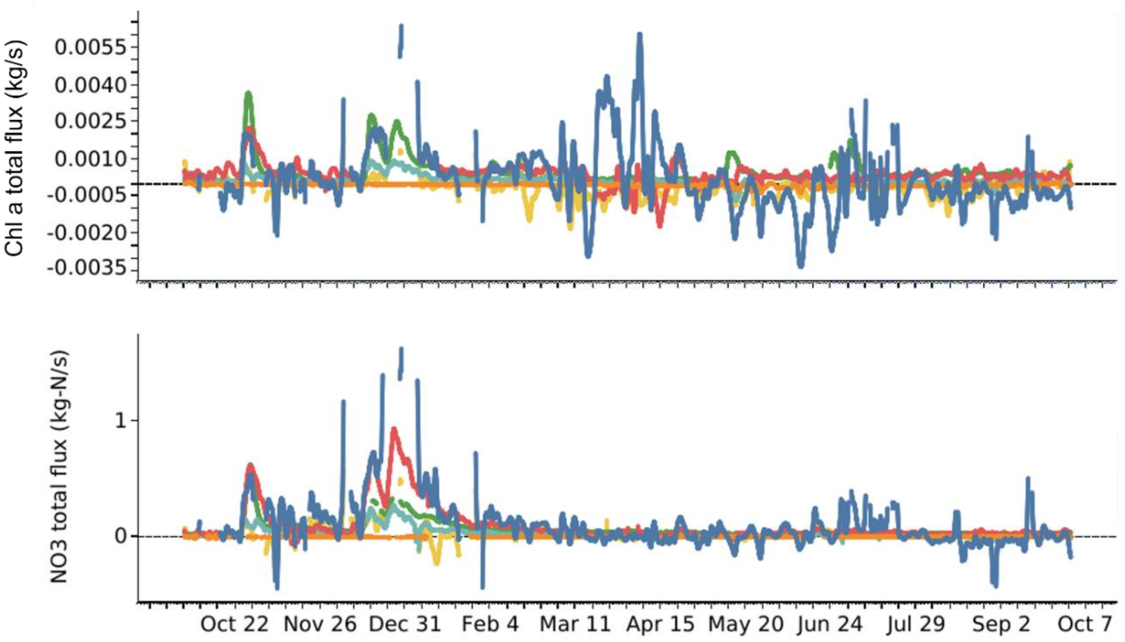
Figure J-27. Chlorophyll Flux in March 2019, March 2022, April 2019, and April 2022

Total flux of both NO3 and chlorophyll a in 2019 and 2022 show similar responses to storm events during late winter and late fall/early winter, respectively (Figure J-28 and Figure J-29). Estimated fluxes were generally seaward (positive) during these storm events at all sites except SJJ and SDC. In March 2022, a phytoplankton bloom occurred between the confluence and lower Sacramento River. Annual spring blooms in the low salinity zone have been observed consistently and are likely due to light availability and tidal timescale dynamics, in addition to other drivers (Figure J-30).



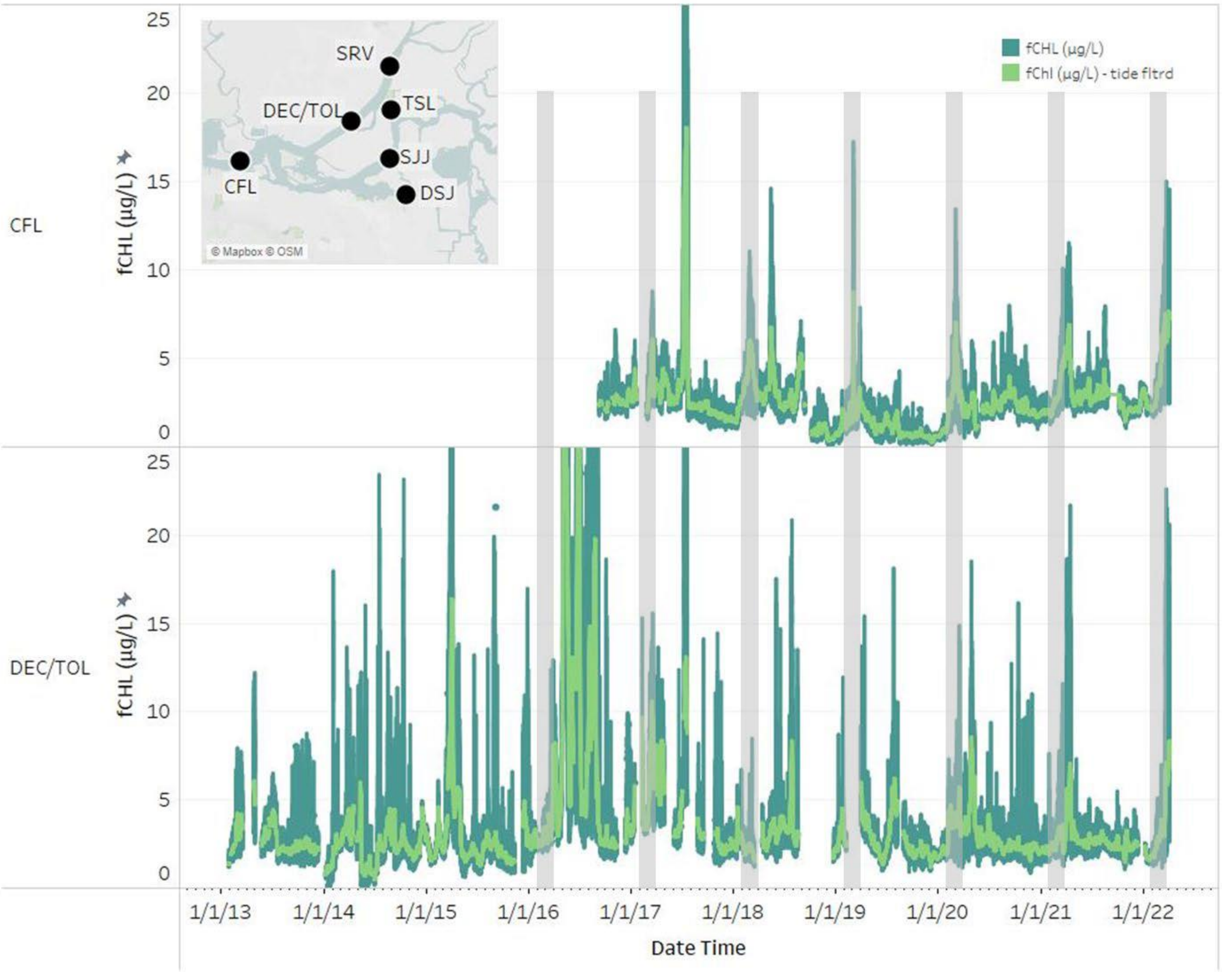
Chl a = chlorophyll a; kg/s = kilograms per second; NO3 = nitrate; kg-N/s = kilograms of nitrogen per second. Sample stations: Channel Marker 72 = orange; Sacramento River at Walnut Grove = green; Cache Slough at Ryer Island = light blue; San Joaquin River at Jersey Point = yellow; Decker Island/Toland = red; Confluence = dark blue.

Figure J-28. Total Flux of Chlorophyll a and Nitrate during Water Year 2019



Chl a = chlorophyll a; kg/s = kilograms per second; NO3 = nitrate; kg-N/s = kilograms of nitrogen per second. Sample stations: Channel Marker 72 = orange; Sacramento River at Walnut Grove = green; Cache Slough at Ryer Island = light blue; San Joaquin River at Jersey Point = yellow; Decker Island/Toland = red; Confluence = dark blue.

Figure J-29. Total Flux of Chlorophyll a and Nitrate during Water Year 2022



µg/L = micrograms per liter; CFL = Confluence; DEC/TOL = Toland.
Gray bars indicate February through April for each year.

Figure J-30. Chlorophyll Fluorescence at the Confluence and Toland Show Annual Elevations during Late Winter to Early Spring

J.6.3 Effect of Spring Inflow and Outflow on Ecosystem Productivity

Ecosystem productivity in the Delta, integrating both primary production and densities of zooplankton like *E. affinis*, reflects a balance of numerous forcing factors, including riverine carbon inputs (i.e., detritus), floodplain inundation, salinity conditions, water residence time, turbidity, and inorganic nutrient loading. Of these forcing factors, the effects of turbidity and inorganic nutrient availability will be minimally affected by spring outflow. Given plentiful nutrients in the Delta, light availability due to high turbidity historically has been a limiting factor for primary productivity in the Delta, and increased spring outflow is not necessarily expected to affect this constraint (Jassby et al. 2002).

Supply of detrital-based organic carbon from river inflows to the Delta can match or exceed carbon produced by local phytoplankton, depending on annual river flow. High freshwater inflow has been correlated with dominance of detrital or river-based carbon in Suisun Bay (Jassby et al. 1993). Detrital matter has been observed to be only weakly linked to the Delta's pelagic food web due to its reliance on the microbial loop to be made bioavailable (Sobczak et al. 2002; Sobczak et al. 2005).

