Delta Smelt Summer-Fall Habitat Seasonal Report for WY 2024

Central Valley Project and State Water Project

California-Great Basin Region 10

U.S. Department of the Interior and State of California **July 2026**

Mission Statements

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The mission of the California Department of Water Resources is to sustainably manage the water resources of California, in cooperation with other agencies, to benefit the state's people and protect, restore, and enhance the natural and human environments.

Delta Smelt Summer-Fall Habitat Seasonal Report for WY 2024

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California-Great Basin Region 10

Prepared by

California Department of Water Resources
United States Bureau of Reclamation

In coordination with the California's Department of Fish and Wildlife, United States Fish and Wildlife Service, National Marine Fisheries Service and Delta Coordination Group

Cover Photo: California Department of Water Resources

Contents

List of Tables

List of Figures

List of Abbreviations and Acronyms

Abbreviation	**Definition**
SWP	State Water Project
BPUE	Biomass per unit effort
CDFW	California Department of Fish and Wildlife
CVP	Central Valley Project
DCG	Delta Coordination Group
DOP	Directed Outflow Project
DWR	Department of Water Resources
EDSM	Enhanced Delta Smelt Monitoring Program
EMP	Environmental Monitoring Program
FMWT	Fall Midwater Trawl Survey
FCCL	Fish Conservation and Culture Laboratory
FNU	Formazin nephelometric units
FTU	Formazin Turbidity Units
GRI	Growth model index
GRP	Growth rate potential
IEP	Interagency Ecological Program
LSZ	Low Salinity Zone (<6 PSU)
LTO	Long-term Operations of the CVP and SWP
NDFS	North Delta Food Subsidies/Colusa Basin Drain Study
NEPA	National Environmental Protection Act
NMFS	National Marine Fisheries Service
Reclamation	United States Bureau of Reclamation
ROD	Record of Decision
SDWSC	Sacramento River Deepwater Ship Channel Food Study
SWP	State Water Project
SCHISM	Semi-Implicit Cross-scale Hydroscience Integrated System Model
State Water Board	State Water Resources Control Board
SDM	Structured decision-making
SMSCG	Suisun Marsh Salinity Control Gates
STN	Summer Townet Survey
SFHA	Summer-Fall Habitat Action

TAF	Thousand Acre-Feet
D-1641	Water Rights Decision 1641
WY	Water Year
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
X2	Location of the 2 PSU isohaline in kilometers from the Golden Gate

Executive Summary

The Delta Smelt Summer and Fall Habitat Action (SFHA) includes operational actions aimed to improve habitat and food for the species during June-October when the population generally experiences low survival. Water year (WY) 2024 was classified as Above Normal, and both Suisun Marsh Salinity Control Gates (SMSCG) actions and Fall X2 action (in September only) were implemented. This followed the action of WY 2023, and no-action years of 2020-2022. The SMSCG were operated from July 1 to August 30, 2024, and again from September 6 through September 30, 2024. While not officially part of the action, the gates were also operated October 28 to November 4, 2024 to prepare for a scheduled maintenance closure. Water was managed to target a monthly average X2 location of 80 km for the month of September, and an average X2 of 80.5 km was achieved.

The primary hypotheses of the SFHA are that Delta Smelt growth and survival will increase through increased habitat quality and increased copepod biomass in Suisun Bay by decreasing X2, and in Suisun Marsh and Grizzly Bay by SMSCG operations. Habitat quality includes abiotic factors (salinity, turbidity, and temperature) and biotic factors (food availability) and habitat quantity includes the acreage of suitable low salinity habitat. Suitable Delta Smelt thresholds for the abiotic factors are temperature ≤22°C (considered optimal for smelt growth, although smelt can survive at higher temperatures), salinity <6 PSU, and turbidity ≥12 FNU.

After analyzing empirical data on habitat conditions, Delta Smelt survey detections, and an *in situ* enclosure experiment, our findings partially inform some of the SFHA hypotheses:

1. **Decreasing X2 will increase habitat quality and copepod biomass in Suisun Bay which will increase Delta Smelt growth and survival**– *Partially supported*.
    a. The number of days with salinity less than 6 PSU in Suisun Bay in 2024 was lower than previous years with X2 actions in September and October, but higher than years without actions. Temperatures in 2024 were less frequently limiting than in 2023, but were the most frequent limiting factor in smelt habitat.
    b. Modeling (with and without the action) showed an increase of LSZ area in both Suisun Marsh and Suisun Bay in August, September and October. However, much of the LSZ area in August was >22°C, indicating low potential for Delta Smelt growth.
    c. Biomass of the calanoid copepod *Pseudodiaptomus sp*. was higher in 2024 than previous non-action years, though not as high as during the wetter action year of 2023 when the X2 action was longer.
    d. One Delta Smelt was caught in Suisun Bay during the action which is not enough sample to credibly assess the impact of the action on smelt growth or survival.
2. **Operating the SMSCG will increase habitat quality and copepod biomass in Suisun Marsh which will increase Delta Smelt growth and survival** – *Partially supported.*
    a. The number of days with salinities <6 PSU in Suisun Marsh was similar to number of days in other high-flow years (2017, 2019, 2023) and the 35-day SMSCG action in 2018, though high temperatures limited total number of suitable habitat days. Temperatures were higher in Suisun Marsh than Rio Vista, similar to results in 2023.

   b. Modeling (with and without the action) showed an increase LSZ area in both Suisun Marsh and Grizzly Bay in July, August and September. However, much of the LSZ habitat in August was >22°C, indicating low potential for smelt growth.
   c. No wild Delta Smelt were caught in the marsh during the action, so we cannot credibly determine the impact of the action on smelt growth and survival. Cultured Delta Smelt in enclosures had lower growth and survival at Belden's Landing than Rio Vista, similar to results from 2023. These results challenge the hypothesis that the marsh is better smelt habitat than the river; however, results may have been due to cage effects rather than a broader indication of habitat quality.
   d. Biomass of the calanoid copepod *Pseudodiaptomus sp*. was higher in 2024 than previous non-action years, though not as high as the biomass during the wetter action year of 2023 when the X2 action was longer.
3. **Operating the SMSCG will increase Delta Smelt habitat in Grizzly Bay –** *Partially supported*.
   a. LSZ habitat in Grizzly Bay was increased by several hundred acres during the SMSCG action in July and August. During August much of the low salinity habitat was above 22°C, meaning Delta Smelt growth was most likely low if they were occupying this area, however temperatures were mostly below the lethal limit (25-26°C).

Although no food web actions were implemented in 2024, monitoring and ongoing special studies were conducted to help inform their implementation in future years. The study of managed wetlands in Suisun Marsh yielded promising initial results showing high densities of phytoplankton and zooplankton exported from managed wetlands, though most of this export occurs in winter and spring rather than summer and fall. Concentrations of zooplankton in managed wetlands in 2024 were lower than in 2023, but growth rates are not yet available to provide a mechanism for this difference. The study will continue through 2025 when we will be experimenting with a pilot study of early flood-up to try and increase food resources in fall. DWR and Reclamation, in collaboration with USGS and UC Davis are conducting a modeling exercise to determine where and when the Sacramento Deep Water Ship Channel provides good habitat for Delta Smelt. Preliminary results are expected mid-2025.

The Delta Coordination Group (DCG) evaluated a termination proposal of the North Delta Food Subsidy (NDFS) in early 2025, and the action will no longer be pursued. In 2024, the NDFS study shifted focus to summer (and not fall) following past SDM recommendations from the DCG to pivot away from fall agriculture flow pulses that result in high contaminant concentrations. Data from summer habitat and prey monitoring and Delta Smelt enclosures deployed across the Cache Slough Complex and adjacent Sacramento Deepwater Ship Channel indicate habitat quality standards cannot be met, with high temperatures exceeding Delta Smelt thresholds, contaminant exposures, and low zooplankton biomass and abundance. The weight of evidence from the 2024 summer study, and recent NDFS synthesis of a decade of monitoring, suggest that much of the existing habitat in the North Delta is unsuitable for Delta Smelt in summer. Furthermore, this unsuitability is linked to thermal and contaminant stress which cannot be remedied by food subsidy actions. Ultimately, it appears that unintended consequences of future flow pulses outweigh ecological benefits for the species.

Purpose

The following 2024 Seasonal Report for the Delta Smelt SFHA describes the operations of the Central Valley Project (CVP) and State Water Project (SWP), and Delta Smelt habitat conditions in water year (WY) 2024. This report may support adaptive management adjustments, if necessary, to future operations, including Delta Smelt SFHA plans, by documenting the ecological responses that occurred during habitat actions or in some cases the absence of an action (e.g., food actions), and comparisons to previous years where appropriate.

This document informs the Long-Term Operations of the CVP and SWP, and acts as the Delta Smelt SFHA report (Condition of Approval (COA) 9.1.3.1) outlined in the California Department of Fish and Wildlife (CDFW) ITP for the Long-Term Operation of the California SWP issued to the California Department of Water Resources (DWR). This document may inform independent reviews required by the 2020 ITP (ITP Adaptive Management Plan; Attachment 2). This document strives to provide an integrated view of the factors affecting the low salinity zone and adjacent habitats within the Sacramento-San Joaquin Delta with regard to their suitability to support Delta Smelt growth and survival. This report for WY 2024, was drafted after adoption of the new 2024 CDFW ITP, and 2024 ROD, and does not include any changes made to actions or reporting requirements detailed in 2024. However, DWR and CDFW agreed to slightly modify reporting requirements for WY 2024 given the change in reporting requirements related to the transition between the 2020 and 2024 ITP's during the drafting of this report.

Background

Delta Smelt Summer-Fall Habitat

The Delta Smelt SFHA provides for operational actions that are hypothesized to improve habitat and food availability for Delta Smelt. Operational actions include use of the SMSCG in the summer or fall months, Delta outflow augmentation, and optional food enhancement actions, including the North Delta Food Subsidies-Colusa Basin Drain Study (NDFS). Other food studies are still in development, specifically food production in managed wetlands in Suisun Marsh and use of nutrient enhancement and flow augmentation in the Sacramento Deepwater Ship Channel to increase food availability for Delta Smelt.

Most Delta Smelt complete their entire life cycle within or immediately upstream of the estuary's low salinity zone (LSZ, Merz et al. 2011). Scientific research has generally shown that lower salinity in Suisun Marsh and other areas within the Sacramento-San Joaquin Delta, either through increased outflow (Sommer and Meija 2013) or specific management actions (Sommer et al 2020), is beneficial for the Delta Smelt population due to increased distribution, foraging opportunities, and habitat complexity. The highest quality habitats in this large geographical region include areas with complex bathymetry, in deep channels close to shoals and shallows, and in proximity to extensive tidal or freshwater marshlands and other wetlands (Pg. 1 and 2, Guidance Document) (Bever et al. 2016, Hammock et al. 2019).

Abiotic habitat conditions for Delta Smelt in the San Francisco Bay-Delta are generally better in years when the low salinity zone in the summer and fall (as indexed by X2) is located further downstream (Brown et al. 2014, IEP MAST 2015). Three commonly measured water quality parameters form the underlying basis for this hypothesis: salinity, water temperature, and turbidity (Nobriga et al. 2008, Mac Nally et al. 2010, Feyrer et al. 2011, Bever et al. 2016). Consequently, abiotic habitat attributes within suitable ranges for Delta Smelt are defined in this report as low salinity conditions of 6 PSU or less, turbidity higher than 12 FNU, and water temperatures below 22°C based on temperatures at which smelt experience positive growth (see DCG Temperature Constructs 2023Sep28 Draft.pdf).

Salinity: Delta Smelt is a semi-anadromous species. The species spawns in freshwater and most juveniles migrate into the low-salinity zone (0.5-6 PSU) where they rear during the summer and fall (Hobbs et al. 2019). Delta Smelt have a physiological stress response to high salinity (Komoroske et al. 2016) and higher occurrence in low salinity habitat (Feyrer et al. 2007, Nobriga et al. 2008), so the size and location of the low salinity zone have been described as indicators of Delta Smelt habitat suitability.

Temperature: Evidence of Delta Smelt sensitivity to warm water temperature has come from both laboratory and field studies. Critical thermal maxima of juvenile Delta Smelt appear to range somewhere between 25 to 29°C in a controlled laboratory setting (Swanson et al. 2000, Komoroske et al. 2014, Davis et al. 2019; Davis et al. 2024), a temperature range that is observed in the field at times; however, recent studies suggest field-derived thermal maxima may be ~2°C lower (Davis et al. 2024). High summer temperature (means closer to 23 than 20°C) was also found to have a negative impact on juvenile Delta Smelt survival from spring to fall based on data analyses and models using field data (e.g., Mac Nally et al. 2010, Polansky et al. 2021). Moreover, occurrence of postlarval and juvenile Delta Smelt peaks near 20°C, indicating that warmer temperatures are increasingly stressful (Nobriga et al. 2008, Sommer and Mejia 2013, Komoroske et al. 2014). In this report, we use 22°C as a threshold below which Delta Smelt typically experience positive growth. Above 22°C, growth may be limited (Lewis et al. 2021) due to sublethal stress responses (Komoroske et al. 2015, Jeffries et al. 2018), behavioral changes (Davis et al. 2019), and foraging and consumption constraints (Smith and Nobriga, 2023).

Turbidity: Water clarity is also believed to be a key determinant factor in the occurrence and abundance of Delta Smelt in the field (Feyrer et al. 2007, Nobriga et al. 2008, Bever et al 2016), because it improves feeding and reduces predation (Hasenbein et al. 2016, Ferrari et al. 2014). Turbidity >10 FNU has been shown to reduce smelt physiological stress, improve energy availability, and condition, compared to lower turbidity levels in laboratory studies (Pasparakis et al. 2023).

Biotic habitat attributes such as food availability and quality are other essential components of Delta Smelt habitat. The amount of food needed is difficult to evaluate in the field because prey densities necessary to sustain growth vary as a function of physical habitat conditions (Smith and Nobriga 2023). Food may contain toxins due to harmful algal blooms (Lehman et al. 2010; Acuña et al. 2012) or chemical contaminants (Orlando et al. 2024) and access to otherwise available food may be impacted by competition between Delta Smelt and other fishes (IEP MAST 2015). However, it is well established that high densities of calanoid copepods provide the best conditions for Delta Smelt foraging (Hammock et al. 2022; Smith and Nobriga 2023) with the copepod *Pseudodiaptomus forbesi* being particularly important during the summer (Slater and Baxter 2014; Slater et al. 2019), and densities of *P. forbesi* in the low salinity zone increase with increased flow (Kimmerer et al. 2018).

Due to hypothesized benefits of habitat in Suisun Bay and Suisun Marsh, the 2020 ROD and ITP included a Delta Smelt SFHA intended to improve Delta Smelt access to zooplankton and other important physical habitat attributes, which is believed to increase the growth, survival, and recruitment of Delta Smelt (Pg. 33, ROD; Pg. 113 ITP). The SFHA investigates summer-fall habitat to better quantify and integrate information on how food, turbidity, salinity, water velocity, and water temperature interact to contribute to improved overall recruitment in response to one or more actions (Pg. 1, Guidance Document). Overall, the SFHA is intended to increase the spatial overlap of Delta Smelt habitat attributes with a focus on Suisun Marsh and to experiment with potential enhancements of prey supply in the Cache Slough Complex.

Environmental and biological goals for summer and fall (June through October) of below normal, above normal, and in wet years are (Pg. 4-72, 2019 BA):

1. Maintain low salinity habitat in Suisun Marsh and Grizzly Bay when water temperatures are suitable;
2. Manage the low salinity zone to overlap with turbid water and available food supplies; and
3. Establish contiguous fresh water- low salinity habitat from Cache Slough Complex to the Suisun Marsh (Pg. 2 and 15, Guidance Document).

Management Actions

Actions taken this year:

1. SMSCG operation from July 1-August 29 and September 6-September 30, 2024.
2. Monthly average Fall X2 targeted at 80 km in September.

Actions that may be taken in future years and studies to explore additional actions included in this report:

1. Sacramento River Deepwater Ship Channel Food Study (SDWSC)
2. Managed Wetlands

WY 2024 was an above average year, Reclamation and DWR developed an SFHA Action Plan for the WY 2024 based on recommendations by the Delta Coordination Group (DCG) (Attachment B - 2024 SFHA Action Plan - Final.pdf).

Action Plan Revisions

The 2024 Action Plan underwent two major revisions following delivery to CDFW and FWS in May. This Seasonal Report reflects the final implemented action.

1. As described in the Action Plan, the final 2024 Sacramento Valley WY designation was Above Normal and CDFW decided to implement the 100 TAF action (ITP COA 8.19) through extending daily operations of the SMSCG for an additional 60 days (or when the 100 TAF was expended) immediately following the initial 60 days of operation. However, following the completion of the Action Plan, spring conditions and additional evaluation of projected hydrologic conditions for WY 2025 were further discussed between DWR and CDFW Directors regarding the use of the additional 100 TAF block of water in the 2024 action versus deferring to summer-fall of WY 2025. On August 23, DWR and CDFW notified the DCG of the decision that the 100 TAF action would not be used and would be deferred to WY 2025 based on the probability of drier water year conditions[1]. Under the 2024 ITP, this 100 TAF block of water was integrated as part of COA 9.1.3 and is subject to reservoir spill in WY 2025 if the WY is Wet or Above Normal. If available, CDFW and DWR would plan how the 100 TAF from Oroville Reservoir would be implemented.
2. In addition to SMSCG operations, the Above Normal WY designation required DWR and Reclamation to maintain X2 at 80 km for Sept and Oct. DWR and Reclamation received letters from State Water Contractors and public water agencies in summer of 2024 to consider alternative implementation of the summer-fall action, specifically removal of the Fall X2 standard. After consideration of real-time data and recent Delta Smelt life-cycle model analysis highlighting greater benefits of flow in summer rather than fall (Polanksy et al. 2024), DWR proposed an alternative summer-fall action (with Reclamation participation). On Sept 6 DWR shared the proposed alternative action with the DCG, including reoperating the SMSCG daily through September to overlap with X2 at 80 km, with no X2 requirement during October. Daily operations of SMSCG were resumed September 6th. On September 18 DWR submitted an application for an amendment to their ITP to CDFW. On September 27 Reclamation determined the proposed alternative summer-fall action was within the range of impacts analyzed the 2019 FEIS for compliance with NEPA, and confirmed with USFWS the effects were within the range of effects of the 2019 Biological Opinion. A draft memorandum of Reclamation's conclusions were publicly shared with LTO interested parties on Sept 12. The 100 TAF

[1] The 2024 CDFW ITP provides for the one-time deployment of a 100 TAF block of water to supplement Delta Outflow in WY 2025 (2024 ITP, Condition 9.1.3.2).

block of water from Oroville Reservoir was not used for the SMSCG operations in September and was deferred to WY 2025 for CDFW and DWR to agree upon its use.

Following the action period, planned maintenance of the SMSCG occurred in November. All gates were held in the 'closed' position from November 5th to 18th, after which tidal Operations resumed per D-1641 and the Suisun Marsh Preservation Agreement on November 18, 2024.