Changes in spring outflow due to floodplain inputs can temporarily increase riverine ecosystem productivity in riverine floodplain habitats like the Yolo Bypass. Primary production in the Yolo Bypass, as measured by chlorophyll a, was observed to increase rapidly after flooding and subsequent draining back to the level of the perennial channel (Schemel et al. 2004). These levels of primary production were approximately two times (or more) greater than levels in the main Sacramento River channel (Lehman et al. 2008). Copepod and cladoceran densities did not appear to vary meaningfully between floodplain and channel habitat, but floodplain habitat supported higher densities of Diptera and terrestrial invertebrates (Sommer et al. 2004). High biomass can remain in the Yolo Bypass for several weeks before decreasing to pre-flooding levels. The floodplain habitat can contribute substantial loads of primary producer biomass and, particularly, biomass of wide-diameter diatoms and green algae, to downstream reaches of the Sacramento River entering the north and west Delta (Lehman et al. 2008). Results from this research suggest that multiple flooding and draining cycles will maximize transport of primary production downstream of the Yolo Bypass. The minimum necessary flood pulse, as measured in river flow, to inundate the Yolo Bypass floodplain was estimated to be 2,000 cfs; the estimated flow necessary to flood the entire bypass was 8,000 cfs (Williams et al. 2009). The expected contributions of Yolo Bypass productivity to overall productivity in the Delta is unknown.

Effects of spring outflow on the Delta include changing the distribution of salinity (e.g., the low-salinity zone and X2). There is a strong negative relationship between X2 and Delta outflow (Jassby et al. 1995). Specific relationships between Delta outflow, X2, and the corresponding low-salinity zone are modeled by past studies (Kimmerer et al. 2013; MacWilliams et al. 2015); these studies found that X2 changes more rapidly at higher Delta outflows. Therefore, the ability to meaningfully influence X2 with relatively low additional Delta outflows may be limited.

Past research has tested the hypothesis that species abundance varies with the volume of low-salinity habitat and documented a negative relationship between focal copepod species like *E. affinis* and X2 (Kimmerer 2002a). This relationship is also supported by model predictions that pulse spring flows in dry water years can increase copepod biomass near Suisun Bay (Hamilton et al. 2020). Other recent analyses have provided additional support for higher smelt copepod and mysid prey with greater spring Delta outflow (Hennessy and Burris 2017; Greenwood 2018). However, as shown by Reclamation and DWR (2021:2–11), there are more significantly negative relationships of zooplankton to spring Delta outflow than positive relationships at the scale of the regions sampled by the Environmental Monitoring Program and 20-Millimeter Survey.

Primary productivity in the Delta is influenced by the water residence time. At higher river inflows, water residence time in most of the estuary decreases. Decreased residence time limits the buildup of primary producers and typically results in lower plankton biomass (Kimmerer 2004; Jassby 2008). Conversely, very high residence times associated with lower river inflow may be offset by losses from water diversions. The effects of residence time on primary productivity in areas in the Delta, like Suisun Bay, appear muted by the grazing pressure of the invasive clam *P. amurensis* (Jassby 2008; Kimmerer et al. 2012; Kimmerer and Thompson 2014). Grazing from clams and zooplankton has exceeded net phytoplankton growth in some regions, requiring a subsidy from other regions. In Suisun Bay, the probability of spring blooms of primary productivity, which has been rare in recent decades, may be enhanced by maintaining sufficient river flows to dilute anthropogenic sources of ammonium and simultaneously preventing washout of primary productivity at higher river flows (Dugdale et al. 2012; Glibert et al. 2014). The role of ammonium has been debated, and one recent study suggested that high ammonium loading is not a driver of the lower productivity in the San Francisco Bay Delta (Strong et al. 2021).

In total, increased spring outflows from the Delta can expand the area and volume of the low-salinity zone with potential ramifications for zooplankton distribution and abundance; but the extent of expansion will be muted at lower levels of outflow. High spring outflow may increase zooplankton biomass, and particularly zooplankton preferred by Delta and longfin smelt, in more habitats occupied by these species. Increased outflows are not necessarily expected to increase primary productivity via nutrient supplementation, due to existing nutrient availability, or via effects on light availability. Spring flows that are too high may decrease primary productivity by decreasing water residence time, while low spring outflow alternatives may increase the proportion of productivity that is removed by exports. The response of zooplankton production to increased, river-based detrital inputs may be minimal; and transport of primary production from one area of the Delta to another may be limited (Kimmerer et al. 2018).

J.6.4 Effects of Spring Outflow on Migratory Conditions and Habitat Use

Spring outflow has important effects on migratory conditions, through impacts on factors such as water quality and food availability. Water quality effects of spring outflow—such as temperature, salinity, turbidity or sedimentation, oxygen, nutrients, and contaminants (Schoellhamer et al. 2016)—are included in the conceptual models of juvenile winter-run Chinook salmon (Figure 1) from Windell et al. (2017). High river inflows in the spring provide connectivity to off-channel habitat such as floodplains (Takata et al. 2017). Floodplains increase aquatic food availability, and juvenile salmon growth is highest in these habitats. Measurement of fall-run Chinook growth in the Delta compared to the natal stream (American River) from 2014 through 2016 showed that growth in the Delta was faster than in the natal stream in 2016, but not in the drought years of 2014 and 2015 (Coleman at al. 2022). Differences were attributed to factors such as food availability and density-dependent competition that are affected by lower river inflows in drought years.

Flow has important effects on salmonid migratory behavior and survival. Downstream migration and arrival of juveniles at Knights Landing in the Sacramento River is correlated with the timing of the first high flows in spring (del Rosario et al. 2013). Migratory travel times of Sacramento River salmon smolts decreases with increasing river discharge (Michel et al. 2013; Steel et al. 2020; Hance et al. 2022). There are positive relationships between river inflow and juvenile Chinook salmon migration survival in the rivers upstream of the Delta (Henderson et al. 2019, Michel et al. 2021, Hassrick et al. 2022) and in the Delta, primarily in the riverine reaches; however, as tidal action becomes the predominant force controlling water velocity and direction of flow (e.g., in the Sacramento River downstream of Georgiana Slough), inflow has less effect on survival (Perry et al. 2018; Hance et al. 2022). The magnitude of river inflow influences predation risk within the Delta and entry into the interior Delta increases with decreasing flow (e.g., at the Sacramento River–Georgiana Slough junction (Perry et al. 2018; Hance et al. 2022). Exports are not identified to influence predation risk within the Delta (Hance et al. 2022), so increased outflow by reducing exports may not affect predation risk. Differences in the survival and migratory success of different life stages of Chinook (e.g., fry, smolt, juvenile) may have different relationships to water year types and managed flow regimes (Sturrock 2015, 2020). Reach-specific pulse flow events also have been observed to increase survival, particularly in low flow years (Henderson et al. 2019; Hassrick et al. 2022). Additional research to quantify how much spring export reductions, tributary releases, and/or both improve migratory conditions will be forthcoming.

An acoustic telemetry study of steelhead released in the San Joaquin River upstream of the head of Old River found no association between migratory survival from the head of Old River to Chipps Island and south Delta exports, and only weak support for an association between migratory survival and CVP proportion of combined exports (Buchanan et al. 2021). This finding would suggest that spring management may have limited effects on migratory conditions for steelhead. However, this study was conducted during a period with relatively low variability in export levels, making it difficult to detect potential survival effects. Survival in the upstream reaches of the Delta was associated with river discharge into the Delta, while survival through the lower reaches of the Delta was associated with migration routes (Buchanan et al. 2021). For fall-run Chinook salmon released upstream of head of Old River, Buchanan and Skalski (2020) found survival from the head of Old River to Chipps Island was positively related to the volume of Old River flow (regardless of flow direction) in the strongly tidal interior Delta, but was not related to San Joaquin River flow either entering the Delta from upstream or measured in the Delta near the riverine/tidal interface. However, survival in the upstream, more riverine region of the Delta was positively associated with San Joaquin River flow in the Delta. Buchanan and Skalski (2020) noted that their finding of generally limited effects of flow and south Delta exports on survival was generally similar to the findings of Zeug and Cavallo (2013), who studied the effects of those predictors as reflected in survival of juveniles to capture in ocean fisheries.

Another migrating species, white sturgeon, has a positive relationship between year class strength and Delta outflow (Fish 2010). Among several Delta outflow periods examined, similar magnitudes of positive correlation with year class strength were found for November through February, April alone, July alone, and March through July (Fish 2010). Fish (2010) suggested that fall and winter river inflows provide stimuli for adult migration and gonadal maturation, with spring flows providing stimuli for spawning; increased survival of eggs, larvae, and early juveniles; and transport of juveniles to the estuary.

J.6.5 Effect of Spring Inflow and Outflow on Delta Fish Abundance

Various fish-flow relationships have been established in the Bay-Delta and have been recently reviewed (Tamburello et al. 2019). However, some questions remain regarding which flow metrics are most correlated with fish abundance metrics/indices. Analysis was conducted for a few fish-flow relationships using more recent data to see if R^2 values of ordinary least squares regressions from previous studies are improved or worsened by the use of different flow metrics (Table J-1).

Table J-1. R^2 Value Output for Each Ordinary Least Squares Model Sorted by Flow Metric and Fish Species

Species	**X2**	**Delta Outflow**	**Delta Inflow**	**Unimpaired Runoff**
Longfin smelt	0.67	0.64	0.64	0.65
Striped bass	0.17	0.11	0.06	0.24
Splittail	0.23	0.28	0.29	0.28

The longfin smelt and splittail relationships are from Kimmerer (2002a). The striped bass relationship is a recreation of Stevens (1977) with the full-time series, using the data from Tamburello et al. (2019) (https://aslopubs.onlinelibrary.wiley.com/doi/full/10.1002/lno.11037). Note that the exact month range that was used in the original analyses cannot be recreated for unimpaired runoff since there is no runoff in the drier months of June and July. Therefore, combined water year runoff value was used.

Longfin smelt abundance is related to all variables. The stronger fit with delta outflow and X2 are likely a consequence of longfin smelt being distributed downstream of the confluence for most of their life cycle, and indicates that the underlying driver of abundance is related to X2 or outflow instead of unimpaired runoff. Note, however, that other modeling approaches have found unimpaired runoff to have a higher correlation with longfin smelt population dynamics than Delta outflow (Maunder et al. 2015). Indices of parental stock size have also been shown to have strong correlations with longfin smelt abundance indices, and the intercept of flow-abundance relationships has shifted downward over time (Nobriga and Rosenfield 2016; California Department of Water Resources 2022:Appendix 12B, pp.12B-99–12B-104).

Splittail exhibited good fit with inflow, which is likely related to their reliance on floodplain habitat (located upstream of the export facilities) for spawning (Kimmerer 2002a). Other species occurring in the Bay-Delta with statistically significant relationships with Delta outflow and X2 include American shad, starry flounder, and California bay shrimp (Kimmerer et al. 2009; Tamburello et al. 2019).

Delta smelt generally have not been shown to have statistically significant relationships with spring Delta outflow using linear models (Kimmerer et al. 2009), although more complex state-space modeling has found evidence for summer Delta outflow being positively related to survival of postlarval Delta smelt (Smith et al. 2021).

J.6.6 Longfin Smelt Outflow

This section will summarize results from Attachment J.1, *Longfin Smelt Outflow*. This line of evidence was not used in the Initial Alternatives Report. Results will provide an evaluation of the relationship between longfin smelt abundance and Delta outflow for the Proposed Action and each of the alternatives binned by water year type.

Key Takeaways:

1. The relationship between Delta outflow and the FMWT index of longfin smelt abundance was estimated and used to predict longfin smelt abundance under alternative Delta outflow operational scenarios.

2. The relationship between Delta outflow and the FMWT index of longfin smelt abundance was estimated during the 52 available FMWT survey years, between 1967 and 2022.

3. Model uncertainty was incorporated in the projections of abundance through a Bayesian statistical approach, called model "stacking". Instead of calculating model weights based on the relative predictive ability for each individual model—where the best model for prediction would be given the highest weight—the model weights estimated through stacking minimize the leave-one-out cross-validation mean squared error of the resulting averaged posterior predictive distribution across models. In other words, stacking was used to estimate the optimal linear combination of model weights for averaging the predictive distributions across the model set.

4. In this case, model uncertainty represents uncertainty in different hypotheses about which time period of Delta outflow is representative of effects on longfin smelt abundance, as well as uncertainty about how the timing of Delta Outflow may interact with different ecological regimes in terms of the effects of Delta Outflow through time on trends in longfin smelt abundance.

5. Model averaged predictions were consistent with higher levels of Delta Outflow resulting in higher longfin smelt abundance. Across all scenarios, there was a monotonic decrease in predicted average longfin smelt abundance across water year types, with the highest predicted abundance within each scenario corresponding with wet water years, and the lowest average annual predicted abundance in dry and critical water years. Alternative 1 had the lowest Delta Outflow values and average predicted longfin smelt abundance for that scenario ranged from -5% to -10% by water year type relative to the No Action Alternative (Table J-3). Conversely, those scenarios with larger Delta Outflow values (e.g., Exploratory 1 and Exploratory 3) had the highest predicted abundance (Table J-2). This pattern also followed for Alternative 3, which had a 19%–40% higher average annual predicted abundance relative to the No Action Alternative (Table J-3). Likewise, because Delta outflow was similar for several scenarios relative to the No Action Alternative, the predicted abundance for those scenarios (i.e., Alternative 4, and the Alternative 2 scenario variations) were within plus or minus five percent of the average annual predicted abundance under the No Action Alternative for longfin smelt (Table J-3).

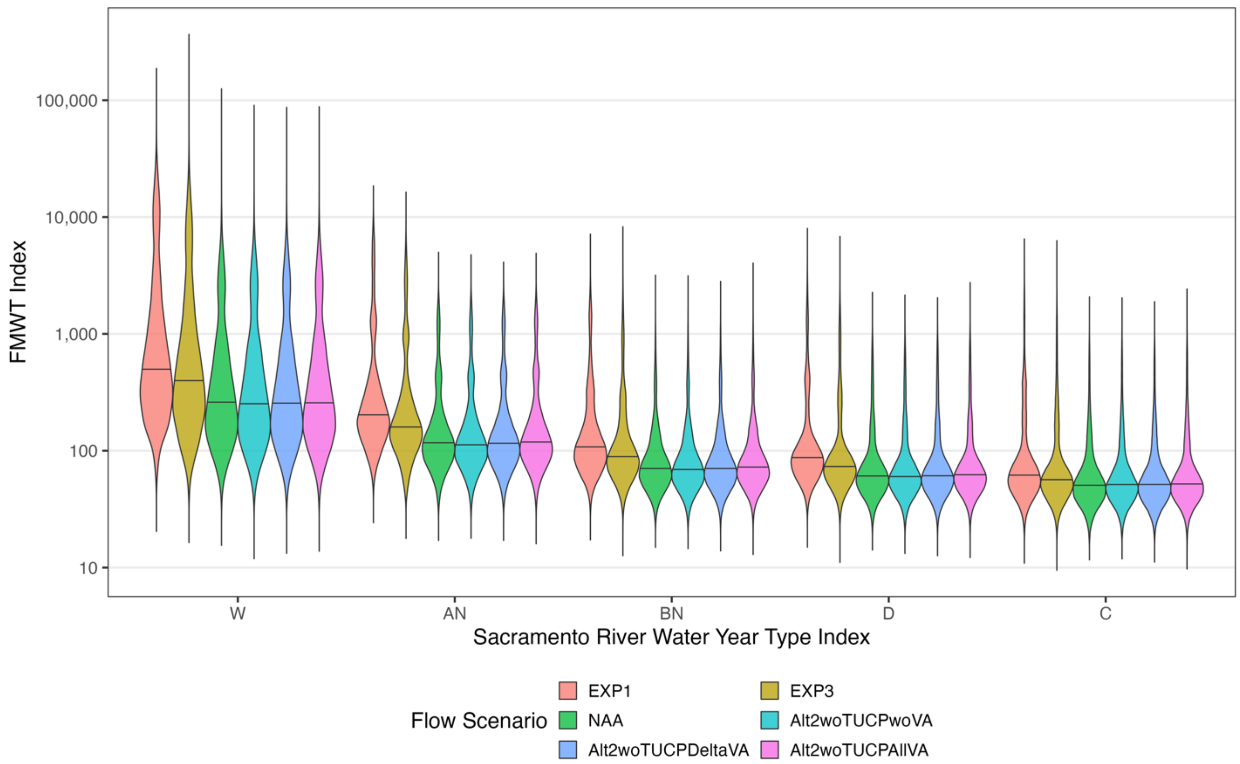
Table J-2. Means of Annual Posterior Predictive Means for the Fall Midwater Trawl Index of Longfin Smelt Abundance by Water Year Type, Providing a Comparison for the Biological Assessment Effects Analysis

Water Year Type	EXP1	EXP3	NAA	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA
Wet	2186.2	1626.5	725.6	704.6	701.5	713.9	716.3
Above Normal	592.7	423.6	215.8	210.9	208.8	215.0	221.8
Below Normal	216.0	170.2	104.8	103.8	103.0	105.6	109.1
Dry	196.3	151.2	95.9	95.5	94.7	96.4	99.2
Critical	130.7	107.3	76.4	76.8	77.8	77.8	79.1

Table J-3. Means of Annual Posterior Predictive Means for the Fall Midwater Trawl Index of Longfin Smelt Abundance by Water Year Type