Assumptions

The objectives and hypotheses for this action were developed from analyses contributing to the 2020 and 2024 ITP for the SWP. In those effects analyses, 80 km was identified as the minimum location for X2 where portions of Grizzly Bay would be within the LSZ, and CDFW analyzed an action that had an X2 at 80 km for each day of that period. However, the ITP condition (9.1.3) set 80 km as the average location of X2 over a 30-day period, meaning that some of this period could have been above 80 km so long as there was an equal period below 80 km. The permit analysis also analyzed 60 days of SMSCG operation continuously, whereas the permit was written with the option of non-continuous operations. Both analyses assumed that fish would move into the habitat as it is made available by the actions. This report reflects the actions as they were taken in 2024 and noted where these differed from conditions analyzed in the permit analysis.

Objectives and Hypotheses

Hypotheses:

1. Maintaining an average X2 of 80 km will increase the area of Delta Smelt habitat in Suisun Bay with appropriate temperatures, turbidity, and salinity, which will result in higher Delta Smelt growth and survival.
2. Maintaining an average X2 of 80 km will increase biomass of the calanoid copepod *Pseudodiaptomus forbesi* in the low salinity zone through increased transport from upstream, which will result in higher Delta Smelt growth and survival.
3. Operating the SMSCG during the summer and fall will increase the duration and area of Delta Smelt habitat in Suisun Marsh with appropriate temperatures, turbidity, and salinity, which will result in higher Delta Smelt growth and survival.
4. Operating the SMSCG during the summer and fall will increase biomass of the calanoid copepod *Pseudodiaptomus forbesi* in Suisun Marsh through increased transport from upstream, which will result in higher Delta Smelt growth and survival.
5. Operating the SMSCG will increase the area of appropriate Delta Smelt habitat in Grizzly Bay.

To address each of these hypotheses, we rely on three primary comparisons:

1. Inter-annual comparisons – We compare constituents during 2024 to conditions in previous years with X2 actions (2017, 2019, 2023), previous years with SMSCG actions (2018, 2023) and dry years with no action (2020-2022). The actions were not implemented in the same way in each year (Table 1), and other differences between

water years make these comparisons difficult, but historical years still provide useful context for this year's observations. A synthesis project is currently underway to provide a more in-depth analysis of summer-fall conditions from 2011-2024 and should have results by fall of 2025.

2. Regional comparisons – We expect X2 actions to improve conditions in Suisun Bay. We expect SMSCG actions to improve conditions in Suisun Marsh and potentially Grizzly Bay. Neither action will change conditions in the River.

Table 1. Historical years used for comparison to 2024, with actions taken in each year.

Year	Water Year Type	X2 Action	SMSCG Action
2017	Wet	X2 at or below 74 km for September and October	None
2018	Below Normal	None	35-day gate operation, Aug. 2 – Sept. 7
2019	Wet	X2 at or below 74 km for September and October	None
2020	Dry	None	SMSCG operation starting Sept. 1*
2021	Critical	None	SMSCG operation starting Sept. 1*
2022	Critical	None	SMSCG operation starting Sept. 1*
2023	Wet	X2 at or below 80 km for September and October	SMSCG operating Aug. 15-Oct. 17
2024	Above Normal	X2 at or below 80 km for September	SMSCG operating July1-Aug. 29 and Sept. 6-Sept. 30

*The Suisun Marsh Preservation Agreement requires SMSCG operation starting in September when the seven-day running average mean daily high tide salinity at any compliance station is 17.0 mS/cm or greater.

Delta Coordination Group

The DCG completed several activities in 2024 including updating the Monitoring and Science Plan, a third iteration of the structured decision-making (SDM) model, providing recommendations for the Action Plan (Attachment B), discussing outcomes of DWR's peer-review, and review of DWR's proposed alternative summer-fall action (as described in the 'Action Plan Revisions' section above). Within the Action Plan, the DCG collaboratively developed a simplified decision-model to evaluate different Summer-Fall operation scenarios with focus on the 100 TAF action. This included comparing SMSCG operation schedules such as daily consecutive operations versus an operation cycle with seven days of tidal operation followed by seven days with the gates held, and with and without the 100 TAF block of water for additional SMSCG operations in September. Key performance metrics evaluated were acreage/area of low salinity zone, percent increase of LSZ area, and *P. forbesi* biomass.

The DCG also participated in a series of discussions of the independent review findings. The independent review was facilitated by the Delta Stewardship Council for DWR compliance with the 2020 ITP (COA 3.13.8). Review Letters were completed and publicly shared in June 2024 (see DSC Summer-Fall Habitat Action peer-review webpage). The independent review included four panelists and focused on reviewing the current monitoring and science in place and providing guidance on a path the DCG may take for improvements to decision making, monitoring, and adaptive management of the SFHA. Collectively, the panel commended the science and decision approach the DCG has developed and implemented, while also highlighting limitations and areas that can be improved. The DCG discussed what recommendations should be adopted in WY 2025 (e.g., power analysis, value of information analysis), are already underway or done (e.g., foodweb synthesis, clam studies, improvements to bioenergetics model), warrant further consideration (e.g., eDNA, formal uncertainties in SDM model), or are not feasible or within scope of the summer-fall action or resources. Several DCG members also participated in Reclamation's National Academies of Sciences, Engineering and Mathematics (NASEM) Independent Review meetings focused on the Summer-Fall Habitat theme (NASEM CVP project webpage) in March 2024. Outcomes from this multiyear review process are forthcoming in 2025.

Action Implementation

SMSCG and X2 Implementation

The SMSCG were not operated from January 30, 2024 to July 1, 2024; two out of the three gates were held open, and one was removed with a stoplog in its place for refurbishment (note that this configuration is hydraulically equivalent to having two gates operational and one closed). SMSCG operations began on July 1st to comply with the 2024 Delta Outflow Operations Plan as required under the ITP, see Table 2 below. The SMSCG were operated from July 1 to August 30, 2024, and again from September 6 through September 30, 2024. While not officially part of the WY 2024 action, the gates were also operated October 28 to November 4, 2024 to prepare for a scheduled maintenance closure. When not operating, two out of the three gates were held open. This operational schedule maintained the daily-average salinity at Belden's Landing below 3 PSU for all of June through September, though salinity increased to 6 PSU in the latter half of October. Salinity in September of 2024 was similar to 2023, but lower than previous wet years without SMSCG actions and much lower than previous dry and critically dry years (Figure 2).

To provide a visual comparison of flow conditions in 2024 versus previous years, we have graphed daily Delta Outflow and X2 positions from DWR's Dayflow model for 2017- September 30th of 2024. Dayflow is not available for water year 2025 (including October of 2024), so we instead used daily estimates of X2 and Delta Outflow from CDEC for the last month of the reporting period. The CDEC estimates of X2 are made by interpolating between the salinity at several discrete monitoring stations in the system, with the furthest upstream station at 81 km. Therefore, this method does not provide estimates of X2 when it is greater than 81 km (Figure 1). The daily estimates from Dayflow are provided here as an indicator of habitat conditions, but are not used for compliance, which is calculated on a monthly basis.

X2 in 2024 differed from the previous wet years of 2017 and 2019 as calculated by the Dayflow model (Figure 1, Figure 3). This difference is consistent with the change in the Fall X2 requirement from 74 km to 80 km with the 2019 Biological Opinions. Published models of low salinity zone habitat area versus X2 suggest that habitat area is lower with an X2 above 81 km than below 80 (Kimmerer et al. 2013), so Figure 1 indicates lower habitat area in 2024 than 2017 and 2019, with higher habitat area in September of 2024 than October of 2024 when no X2 standard was in place. Furthermore, the average X2 during September was 80.5, with periods in September above 81 km followed by a drop in X2 to 76 km during the final week in the month in an attempt to meet the X2 standard. This means habitat in Grizzly Bay was not available during the entire X2 action period. More detailed maps of habitat availability are available in the "Results" section below (Figure 17, Figure 18).

Export rates from the SWP and CVP in 2024 were similar to or lower than previous wet years (Figure 4), but higher than most previous below normal, dry and critical years.

Table 2. 2024 Suisun Marsh Salinity Controls Gate Operations. Flashboard Status indicates if they are installed or removed. Boat Lock Status indicates if it is closed or in operation.

Date	Gate Status	Flashboard Status	Boat Lock Status	Notes
1/1/24 – 1/29/24	2 Operational 1 Closed*	Installed	Operational	Gates operated manually due to sensor malfunctions.
1/30/24 – 6/30/24	2 Open 1 Closed*	Installed	Operational	Operations suspended due to declining salinities.
7/1/24 - 8/29/24	2 Operational 1 Closed*	Installed	Operational	Operations began for Summer-Fall Action, running for 60 days.
8/30/24 – 9/5/24	2 Open 1 Closed*	Installed	Operational	Operations suspended due to the end of the 60 days of Delta Smelt Summer-Fall operations.
9/6/24 – 9/30/24	2 Operational 1 Closed*	Installed	Operational	Operations extended for Summer-Fall Action, running through the end of September.
10/1/24 – 10/27/24	2 Open 1 Closed*	Installed	Operational	Operations suspended due to the end of the September Delta Smelt Summer-Fall operations.
10/28/24 – 11/4/24	2 Operational 1 Closed*	Installed	Operational	Operating for one week prior to removing the stoplog and reinstalling Gate 2.