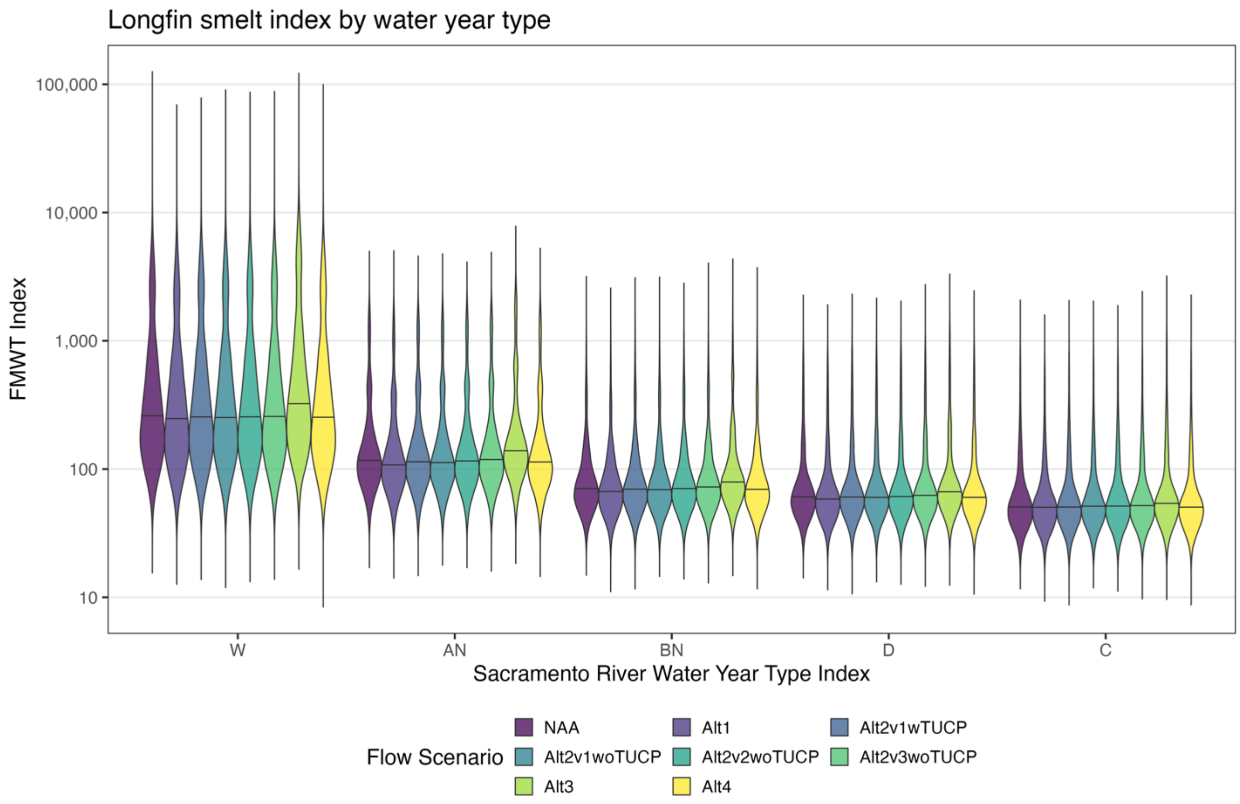
Water Year Type	NAA	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4
Wet	725.6	664.2 (-8%)	704.6 (-3%)	701.5 (-3%)	713.9 (-2%)	716.3 (-1%)	1015.7 (40%)	702.5 (-3%)
Above Normal	215.8	194.0 (-10%)	210.9 (-2%)	208.8 (-3%)	215.0 (0%)	221.8 (3%)	285.4 (32%)	210.1 (-3%)
Below Normal	104.8	96.1 (-8%)	103.8 (-1%)	103.0 (-2%)	105.6 (1%)	109.1 (4%)	129.0 (23%)	103.5 (-1%)
Dry	95.9	88.2 (-8%)	95.5 (0%)	94.7 (-1%)	96.4 (0%)	99.2 (3%)	116.8 (22%)	94.6 (-1%)
Critical	76.4	72.3 (-5%)	76.8 (0%)	77.8 (2%)	77.8 (2%)	79.1 (4%)	91.0 (19%)	76.3 (0%)

The percentage difference between scenarios and the No Action Alternative is shown in parentheses, providing a summary of the differences between the alternatives and No Action Alternative for the Environmental Impact Statement.



FMWT = Fall Midwater Trawl.
The horizontal line in the distribution for each scenario represents the median predicted value.

Figure J-31. Posterior Predictive Distributions for the Fall Midwater Trawl Index of Longfin Smelt Abundance, Aggregated by Water Year Type for Each Scenario



FMWT = Fall Midwater Trawl.
The horizontal line in the distribution for each scenario represents the median predicted value.

Figure J-32. Posterior Predictive Distributions for the Fall Midwater Trawl Index of Longfin Smelt Abundance, Aggregated by Water Year Type for Each Scenario

J.6.7 Inflow-Abundance Curves

J.6.7.1 Background

Various fish-flow relationships have been established in the Bay-Delta and have been recently reviewed Tamburello et al. (2019). However, as noted by Tamburello et al. (2019), these relationships can break down over time as ecosystems change. Furthermore, various flow metrics in the system are highly correlated (e.g., X2, Delta inflow, Delta outflow, unimpaired runoff) due to climate and weather being the primary drivers of flow in the system rather than water operations (Kimmerer 2004), but most studies have focused mainly on a single flow metric (e.g., X2) in their analyses. A few flow-species relationships from the scientific literature were selected in the analysis below to evaluate which flow metrics (X2, Delta inflow, Delta outflow, unimpaired runoff) are most correlated with the specific fish abundance metric or index.

J.6.7.2 Methods

Based on data availability, the X2 relationships with longfin smelt (*Spirinchus thaleichthys*) and splittail (*Pogonichthys macrolepidotus*) from Kimmerer (2002) were selected for analysis. The relationship between Delta outflow and striped bass (*Morone saxatilis*) from Stevens (1977) was also evaluated. For all three species, the analysis was done using updated data from Tamburello et al. (2019). Ordinary least squares regressions from the studies were re-created with updated data to see if R^2 value is improved or worsened by the use of different flow metrics: X2, Delta outflow, Delta inflow, unimpaired runoff. X2, Delta inflow, and outflow data were acquired from DAYFLOW (https://data.cnra.ca.gov/dataset/dayflow). Unimpaired runoff estimates were acquired from DWR water year index (https://cdec.water.ca.gov/reportapp/javareports?name=WSIHIST). Species-specific range of months used the flow values were as follows: January to June for longfin smelt, February to May for splittail, and June to July for Striped Bass. Note that the exact month range used in the original analyses cannot be recreated for unimpaired runoff since there is no runoff in the drier months of June and July; as such, the total water year sum runoff for both Sacramento and San Joaquin Valley was used for all species. Analysis was conducted in R. Codes to pull datasets, run models, and produce the table output can be found at https://github.com/bmahardja/flow-fish-relationship.

J.6.7.3 Results

Fit based on adjusted R^2 values was better overall for longfin smelt relative to the other two species (Table J-4). The covariate that resulted in the highest R^2 for each species were as follows: X2 for longfin smelt, unimpaired runoff for striped bass, Delta inflow for splittail. The best fit model for striped bass still had relatively poor R^2, consistent with findings of Tamburello et al. (2019) that the relationship has deteriorated over the years.

Table J-4. R^2 Value Output for Each Ordinary Least Squares Model Sorted by Flow Metric and Fish Species

Species	**X2**	**Delta Outflow**	**Delta Inflow**	**Unimpaired Runoff**
Longfin smelt	0.67	0.64	0.64	0.65
Striped bass	0.17	0.11	0.06	0.24
Splittail	0.23	0.28	0.29	0.28

Results from this analysis are generally aligned with our general understanding of the biology of these species. Striped bass are distributed throughout the Central Valley and spawn in tributaries. Although longfin smelt abundance is highly correlated to all variables, the slightly stronger fit with X2 may be a consequence of longfin smelt being distributed downstream of the confluence for most of their life cycle. Note, however, that other modeling approaches have found unimpaired runoff to have a higher correlation with longfin smelt population dynamics than Delta outflow (Maunder et al. 2015). Indices of parental stock size have also been shown to have strong correlation with longfin smelt abundance indices, and the intercept of flow-abundance relationships has shifted downward over time (Nobriga and Rosenfield 2016). Meanwhile, splittail exhibited good fit with inflow, which is likely related to their reliance on floodplain habitat (located mostly upstream of the export facilities) for spawning (Kimmerer 2002)

J.6.8 Zooplankton-Delta Outflow Analysis

This section will summarize results from Attachment J.3, *Zooplankton-Delta Outflow Analysis*. This line of evidence was not used in the Initial Alternatives Report. Results for the Environmental Impact Statement will provide an evaluation of potential changes to the food web for the Proposed Action and each of the alternatives binned by water year.

J.6.8.1 Winter

- **Driver of Variation:** The main driver of variation in the model was outflow; while the mechanism has not been definitively established, increased outflow may increase subsidies of zooplankton prey from higher abundance freshwater regions into the low-salinity zone.
- **Calibration and Calibration Period:** The analysis used historical catch of Delta smelt and longfin smelt zooplankton prey from 2000–2021 and historical outflow records to develop a regression relationship between zooplankton prey and outflow which was then applied to CalSim 3 modeled data.
- **Uncertainties:** Relatively low R^2 values for significant relationships between zooplankton taxa and outflow suggest there are other factors that affect zooplankton CPUE besides outflow.
    - Historically, relationships between outflow and zooplankton abundance have changed over time and seasons, either becoming significant or insignificant (Kimmerer 2002). Zooplankton also exhibits high variability over space and time which may limit statistical power to detect changes in abundance due to flow alterations (Brandon et al. 2022).
    - Generally, there is strong overlap between the different alternatives (see Attachment J.3, Figure J.3-1 through Figure J.3-27) making it difficult to distinguish between any statistical or ecological differences.
- **Performance Measures:** *Daphnia*, Decapod larvae, *E. affinis* (copepod) adults, other calanoid copepod adults (including *Acartia* spp., unidentified calanoids, *Sinocalanus doerrii*, *Tortanus* spp., and Diaptomidae), and other calanoid copepod copepodites (including *Acartia* spp., *Acartiella* spp., unidentified calanoids, *E. affinis*, *Sinocalanus doerrii*, *Tortanus* spp., and Diaptomidae) (Attachment J.3, Table J.3-1) had a significant, positive relationship with outflow. Results for Decapod larvae were not presented because changes to CPUE were negligible (values were zero after rounding to the nearest whole integer).
    - In the winter, across all significant zooplankton taxa, CPUE was highest for the wet water year types, due to higher outflow. CPUE was the lowest for the critical water year type which had the lowest outflow.
    - Across all water year types, for all significant zooplankton taxa, Alternative 3 had the highest CPUE, and outflow compared to other scenarios and the No Action Alternative.

  - Compared to the No Action Alternative, increases ranged from 4% for *Daphnia* during the wet water year type to 50% for Other calanoid copepod adults for the critical water year type.
- Across all water year types, for all significant zooplankton taxa, Alternative 1 had the lowest CPUE and outflow.
  - Compared to the No Action Alternative, decreases ranged from 1% during the wet water years for *E. affinis* adults to 33% during the dry water years for other calanoid copepod adults.
- The CPUE and outflow of the different phases of Alternative 2 and Alternative 4 were relatively similar to the No Action Alternative. Differences ranged from 0%–6% (except for *Daphnia*, which showed a 20% increase, but this was only an increase of 1 CPUE).