*One gate removed with a stoplog in its place, hydraulicly equivalent to one gate closed

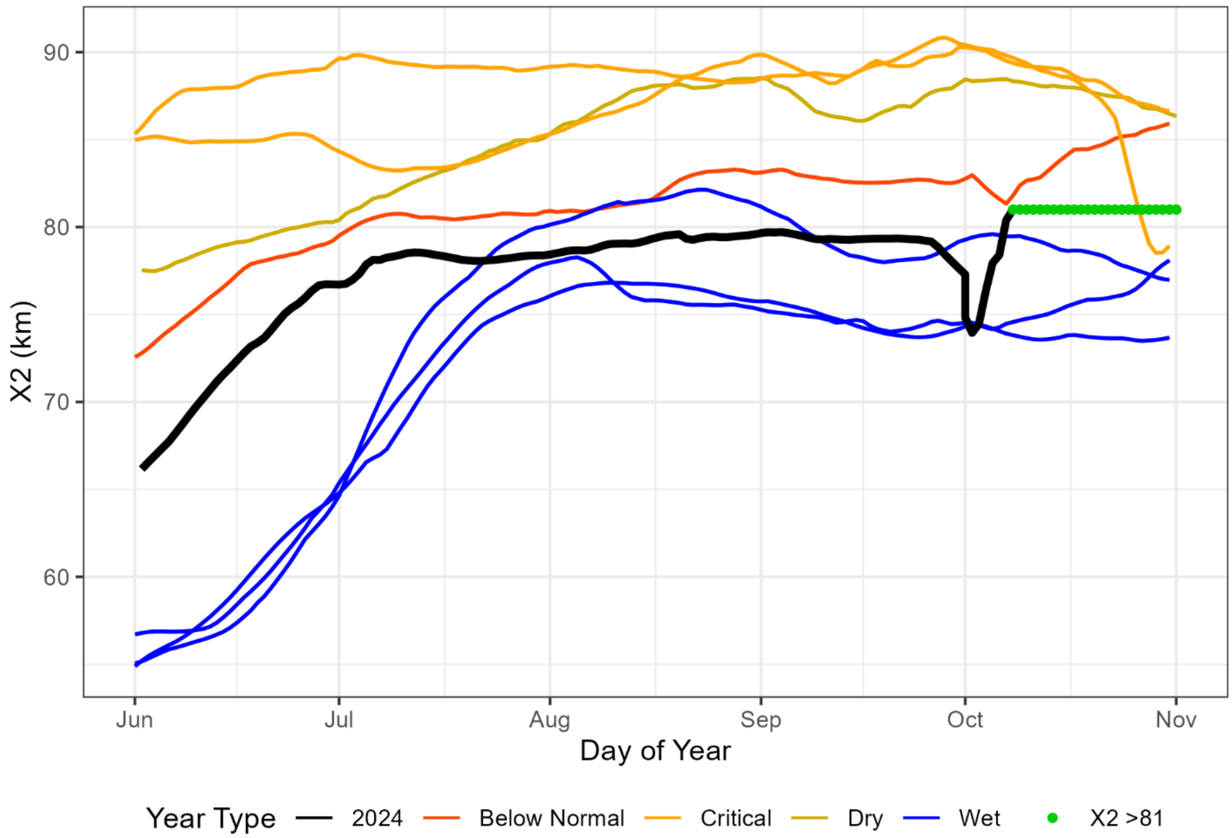

Figure 1. Location of X2 for June-October of 2024 (black line), and 2017-2023 (colored lines) as calculated by Dayflow. Dayflow data were only available through Sep 30 of 2024, so October data comes from CDEC station CX2. Real-time calculations for X2 when it is above 81 km from CDEC are not available (green points).

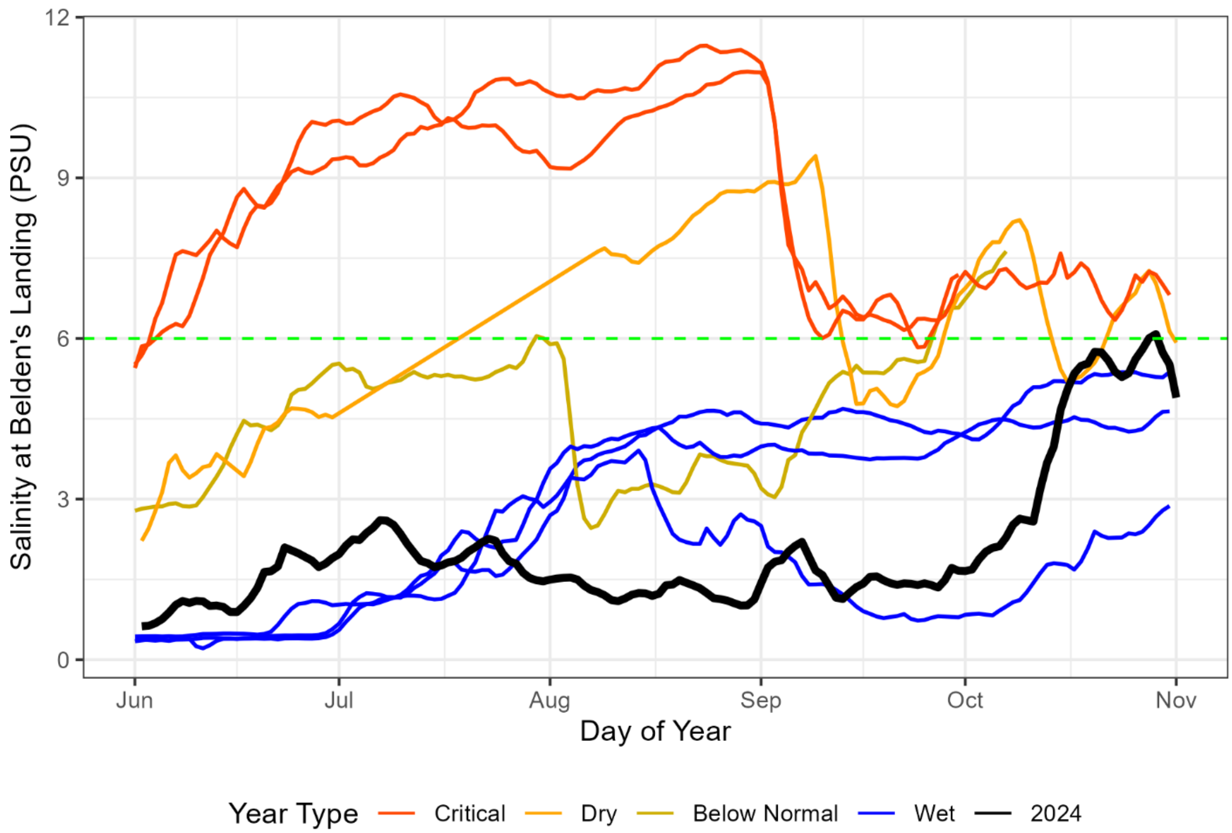

Figure 2. Salinity at Belden's landing in 2024 (black line) in comparison to previous critical years (2021, 2022), dry years (2020), below normal years (2018) and wet years (2017, 2019, 2023). Green dotted line shows the six PSU threshold for good Delta Smelt habitat.

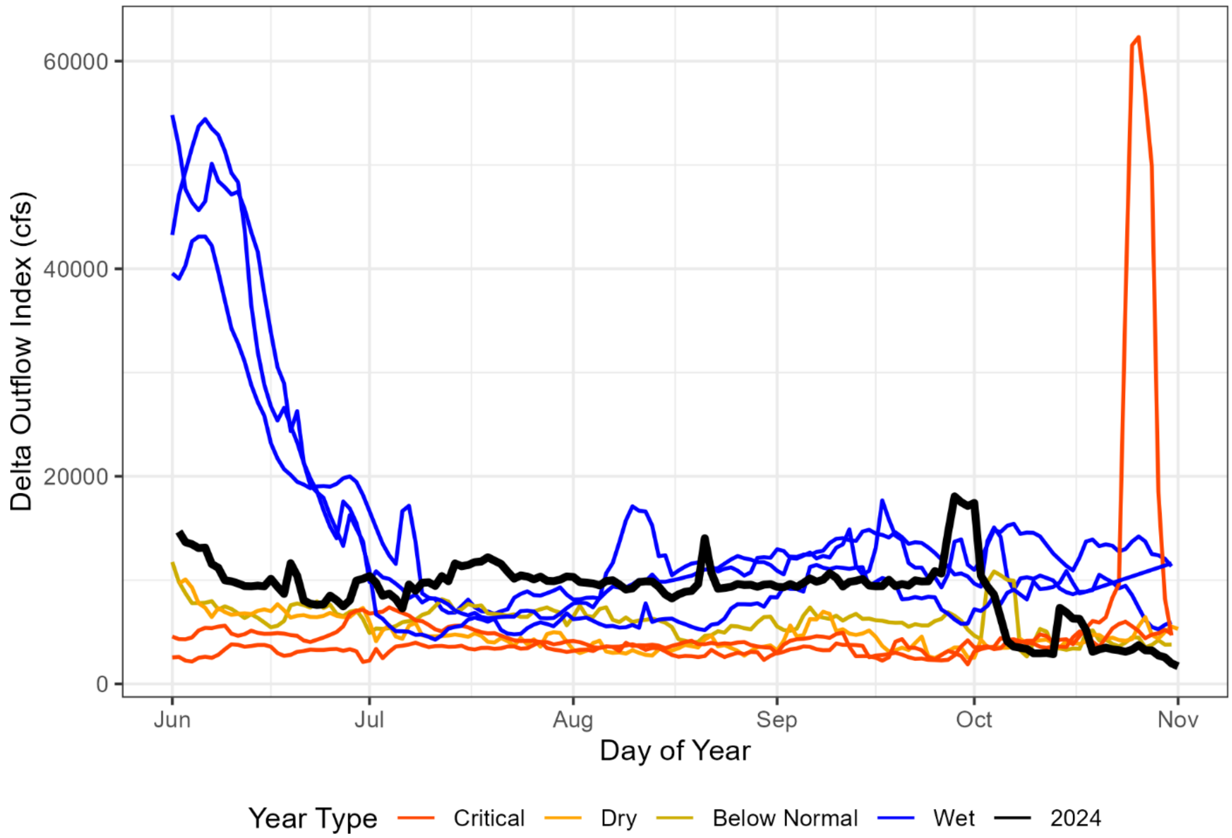

Figure 3. Daily Net Delta Outflow Index for the summer-fall period for 2024 (black line) in comparison to previous critical years (2021, 2022), dry years (2020), below normal years (2018) and wet years (2017, 2019, 2023).

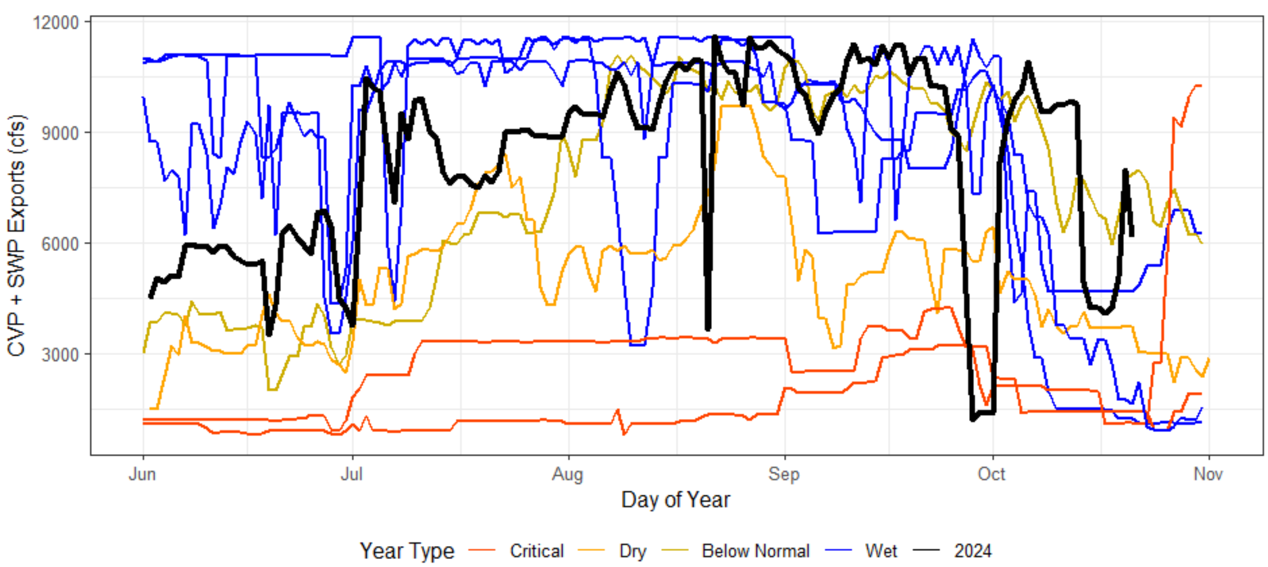

Figure 4. Daily combined exports from the Central Valley Project (CVP) and State Water Project (SWP) for the summer-fall period for 2024 (black line) in comparison to previous

critical years (2021, 2022), dry years (2020), below normal years (2018) and wet years (2017, 2019, 2023).

Monitoring and Methods

Water Quality

Water quality monitoring relies on the network of continuous sondes distributed throughout the region (Figure 9). In 2021, three new sondes were placed in Grizzly Bay, as per the requirements in the 2020 ITP, one at the mouth of Montezuma Slough (GZM), one in the eastern region of Grizzly Bay (GZB), and one at the Tule Red restoration site (TRB) (Figure 5). Sondes are calibrated and exchanged per their organization's Quality Assurance Project Plans.

Water temperature, specific conductance, and turbidity data were compiled from various continuous water quality stations in and around Suisun Marsh, Grizzly and Suisun Bays, and in the lower Sacramento River. The Grizzly Bay Buoy (station GZB) was offline for three weeks during the summer due to a malfunctioning data logger, but all other stations were functioning. Specific conductance values were converted to salinity using the wql R package (Jassby et al. 2017) and daily averages were calculated for water temperature, turbidity, and salinity. We then compared the number of days each region had salinities below 6 PSU, turbidities above 12 FNU, and temperatures below 22 °C from June-October of each year. Increased duration of suitable temperature, turbidity, and salinity in Suisun Marsh would support the hypothesis that the 100 TAF action or SMSCG action increased Delta Smelt habitat. Increased duration and/or area of suitable temperature, turbidity, and salinity in Suisun Bay would support the hypothesis that the X2 action increased Delta Smelt habitat.

We also graphed salinities at stations in Grizzly Bay versus SMSCG operations to see whether gate operations cause a decrease in salinity at these stations. If salinities at these stations drop when the Gates are operated, it will support our hypothesis that gate operations can improve Delta Smelt habitat in Grizzly Bay.

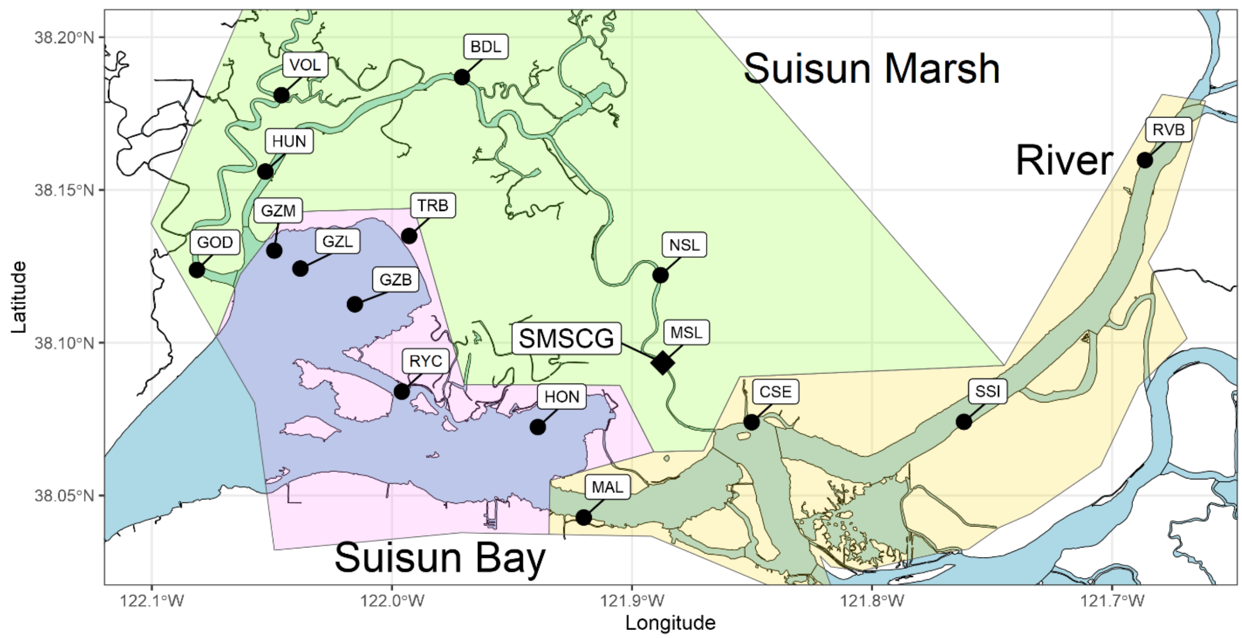

Figure 5. Map of water quality sondes used for analysis of Delta Smelt habitat. Note that station GZB was out of service for three weeks in August due to a malfunction.

Delta Smelt Habitat Hindcast Models

We modeled the area of habitat with appropriate salinity, temperature, and turbidity for Delta Smelt using the Bay-Delta SCHISM model, which is based on the Semi-Implicit Cross-scale Hydroscience Integrated System Model (SCHISM) (Zhang et al. 2016). The SCHISM hydrodynamic algorithm is based on mixed triangular-quadrangular unstructured grids in the horizontal plane and a flexible coordinate system in the vertical plane (Zhang et al. 2015). The DWR application of SCHISM to the Bay-Delta as well as a regional description of performance is described in Ateljevich et al. (2014, 2015). We used the SCHISM model to produce the area below 6 PSU that also has a turbidity of 12 FNU or higher, and water temperature of 22°C or lower, similar to the metric used in the DCG decision-making process. Temperature and turbidity may be interpolated from discrete water quality monitoring stations and/or data collected from continuous sondes.

DWR studied the impact of the SMSCG fall 2024 operations on habitat in Suisun Marsh and Suisun Bay. The scenarios are composed of 1) 2024 historical run which included SMSCG operations and September X2 actions, 2) no SMSCG operation, but with the September X2 action, 3) with SMSCG operations, but no X2 action and 4) no SMSCG operation and no X2 action. The scenarios are detailed in Table 3Table 3.

Table 3. Scenario descriptions for SCHISM modeling of proposed operations for Suisun Marsh habitat

Label	Adjustments To Scenario	SMSCG Gate operation	Start	Days	Compensating flow (cfs)
Historical (SMSCG, X2)	X2=80km (+)	Tidal	01 Jul	60	500/1000**
No SMSCG, X2	X2=80km (+)	None	NA	0	0
SMSCG, No X2	NA	Tidal	01 Jul	60	500/500**
No SMSCG, No X2	NA	None	NA	0	0

Notes: ** 500cfs used for 60 days starting July 1, 1,000cfs starting September 6.

The main metric of habitat produced by the SCHISM model is the acreage of habitat that met a LSZ threshold of 6 PSU as a time series over the summer-fall season. SCHISM model elements were queried based on their daily and depth averaged salinity, and the spatial area of each element included if the area met the 6 PSU criterion. LSZ acreage was summarized by aggregating within the zones shown in Figure 6. The different zones overlap, and though the acres of benefit are redundant, they are presented because they give a perspective on scale, not because they represent independent habitat. Two other metrics are computed: a 14-day average of daily maximum temperatures and a combined habitat that includes both LSZ and the maximum temperatures to provide more context.