Table J-5. Mean Catch per Unit Effort for *Daphnia* Adults in Winter by Modeled Scenario and Water Year Type

Water Year Type	**NAA**	**Alt1**	**Alt2 wTUCP woVA**	**Alt2 woTUCP woVA**	**Alt2 woTUCP DeltaVA**	**Alt2 woTUCP AllVA**	**Alt3**	**Alt4**
Wet	25	25 (0%)	25 (0%)	25 (0%)	25 (0%)	25 (0%)	26 (4%)	25 (0%)
Above Normal	16	15 (-6%)	16 (0%)	16 (0%)	16 (0%)	16 (0%)	17 (6%)	16 (0%)
Below Normal	9	9 (0%)	9 (0%)	9 (0%)	9 (0%)	9 (0%)	11 (22%)	9 (0%)
Dry	7	6 (-14%)	7 (0%)	7 (0%)	7 (0%)	7 (0%)	8 (14%)	7 (0%)
Critical	5	5 (0%)	6 (20%)	6 (20%)	5 (0%)	5 (0%)	6 (20%)	5 (0%)

Values are rounded to the nearest integer.

Table J-6. Mean Catch per Unit Effort for *Daphnia* Adults in Winter by Modeled Scenario and Water Year Type

Water Year Type	**EXP1**	**EXP3**	**NAA**	**Alt2 wTUCP woVA**	**Alt2 woTUCP woVA**	**Alt2 woTUCP DeltaVA**	**Alt2 woTUCP AllVA**
Wet	29	29	25	25	25	25	25
Above Normal	21	20	16	16	16	16	16
Below Normal	13	13	9	9	9	9	9
Dry	11	10	7	7	7	7	7
Critical	8	7	5	6	6	5	5

Values are rounded to the nearest integer.

Table J-7. Mean Catch per Unit Effort for *Eurytemora affinis* (Copepod) Adults in Winter by Modeled Scenario and Water Year Type

Water Year Type	NAA	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4
Wet	161	159 (-1%)	162 (1%)	162 (1%)	162 (1%)	162 (1%)	169 (5%)	162 (1%)
Above Normal	107	103 (-4%)	107 (0%)	107 (0%)	107 (0%)	108 (1%)	115 (7%)	107 (0%)
Below Normal	67	62 (-7%)	68 (1%)	68 (1%)	67 (0%)	68 (1%)	75 (12%)	68 (1%)
Dry	54	49 (-9%)	55 (2%)	55 (2%)	55 (2%)	55 (2%)	61 (13%)	54 (0%)
Critical	43	38 (-12%)	43 (0%)	44 (2%)	43 (0%)	43 (0%)	47 (9%)	43 (0%)

Values are rounded to the nearest integer.

Table J-8. Mean Catch per Unit Effort for *Eurytemora affinis* (Copepod) Adults in Winter by Modeled Scenario and Water Year Type

Water Year Type	EXP1	EXP3	NAA	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA
Wet	184	187	161	162	162	162	162
Above Normal	135	133	107	107	107	107	108
Below Normal	91	92	67	68	68	67	68
Dry	78	74	54	55	55	55	55
Critical	59	55	43	43	44	43	43

Values are rounded to the nearest integer.

Table J-9. Mean Catch per Unit Effort for Other Calanoid Copepod Adults in Winter by Modeled Scenario and Water Year Type

Water Year Type	NAA	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4
Wet	210	204 (-3%)	212 (1%)	212 (1%)	211 (0%)	211 (0%)	236 (12%)	212 (1%)
Above Normal	69	63 (-9%)	69 (0%)	69 (0%)	69 (0%)	70 (1%)	80 (16%)	69 (0%)
Below Normal	18	15 (-17%)	19 (6%)	19 (6%)	18 (0%)	19 (6%)	24 (33%)	19 (6%)
Dry	9	6 (-33%)	9 (0%)	9 (0%)	9 (0%)	9 (0%)	12 (33%)	9 (0%)
Critical	4	3 (-25%)	4 (0%)	4 (0%)	4 (0%)	4 (0%)	6 (50%)	4 (0%)

Values are rounded to the nearest integer.

Table J-10. Mean Catch per Unit Effort for Other Calanoid Copepod Adults in Winter by Modeled Scenario and Water Year Type

Water Year Type	**EXP1**	**EXP3**	**NAA**	**Alt2 wTUCP woVA**	**Alt2 woTUCP woVA**	**Alt2 woTUCP DeltaVA**	**Alt2 woTUCP AllVA**
Wet	295	308	210	212	212	211	211
Above Normal	123	119	69	69	69	69	70
Below Normal	43	41	18	19	19	18	19
Dry	26	21	9	9	9	9	9
Critical	13	9	4	4	4	4	4

Values are rounded to the nearest integer.

Table J-11. Mean Catch per Unit Effort for Other Calanoid Copepod Copepodites in Winter by Modeled Scenario and Water Year Type

Water Year Type	**NAA**	**Alt1**	**Alt2 wTUCP woVA**	**Alt2 woTUCP woVA**	**Alt2 woTUCP DeltaVA**	**Alt2 woTUCP AllVA**	**Alt3**	**Alt4**
Wet	1708	1669 (-2%)	1717 (1%)	1718 (1%)	1712 (0%)	1713 (0%)	1834 (7%)	1720 (1%)
Above Normal	904	851 (-6%)	906 (0%)	908 (0%)	907 (0%)	911 (1%)	996 (10%)	907 (0%)
Below Normal	434	390 (-10%)	438 (1%)	441 (2%)	436 (0%)	439 (1%)	508 (17%)	441 (2%)
Dry	305	261 (-14%)	313 (3%)	313 (3%)	313 (3%)	314 (3%)	368 (21%)	307 (1%)
Critical	210	176 (-16%)	214 (2%)	216 (3%)	211 (0%)	210 (0%)	244 (16%)	211 (0%)

Values are rounded to the nearest integer.

Table J-12. Mean Catch per Unit Effort for Other Calanoid Copepod Copepodites in Winter by Modeled Scenario and Water Year Type

Water Year Type	**EXP1**	**EXP3**	**NAA**	**Alt2 wTUCP woVA**	**Alt2 woTUCP woVA**	**Alt2 woTUCP DeltaVA**	**Alt2 woTUCP AllVA**
Wet	2087	2141	1708	1717	1718	1712	1713
Above Normal	1280	1249	904	906	908	907	911
Below Normal	700	698	434	438	441	436	439
Dry	539	493	305	313	313	313	314
Critical	353	312	210	214	216	211	210

Values are rounded to the nearest integer.

J.6.8.2 Spring

- **Driver of Variation:** The main driver of variation in the model was outflow; while the mechanism has not been definitively established, increased outflow may increase subsidies of zooplankton prey from higher abundance freshwater regions into the low-salinity zone.
- **Calibration and Calibration Period:** The analysis used historical catch of Delta smelt and longfin smelt zooplankton prey from 2000-2021 and historical outflow records to develop a regression relationship between zooplankton prey and outflow which was then applied to CalSim 3 modeled data.
- **Uncertainties:** Relatively low R^2 values for significant relationships between zooplankton taxa and outflow suggest there are other factors that affect zooplankton CPUE besides outflow.
    - Historically, relationships between outflow and zooplankton abundance have changed over time and seasons, either becoming significant or insignificant (Kimmerer 2002). Zooplankton also exhibit high variability over space and time which may limit statistical power to detect changes in abundance due to flow alterations (Brandon et al. 2022).
    - Generally, there is strong overlap between the different alternatives (see Attachment J.3, Figure J.3-1 through Figure J.3-27) making it difficult to distinguish between any statistical or ecological differences.
- **Performance Measures:** Cladocerans (except Daphnia), *E. affinis* (copepod) adults, Harpacticoid copepods, Other calanoid copepod adults (including *Acartia* spp., unidentified calanoids, *Sinocalanus doerrii*, *Tortanus* spp., and Diaptomidae), and Other calanoid copepod copepodites (including *Acartia* spp., *Acartiella* spp., unidentified calanoids, *E. affinis*, *Sinocalanus doerrii*, *Tortanus* spp., and Diaptomidae) (Attachment J.3, Table J.3-2) had a significant, positive relationship with outflow.
    - In the spring, across all significant zooplankton taxa, CPUE was highest for the wet water year type, due to higher outflow. CPUE was the lowest for the critical water year type which also had the lowest outflow.
    - Across all water year types, for all significant zooplankton taxa, Alternative 3 had the highest CPUE, and outflow compared to other scenarios and the No Action Alternative.
        - Compared to the No Action Alternative, increases ranged from 6% for other calanoid copepodites during the wet water year type to 20% for Cladocerans (except *Daphnia*) for the critical water year type.

- Across all water year types, for all significant zooplankton taxa, Alternative 1 had the lowest CPUE and outflow, except during the critical water year type.
    - Compared to the No Action Alternative, decreases ranged from 1% during the wet water years for Cladocerans (except *Daphnia*) to 8% during the above normal water years for Cladocearns (except *Daphnia*).
    - During the critical water year type, Alternative 2 Without TUCP Without VA and Alternative 4 were the same or only marginally better (1% increase) than the No Action Alternative for all significant zooplankton taxa.