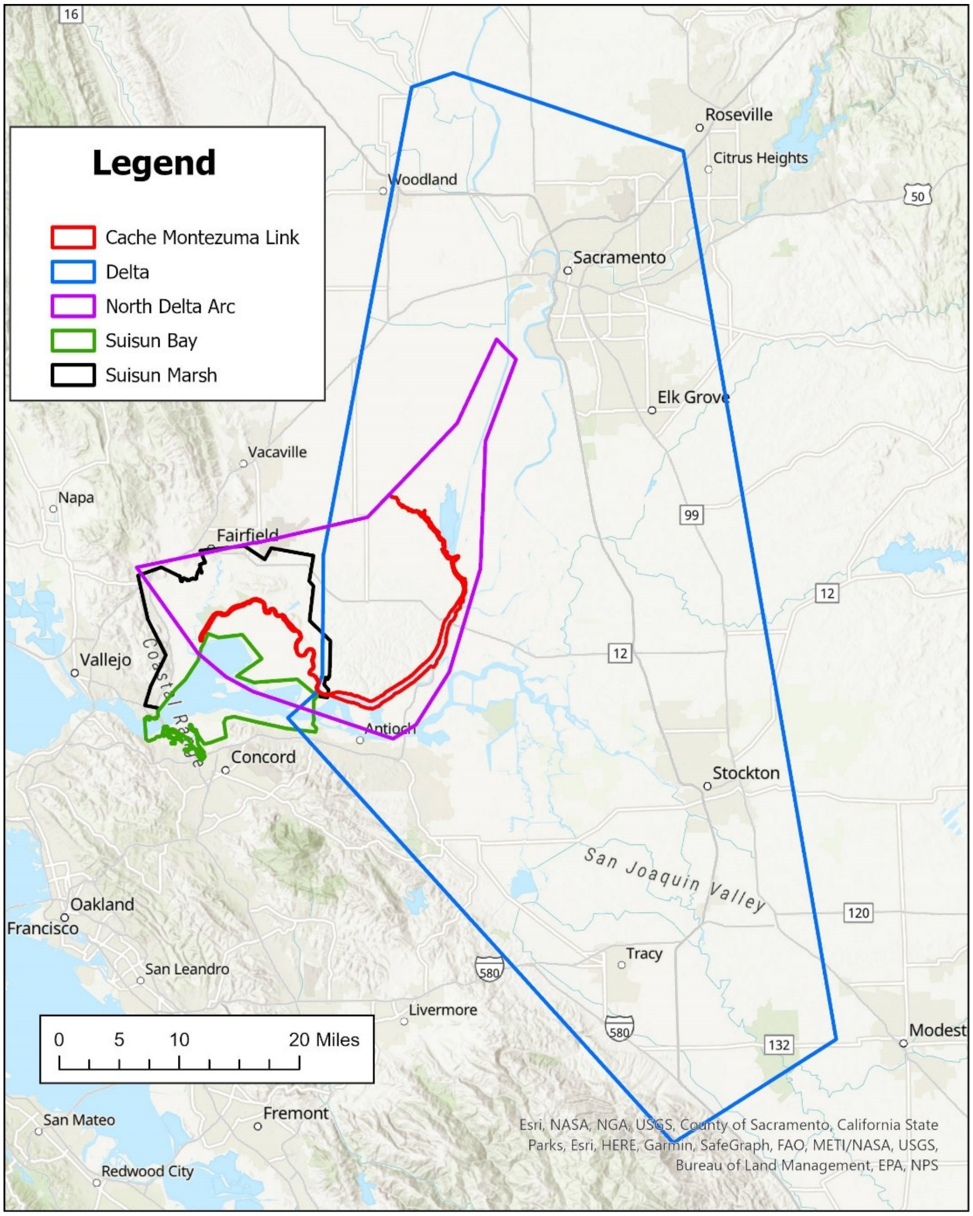

Figure 6. Regions used to aggregate low salinity zone and habitat suitability indexes. The category "All" represents the spatial union of areas in the legal Delta, Suisun Marsh and Suisun Bay.

Aquatic Vegetation

Floating aquatic vegetation (FAV) and submersed aquatic vegetation (SAV) degrade the open water habitat preferred by Delta Smelt, so determining the extent of aquatic vegetation in Suisun Marsh is an important part of the integrated approach for evaluating the availability of suitable Delta Smelt habitat. Suisun Marsh has exhibited less cover of invasive FAV and SAV compared to the Delta, likely because most of these plant species cannot tolerate the brackish conditions that are typical of the marsh. The SMSCGs are operated to move more freshwater from the Delta into Suisun Marsh during the summer and fall months, which could increase the cover of FAV and SAV in the marsh by two mechanisms: (1) increasing the transport of FAV and SAV propagules from the highly infested Delta and (2) reducing the salinity of the marsh to levels amenable to these plants during their peak months for growth and reproduction.

To better understand the distribution of FAV and SAV in Suisun Marsh and how it is changing through time, we created vegetation maps based on airborne hyperspectral imagery collected annually during summer or fall during several recent years, including 2018, 2022, 2023, and 2024. Ground truthing field surveys were conducted around the time of imagery collection to ensure accurate vegetation classification. While FAV is straightforward to monitor with these remote sensing tools, SAV is more challenging because turbidity reduces visibility, and therefore detection, of this type of vegetation (i.e., SAV cover is underestimated) and because we have recently determined that algae-covered mudflats have a spectral signal similar to SAV and can be misclassified as SAV (i.e., SAV cover is overestimated). For all years, we have timed our imagery collection with low tide to minimize underestimation of SAV cover in the turbid waters of the marsh. In 2024, we started collecting field data on mudflats, so we could better differentiate them from SAV. We still need to work on differentiating SAV and mudflats in maps from previous years. Consequently, in this report, we will discuss trends in FAV cover across years but just the 2024 results for SAV cover. The entirety of Suisun Marsh is included in all our vegetation maps, but not all of this area is suitable fish habitat. Therefore, in this report, we focus our analysis on the areas in and around the marsh that consist of permanently inundated, tidally influenced sloughs and channels that could provide open water fish habitat (Figure 7).

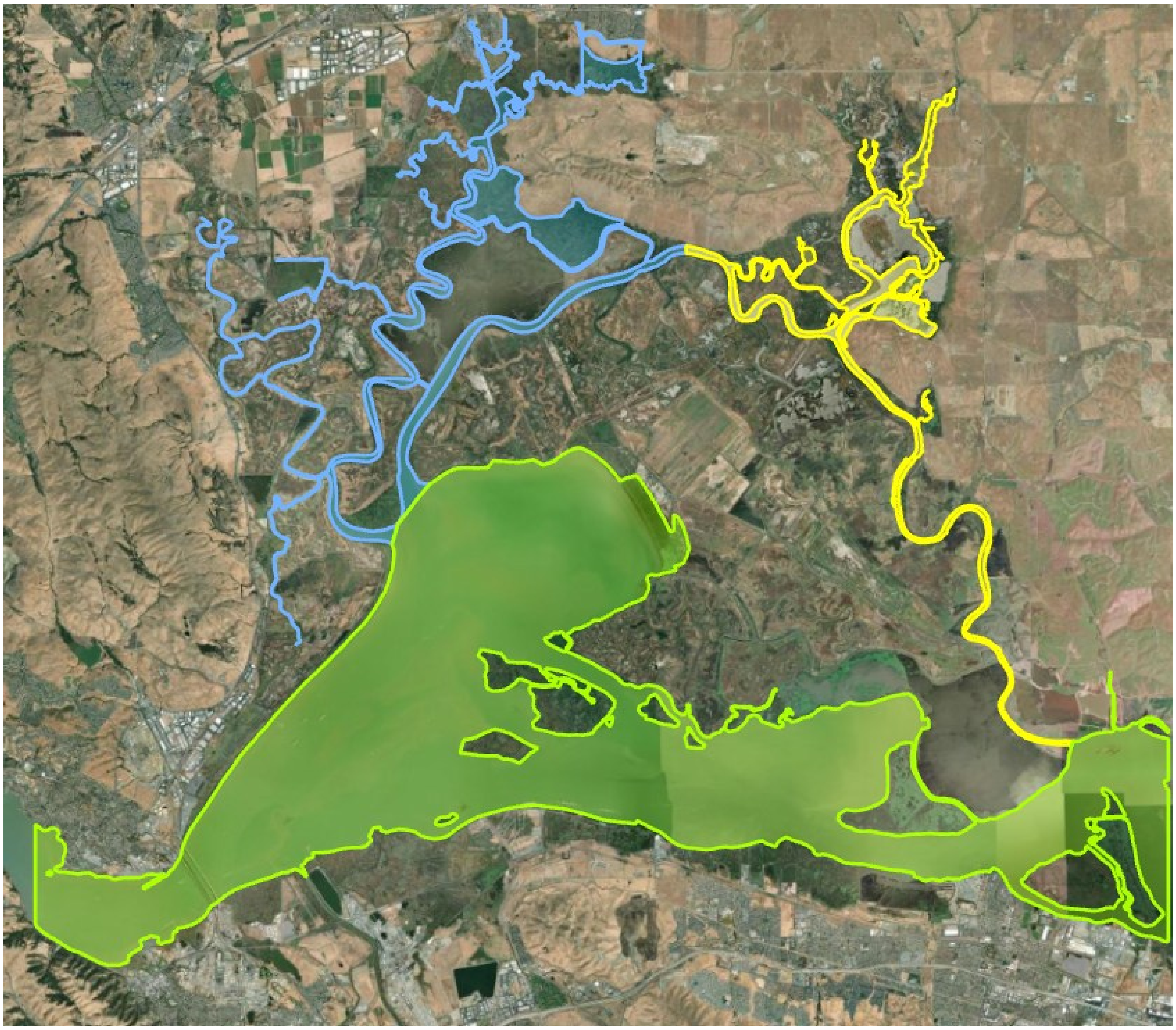

Figure 7. Three regions of tidal waterways in and around Suisun Marsh that were used to evaluate the impacts of aquatic vegetation on open water habitat.

Zooplankton

Zooplankton were monitored primarily using four existing surveys, including the CDFW Summer Townet (STN) and Fall Midwater Trawl (FMWT), as well as the DWR/CDFW Environmental Monitoring Program (EMP) (Kayfetz et al. 2020) under agreements with Reclamation, with some additional samples collected by ICF under contract with Reclamation in Grizzly Bay and Belden's landing (Figure 10). Additional sampling is conducted specifically for this management action to increase the spatial and temporal resolution of data in the area of interest (see SMSCG monitoring plan for details). EMP data for 2024 was not available in time for this report.

We analyzed abundance trends in three of the most important zooplankton taxa for Delta Smelt: *Pseudodiaptomus forbesi* (a calanoid copepod and the most important source of smelt food in the summer), *Limnoithona tetraspina* (a smaller cyclopoid copepod that dominates the LSZ), and

Eurytemora carolleeae (historically important for smelt diets, but now rare in the summer). We compared biomass of each taxon in the LSZ in 2024 versus previous years with different salinity conditions in Suisun Marsh and Suisun Bay using linear mixed effect models with a random effect of month (logBPUE~ Region*Year + (1|Month)). We also compared biomass of each taxon in upstream areas versus the LSZ. Increased zooplankton biomass in Suisun Marsh during 2024 and other years with low salinity would support the hypothesis that operating the SMSCGs increases food availability for Delta Smelt. Increased *P. forbesi* biomass in Suisun Bay and Grizzly Bay during 2024 and other years with low salinity would support the hypothesis that having lower X2 increases food availability for Delta Smelt in Suisun Bay.

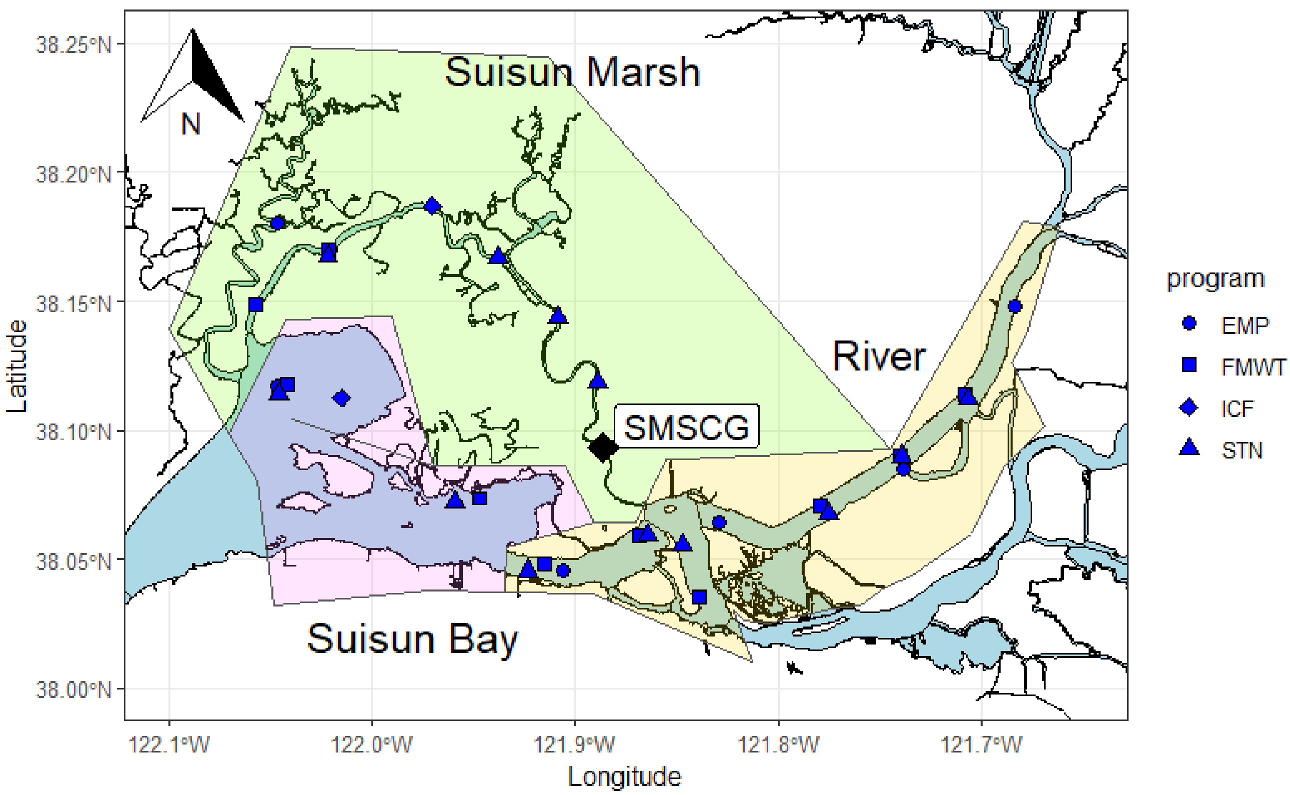

Figure 8. Map of fixed stations where zooplankton samples are collected.

Delta Smelt Abundance and Distribution

Fish monitoring relied entirely on existing surveys such as the USFWS Enhanced Delta Smelt Monitoring Program (EDSM) and Delta Juvenile Fish Monitoring Program (DJFMP), the UC Davis Suisun Marsh Survey, and California Department of Fish and Wildlife's (CDFW) Summer Townet Survey (STN), San Francisco Bay Study, and Fall Midwater Trawl Survey (FMWT) under agreements with Reclamation and DWR. We did not have high enough Delta Smelt catch to statistically analyze any changes in Delta Smelt abundance or distribution as a result of the actions in 2024. However, we graphically present data on Delta Smelt catch by region to see whether they are using habitat in Grizzly Bay, Suisun Bay, and Suisun Marsh made available by the X2 and SMSCG actions.

Experimental Releases

Between the start of experimental releases in 2021 and the beginning of the 2024 Summer-Fall Habitat Action, 190,906 cultured Delta Smelt were released into the Delta. Cultured Delta Smelt have been regularly released from November through February of each year at varied locations, with varied methodologies, and releases have increased over time from 55,733 (WY 2022), to 43,705 (WY 2023), to 91,468 (WY 2024). Previous release locations include Rio Vista, the Sacramento Deepwater Ship Channel, and Suisun Marsh. In WY 2024 all Delta Smelt were released at Rio Vista on the Sacramento River. As of October 2024, there were 49 recaptures for WY2024 out of a total Delta Smelt catch of 189 across lifestages. In WY 2023, there were 93 Delta Smelt captured, of which 43 were recaptures. In WY 2022, 77 of the 115 Delta Smelt caught were recaptures. In all three years, recaptures occurred throughout the Delta, Suisun Marsh and Bay. Experimental Release Reports are available from the USFWS upon request.

Delta Smelt Enclosures

To test whether Delta Smelt have higher growth and survival in Suisun Marsh or Rio Vista, we used experimental enclosures. We used these enclosures at the same two locations in 2023 to test differences between habitats and try and reduce biofouling. While we successfully reduced biofouling, no impact of the reduction was detected on Delta Smelt growth and survival inside the cages. Results showed higher growth and health metrics in Rio Vista than Suisun Marsh (contrary to our predictions). Therefore, in 2024 we repeated the study to see whether the difference in habitats was consistent across years.

Study Questions

a. Does survival, growth, and health differ between field sites?
    i. Are trends similar between 2023 and 2024?
    ii. Is temperature driving observed differences?
    iii. Is food type and/or availability driving observed differences?

Enclosure Methods

Four enclosures, holding 70 Delta Smelt each, were placed in two locations, Suisun Marsh in Montezuma Sough near Belden's Landing, and Sacramento River next to the City of Rio Vista. The enclosures were 1.22m tall and 0.95m in diameter, made of a 14-gauge perforated aluminum sheet with 4.76 mm holes on 6.35 mm centers, providing for 51% open area. These were the same enclosures used in previous field experiments and described in Baerwald et al. (2023).

Smelt came from the Fish Conservation and Culture Facility (FCCL) in Byron, CA, and were approximately 200 days post hatch. They were transferred to the enclosures on August 27th (Rio Vista) and 28th (Belden's Landing). Enclosures were checked immediately after smelt were deployed in the cages and weekly thereafter. We had planned to remove the cages after six weeks to replicate the 2023 experiment; however, the anchors securing the Belden's Landing cages came loose several times causing the cages to drift. Therefore, we removed cages from both sites after four weeks (Sept. 25th and 26th) to prevent them from becoming a navigation hazard.

To quantify Delta Smelt prey abundance inside the cages, we collected zooplankton samples inside and outside the cages every two weeks and scraped the macroinvertebrates off the inside of the cage within a 25 cm^2 quadrat.

To assess whether there were differences in smelt survival and condition between sites, we counted recovered smelt from the cages, measured smelt length, weight, condition factor, hepatosomatic index, and liver glycogen at the end of the deployment. We also assessed the critical thermal maximum for six fish from each cage and analyzed the diet from 10 fish from each cage.