Table J-13. Mean Catch per Unit Effort for Cladocerans (except *Daphnia*) in Spring by Modeled Scenario and Water Year Type

Water Year Type	NAA	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4
Wet	69	68 (-1%)	68 (-1%)	68 (-1%)	68 (-1%)	69 (0%)	76 (10%)	68 (-1%)
Above Normal	48	44 (-8%)	46 (-4%)	46 (-4%)	47 (-2%)	48 (0%)	54 (12%)	46 (-4%)
Below Normal	32	30 (-6%)	31 (-3%)	31 (-3%)	32 (0%)	34 (6%)	36 (12%)	31 (-3%)
Dry	25	24 (-4%)	25 (0%)	25 (0%)	26 (4%)	27 (8%)	29 (16%)	25 (0%)
Critical	15	17 (13%)	17 (13%)	15 (0%)	17 (13%)	18 (20%)	18 (20%)	15 (0%)

Percentage values in parentheses indicate the difference between the No Action Alternative and each alternative. Values and percent difference are rounded to the nearest integer.

Table J-14. Mean Catch per Unit Effort for Cladocerans (except *Daphnia*) in Spring by Modeled Scenario and Water Year Type

Water Year Type	EXP1	EXP3	NAA	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA
Wet	88	78	69	68	68	68	69
Above Normal	65	54	48	46	46	47	48
Below Normal	47	38	32	31	31	32	34
Dry	38	30	25	25	25	26	27
Critical	22	19	15	17	15	17	18

Values are rounded to the nearest integer.

Table J-15. Mean Catch per Unit Effort for *Eurytemora affinis* Adults in Spring by Modeled Scenario and Water Year Type

Water Year Type	**NAA**	**Alt1**	**Alt2 wTUCP woVA**	**Alt2 woTUCP woVA**	**Alt2 woTUCP DeltaVA**	**Alt2 woTUCP AllVA**	**Alt3**	**Alt4**
Wet	404	396 (-2%)	399 (-1%)	399 (-1%)	400 (-1%)	401 (-1%)	432 (7%)	398 (-1%)
Above Normal	312	297 (-5%)	304 (-3%)	306 (-2%)	311 (0%)	316 (1%)	340 (9%)	305 (-2%)
Below Normal	234	223 (-5%)	229 (-2%)	230 (-2%)	235 (0%)	243 (4%)	258 (10%)	229 (-2%)
Dry	200	192 (-4%)	198 (-1%)	198 (-1%)	202 (1%)	209 (4%)	218 (9%)	198 (-1%)
Critical	141	150 (6%)	153 (9%)	141 (0%)	153 (9%)	157 (11%)	158 (12%)	142 (1%)

Percentage values in parentheses indicate the difference between the No Action Alternative and each alternative. Values and percent difference are rounded to the nearest integer.

Table J-16. Mean Catch per Unit Effort for *Eurytemora affinis* Adults in Spring by Modeled Scenario and Water Year Type

Water Year Type	**EXP1**	**EXP3**	**NAA**	**Alt2 wTUCP woVA**	**Alt2 woTUCP woVA**	**Alt2 woTUCP DeltaVA**	**Alt2 woTUCP AllVA**
Wet	480	438	404	399	399	400	401
Above Normal	388	343	312	304	306	311	316
Below Normal	307	264	234	229	230	235	243
Dry	264	226	200	198	198	202	209
Critical	180	163	141	153	141	153	157

Values and percent difference are rounded to the nearest integer.

Table J-17. Mean Catch per Unit Effort for Harpacticoids in Spring by Modeled Scenario and Water Year Type

Water Year Type	**NAA**	**Alt1**	**Alt2 wTUCP woVA**	**Alt2 woTUCP woVA**	**Alt2 woTUCP DeltaVA**	**Alt2 woTUCP AllVA**	**Alt3**	**Alt4**
Wet	690	678 (-2%)	682 (-1%)	682 (-1%)	684 (-1%)	685 (-1%)	736 (7%)	681 (-1%)
Above Normal	541	517 (-4%)	528 (-2%)	531 (-2%)	539 (0%)	548 (1%)	587 (9%)	531 (-2%)
Below Normal	412	393 (-5%)	404 (-2%)	405 (-2%)	414 (0%)	428 (4%)	452 (10%)	404 (-2%)
Dry	355	342 (-4%)	352 (-1%)	352 (-1%)	359 (1%)	370 (4%)	385 (8%)	352 (-1%)
Critical	255	270 (6%)	276 (8%)	256 (0%)	276 (8%)	282 (11%)	284 (11%)	256 (0%)

Percentage values in parentheses indicate the difference between the No Action Alternative and each alternative. Values and percent difference are rounded to the nearest integer.

Table J-18. Mean Catch per Unit Effort for Harpacticoids in Spring by Modeled Scenario and Water Year Type

Water Year Type	EXP1	EXP3	NAA	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA
Wet	813	746	690	682	682	684	685
Above Normal	666	592	541	528	531	539	548
Below Normal	533	462	412	404	405	414	428
Dry	463	399	355	352	352	359	370
Critical	321	292	255	276	256	276	282

Values are rounded to the nearest integer.

Table J-19. Mean Catch per Unit Effort for Other Calanoid Copepod Adults in Spring by Modeled Scenario and Water Year Type

Water Year Type	NAA	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4
Wet	306	300 (-2%)	302 (-1%)	302 (-1%)	303 (-1%)	304 (-1%)	333 (9%)	301 (-2%)
Above Normal	219	206 (-6%)	212 (-3%)	214 (-2%)	218 (0%)	223 (2%)	244 (11%)	213 (-3%)
Below Normal	152	143 (-6%)	148 (-3%)	149 (-2%)	153 (1%)	160 (5%)	172 (13%)	148 (-3%)
Dry	124	118 (-5%)	123 (-1%)	123 (-1%)	126 (2%)	131 (6%)	138 (11%)	123 (-1%)
Critical	80	86 (8%)	89 (11%)	80 (0%)	89 (11%)	91 (14%)	92 (15%)	80 (0%)

Percentage values in parentheses indicate the difference between the No Action Alternative and each alternative. Values and percent difference are rounded to the nearest integer.

Table J-20. Mean Catch per Unit Effort for Other Calanoid Copepod Adults in Spring by Modeled Scenario and Water Year Type

Water Year Type	EXP1	EXP3	NAA	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA
Wet	380	340	306	302	302	303	304
Above Normal	289	247	219	212	214	218	223
Below Normal	216	178	152	148	149	153	160
Dry	178	146	124	123	123	126	131
Critical	109	96	80	89	80	89	91

Values are rounded to the nearest integer.

Table J-21. Mean Catch per Unit Effort for Other Calanoid Copepod Copepodites in Spring by Modeled Scenario and Water Year Type

Water Year Type	NAA	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4
Wet	1653	1626 (-2%)	1635 (-1%)	1635 (-1%)	1641 (-1%)	1643 (-1%)	1757 (6%)	1633 (-1%)
Above Normal	1319	1264 (-4%)	1291 (-2%)	1297 (-2%)	1315 (0%)	1336 (1%)	1423 (8%)	1295 (-2%)
Below Normal	1023	978 (-4%)	1005 (-2%)	1005 (-2%)	1027 (0%)	1059 (4%)	1116 (9%)	1004 (-2%)
Dry	890	860 (-3%)	883 (-1%)	883 (-1%)	900 (1%)	925 (4%)	960 (8%)	882 (-1%)
Critical	653	690 (6%)	704 (8%)	656 (0%)	704 (8%)	719 (10%)	723 (11%)	657 (1%)

Percentage values in parentheses indicate the difference between the No Action Alternative and each alternative. Values and percent difference are rounded to the nearest integer.

Table J-22. Mean Catch per Unit Effort for Other Calanoid Copepod Copepodites in Spring by Modeled Scenario and Water Year Type

Water Year Type	EXP1	EXP3	NAA	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA
Wet	1930	1780	1653	1635	1635	1641	1643
Above Normal	1602	1434	1319	1291	1297	1315	1336
Below Normal	1301	1138	1023	1005	1005	1027	1059
Dry	1139	991	890	883	883	900	925
Critical	808	742	653	704	656	704	719

Values are rounded to the nearest integer.

J.6.8.3 Summer

- **Driver of Variation:** The main driver of variation in the model was outflow; while the mechanism has not been definitively established, increased outflow may increase subsidies of zooplankton prey from higher abundance freshwater regions into the low-salinity zone.
- **Calibration and Calibration Period:** The analysis used historical catch of Delta smelt and longfin smelt zooplankton prey from 2000–2021 and historical outflow records to develop a regression relationship between zooplankton prey and outflow which was then applied to CalSim3 modeled data.

- **Uncertainties:** While some studies have shown that higher abundances of certain species of zooplankton during summer with higher outflow (Kimmerer et al. 2018) or through managed flow pulses (Frantzich et al. 2021, though this action saw benefits further upstream in freshwater regions), others did not find substantial effects on zooplankton prey from flow pulses (Sommer et al. 2020) or with increased outflow (Kimmerer 2002).
    - Evaluating any possible benefits of increased outflow and flow pulses during summer may be difficult given sampling frequency and the effect size of increases to zooplankton abundances (Brandon et al. 2021).
- **Performance Measures:** There were no zooplankton taxa that had a statistically significant relationship with outflow in the low salinity zone during the summer (Attachment J.3, Table J.3-3).

J.6.8.4 Fall

- **Driver of Variation:** The main driver of variation in the model was outflow; while the mechanism has not been definitively established, increased outflow may increase subsidies of zooplankton prey from higher abundance freshwater regions into the low-salinity zone.
- **Calibration and Calibration Period:** The analysis used historical catch of Delta smelt and longfin smelt zooplankton prey from 2000–2021 and historical outflow records to develop a regression relationship between zooplankton prey and outflow which was then applied to CalSim3 modeled data.
- **Uncertainties:** Relatively low R^2 values for significant relationships between zooplankton taxa and outflow suggest there may be other factors that contribute as well too.
    - Historically, relationships between outflow and zooplankton abundance have changed over time and seasons, either becoming significant or insignificant (Kimmerer 2002). Zooplankton also exhibit high variability over space and time which may limit statistical power to detect changes in abundance due to flow alterations (Brandon et al. 2022).
    - Generally, there is strong overlap between the different alternatives (see Attachment J.3, Figure J.3-1 through Figure J.3-27) making it difficult to distinguish between any statistical or ecological differences.
- **Performance Measures:** In the fall, *E. affinis* adults and mysids (Attachment J.3, Table J.3-4) had a significant, positive relationship with outflow.
    - Changes in CPUE for *E. affinis* are likely negligible across all scenarios and water year types (changes were 1–2 CPUE higher than the No Action Alternative at most for scenarios Alternative 1 and Alternative 3, there were no changes for all other scenarios).

- For mysids, when compared to the No Action Alternative, Alternative 3 showed the largest increases in CPUE, except for the critical water year type, because Alternative 3 had the highest outflow compared to the No Action Alternative.
    - Alternative 1 showed the largest decreases (42% during the above normal water year type) for the wet, above normal, and below normal water year type, when the outflow was lower than the No Action Alternative.

Table J-23. Mean Catch per Unit Effort for *Eurytemora affinis* Adults in Fall by Modeled Scenario and Water Year Type

Water Year Type	NAA	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4
Wet	3	2 (-33%)	3 (0%)	3 (0%)	3 (0%)	3 (0%)	4 (33%)	3 (0%)
Above Normal	3	1 (-67%)	3 (0%)	3 (0%)	3 (0%)	3 (0%)	3 (0%)	3 (0%)
Below Normal	1	1 (0%)	1 (0%)	1 (0%)	1 (0%)	1 (0%)	1 (0%)	1 (0%)
Dry	2	1 (-50%)	2 (0%)	2 (0%)	2 (0%)	2 (0%)	2 (0%)	2 (0%)
Critical	1	1 (0%)	1 (0%)	1 (0%)	1 (0%)	1 (0%)	1 (0%)	1 (0%)

Percentage values in parentheses indicate the difference between the No Action Alternative and each alternative. Values and percent difference are rounded to the nearest integer.

Table J-24. Mean Catch per Unit Effort for *Eurytemora affinis* Adults in Fall by Modeled Scenario and Water Year Type

Water Year Type	EXP1	EXP3	NAA	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA
Wet	4	5	3	3	3	3	3
Above Normal	3	4	3	3	3	3	3
Below Normal	2	3	1	1	1	1	1
Dry	3	3	2	2	2	2	2
Critical	0	2	1	1	1	1	1

Values are rounded to the nearest integer.

Table J-25. Mean Catch per Unit Effort for Mysids in Fall by Modeled Scenario and Water Year Type

Water Year Type	NAA	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4
Wet	15	11 (-27%)	15 (0%)	15 (0%)	15 (0%)	15 (0%)	18 (20%)	15 (0%)
Above Normal	12	7 (-42%)	13 (8%)	13 (8%)	13 (8%)	13 (8%)	15 (25%)	13 (8%)
Below Normal	6	5 (-17%)	6 (0%)	6 (0%)	6 (0%)	6 (0%)	7 (17%)	6 (0%)
Dry	7	7 (0%)	7 (0%)	7 (0%)	7 (0%)	8 (14%)	8 (14%)	7 (0%)
Critical	4	4 (0%)	4 (0%)	4 (0%)	4 (0%)	4 (0%)	4 (0%)	4 (0%)

Percentage values in parentheses indicate the difference between the No Action Alternative and each alternative. Values and percent difference are rounded to the nearest integer.

Table J-26. Mean Catch per Unit Effort for Mysids in Fall by Modeled Scenario and Water Year Type

Water Year Type	EXP1	EXP3	NAA	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA
Wet	19	22	15	15	15	15	15
Above Normal	15	16	12	13	13	13	13
Below Normal	11	14	6	6	6	6	6
Dry	13	15	7	7	7	7	8
Critical	3	8	4	4	4	4	4

Values are rounded to the nearest integer.

J.6.9 Delta Outflow vs Sturgeon Year Class Index

This section will summarize results from Attachment J.2, *Sturgeon Year Class Index and Delta Outflow*. This line of evidence was not used in the Initial Alternatives Report. Results will provide estimates of white sturgeon year class index based on its relationship to spring outflow. White sturgeon year class index can be a surrogate for outflow effects on green sturgeon year class strength, because a similar positive correlation between annual outflow and green sturgeon larval and juvenile abundance has been seen (Heublein et al 2017; Beccio pers comm. on August 12, 2021) but not quantified. These results will be presented for the Proposed Action and each of the alternatives binned by water year.

J.6.10 Alternative 3 Ecosystem Thresholds

This section will summarize results from the Alternative 3 ecosystem thresholds line of evidence. This line of evidence was not used in the Initial Alternatives Report. NEPA alternatives proposed for the long-term operations of the CVP and SWP have different types of ecosystem thresholds for spring Delta outflow. The ecosystem threshold analysis reviews these differing criteria. Results will provide estimates for meeting thresholds for tributary inflows, Delta outflow, and Interior Delta Flows.

These results will be presented for the Proposed Action and each of the alternatives binned by water year.

These results will be presented for the Proposed Action and each of the alternatives.

See attachment XX for detailed analysis and assumptions. The key takeaways include: <insert a few sentences>

J.6.11 XT Model

This section will summarize results from Attachment J.4, *XT Model*. This line of evidence was used in the Initial Alternatives Report. Results will provide an evaluation of potential effects of the Proposed Action and alternatives on migrating juvenile salmon in the Sacramento River.

J.6.12 Flow Threshold Salmon Survival

This section will summarize results from Attachment J.5, *Flow Threshold Salmon Survival Model*. This line of evidence was not used in the Initial Alternatives Report. Results for the Environmental Impact Statement will provide an evaluation of potential changes to juvenile Chinook salmon survival for the Proposed Action and each of the alternatives binned by water year.

- **Driver of Variation:** The main driver of variation in this model was the daily Sacramento River flow below Wilkins Slough (cfs) from March 15th to June 15th as modelled by CalSim 3.
    - Increased outflow reduces transit times limiting exposure to predators and other hazards (Michel et al. 2021; Notch et al. 2020).
    - Higher flows can also increase turbidity, providing cover for juveniles, and lower water temperatures (Lehman et al. 2017; Marine and Cech 2004; Gregory and Levings 1998).
- **Calibration and Calibration Period:** The analysis used historical Red Bluff Diversion Dam passage estimates for all runs of juvenile Chinook salmon from January 1st to July 1st from 2005–2022. This data was combined with the USRDOM modeled daily median flow from Sacramento River flow below Wilkins Slough (cfs) for each alternative to calculate a mean seasonal survival rate from March 15th to June 15th based on flow thresholds established by Michel et al. (2021).

- **Uncertainties:** The thresholds established by Michel et al. (2021) are described by a step function with three flow thresholds. In the natural world, rather than a rigid survival threshold there is more likely a steep gradient in survival rates around the flow thresholds.
- **Performance Measures:** Average annual mean survival probability was highest during the wet water year type across all alternatives and decreased as the water year type became drier. Average annual mean survival probability was lowest during the critical water years across all alternatives. Flow, which was the driver of variation, was highest during the wet water year type and lowest during the critical water year type.
    - Alternative 3 had the highest flow during the wet water year type and the highest mean survival (28.91%). Alternative 2 With TUCP Without VA had the lowest flow and lowest mean survival during the critical water years (6.98%). The mean survival was only slightly lower than Alternative 3 and Alternative 4 (7.32% and 7% respectively) during the critical water year type.
    - During wet and above normal water years, Alternative 3 had the highest flow and mean survival (28.91% and 24.57% respectively), while for the below normal, dry and critical water years, Alternative 2 Without TUCP Systemwide VA, Alternative 4 and Alternative 2 Without TUCP Without VA respectively (17.65%, 14.9% and 11.14%) had the highest flow and mean survival.

Table J-27. Average Mean Annual Seasonal Survival Percentage for Different Modeled Scenarios by Water Year Type

Water Year Type	NAA	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4
Wet	24.91	26.19 (5.14%)	26.11 (4.82%)	26.12 (4.86%)	25.87 (3.85%)	26.05 (4.58%)	28.91 (16.06%)	26.13 (4.9%)
Above Normal	19.83	22.05 (11.2%)	20.92 (5.5%)	20.95 (5.65%)	20.51 (3.43%)	22.68 (14.37%)	24.57 (23.9%)	20.92 (5.5%)
Below Normal	15.2	17.16 (12.89%)	16.61 (9.28%)	16.42 (8.03%)	15.14 (-0.39%)	17.65 (16.12%)	14.98 (-1.45%)	16.34 (7.5%)
Dry	12.08	14.45 (19.62%)	14.53 (20.28%)	14.42 (19.37%)	11.72 (-2.98%)	12.24 (1.32%)	11.76 (-2.65%)	14.9 (23.34%)
Critical	5.87	9.64 (64.22%)	6.98 (18.91%)	11.14 (89.78%)	9.97 (69.85%)	10.09 (71.89%)	7.32 (24.7%)	7 (19.25%)

Percent difference from the No Action Alternative is in parentheses.

Table J-28. Average Mean Annual Seasonal Survival Percent for Different Modeled Scenarios by Water Year Type

Water Year Type	EXP1	EXP3	NAA	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA
Wet	36.16	24.04	24.91	26.11	26.12	25.87	26.05
Above Normal	28.71	17.78	19.83	20.92	20.95	20.51	22.68
Below Normal	20.33	12.47	15.2	16.61	16.42	15.14	17.65
Dry	15.76	9.94	12.08	14.53	14.42	11.72	12.24
Critical	8.8	5.71	5.87	6.98	11.14	9.97	10.09

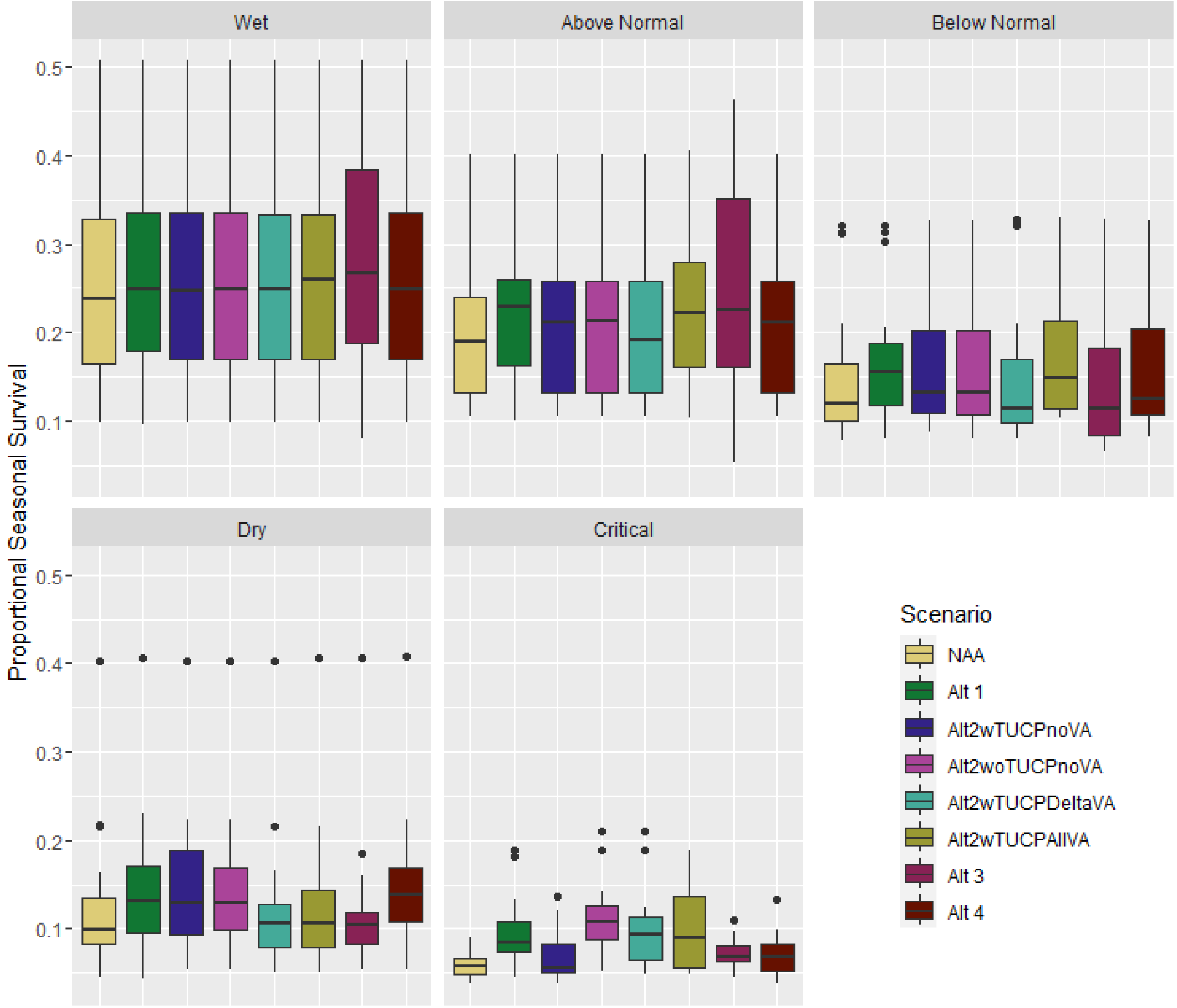


Figure J-33. Boxplots of Mean Annual Seasonal March 15 through June 15 Survival for Different Modeled Scenarios by Water Year Type

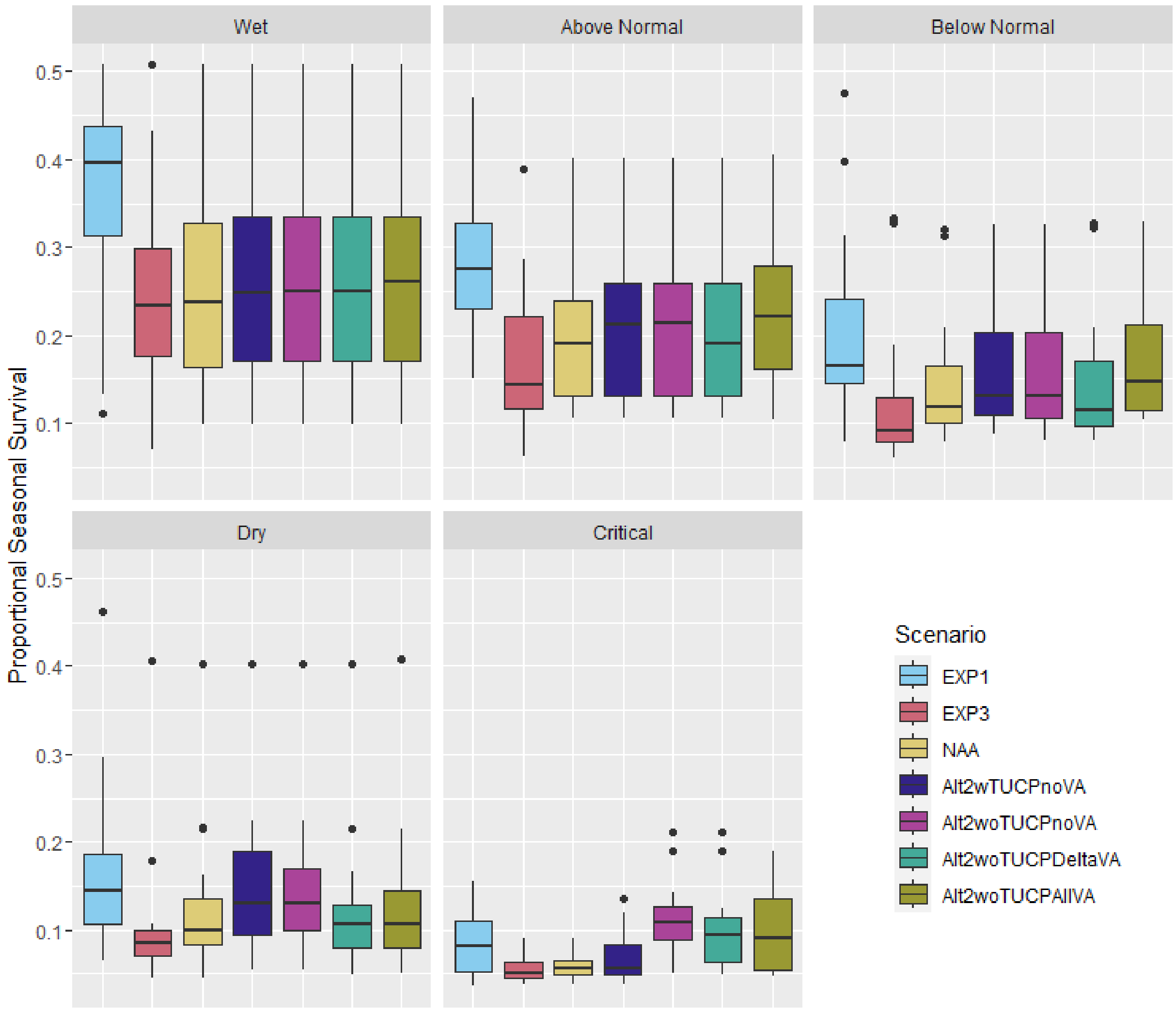


Figure J-34. Boxplots of Mean Annual Seasonal March 15 through June 15 Survival for Different Modeled Scenarios by Water Year Type

J.6.13 STARS

This section will summarize results from the STARS model line of evidence. This line of evidence was used in the Initial Alternative Report. To assess potential effects of alternatives to migrating juvenile salmon, the STARS model was used in the Initial Alternatives Report to estimate salmonid migration parameters (Travel time, survival, entrainment probabilities).

J.7 Uncertainty

To inform reliability and value of information regarding spring Delta outflow special studies include the Shasta Spring Pulse Flows studies and Spring Outflow special studies. These are described in the Proposed Action 9.8, *Special Studies*.

J.8 References

J.8.1 Written References

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J.8.2 Personal Communications

Beccio, Marc. Environmental Scientist. California Department of Fish and Wildlife, Rancho Cordova, CA. August 12, 2021. Email with unpublished relative abundance of juvenile Green Sturgeon in the San Francisco Bay Delta Estuary, provided to Monique Briard and Sophie Unger, ICF, Sacramento, CA.