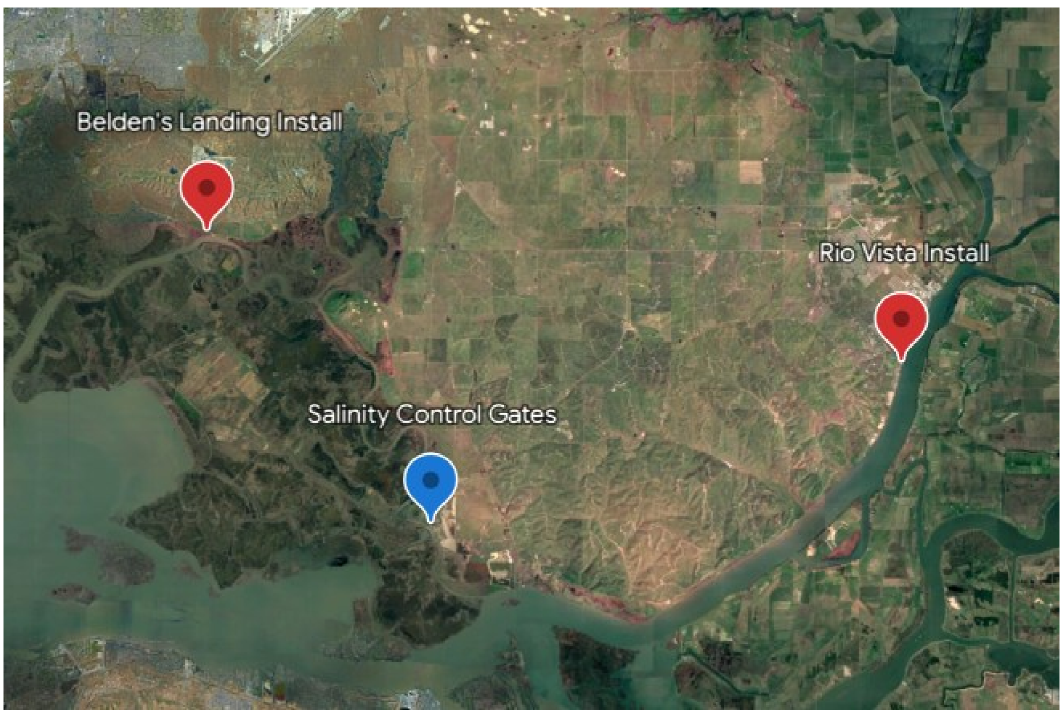

Figure 9. Enclosure deployment study site locations .

Results

Extent of Appropriate Delta Smelt Habitat

Observed Water Quality

In years of high summer Delta outflow (averaging over 10,000 cfs from June-August), habitat with suitable salinity for Delta Smelt (<6 PSU) may extend contiguously from the freshwater Delta to Suisun Bay and Suisun Marsh. All of Suisun Marsh and Suisun Bay are less than 6 PSU when X2 is less than 75 km (FLOAT-MAST 2021), with a large portion of Grizzly Bay and Honker Bay as suitable habitat when X2 is less than 80 km (ITP effects analysis).

During 2024, most stations in Suisun Bay had salinity that was between 5 and 7.5 PSU, indicating that much of the Bay was above the cutoff for optimal Delta Smelt habitat (Figure 10). Chlorophyll in this region was relatively high, though it rarely reached the "bloom" threshold of 10 ug/L. Suisun Bay was the region with the lowest temperatures, but all stations had daily averages above 22°C for most of July and some of August, and station GZM, at the mouth of Montezuma Slough, had higher temperatures, similar to stations in Suisun Marsh. Turbidity was above 12 FNU at all stations throughout the time period.

Most stations in Suisun Marsh remained well below 6 PSU through the summer until the cessation of the gate action at the end of September when salinity increased from 1-5 PSU to 4-8 PSU during the first half of October (Figure 10). The exception is Goodyear Slough (GOD) on the far western edge of the marsh, which was between 6 and 7 for most of the summer. Chlorophyll values were higher than in the River region, however declines in chlorophyll at stations along Montezuma Slough occurred at the beginning of the gate actions. This was the region with the highest temperatures, remaining above 22°C for most of July, some of August, and some of September. Turbidity was greater than 12 FNU for the entire season (Figure 10).

In the Sacramento River all stations stayed below 6 PSU for the entire time period (Figure 10). Temperatures were lower than the Marsh, but higher than most stations in the Bay region, and experienced the same July heat wave as seen elsewhere. Turbidity and chlorophyll were the lowest of any region, with many stations below the 12 FNU threshold for good smelt habitat, meaning that either temperature, turbidity, or both were the most frequently limiting factors in upstream regions.

When comparing conditions in 2024 to previous years (Figure 11, Table 4), we can see how many days each water quality factor was limiting the extent of Delta Smelt habitat in each area. On any given day, either salinity, temperature, or turbidity may be out of the range of optimal smelt habitat, and which factor(s) is limiting may change from day to day or region to region. Salinity was a limiting factor in Suisun Bay in 2024 more frequently than years when the X2 standard was set at 74 km (2017, 2019), or when X2 was set at 80 for two months instead of one month (2023), but conditions in Suisun Marsh and the River were similar to other years with gate actions or X2 actions (2017, 2018, 2019, 2023). Across all three regions, temperature in 2024 was limiting slightly less frequently than in 2023, but it was still one of the warmer summers in recent years, and high temperatures limited the spatial and temporal extent of habitat even when flow actions increased the low salinity habitat. Turbidity in Suisun Bay and Suisun Marsh was almost never limiting, and even conditions in the River were limiting less frequently than most previous years.

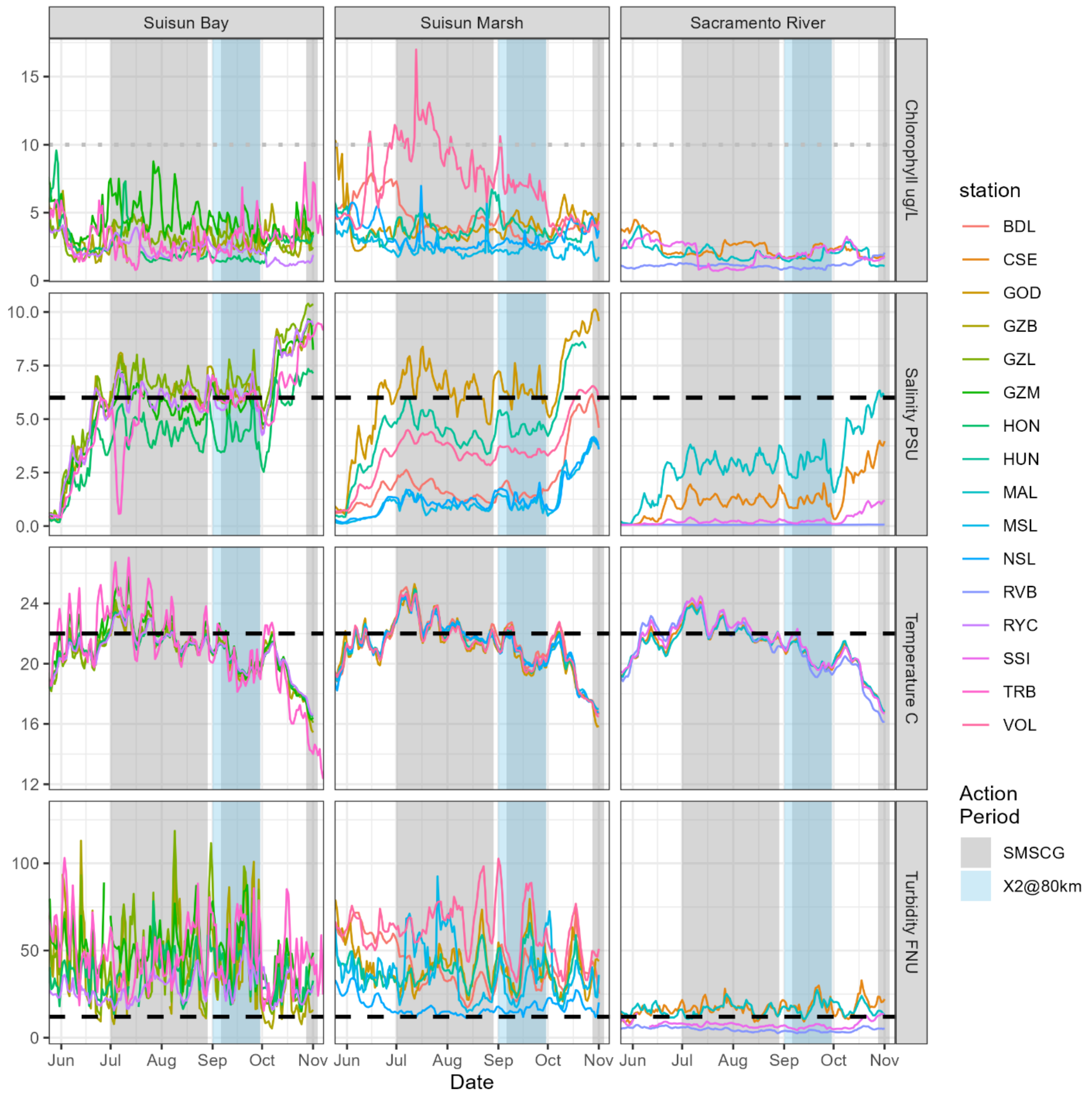

Figure 10. Plot of daily average Chlorophyll (ug/L), Salinity (PSU), Temperature (C) and Turbidity (FNU) at continuous monitoring stations throughout the area (Figure 5). Black dotted lines on salinity, temperature, and turbidity graphs indicate Delta Smelt habitat thresholds, and the gray dotted line on the chlorophyll graph is a commonly used reference point for high plankton growth. Shaded areas indicate time periods where the SMSCGs were operating (Gray) or fall X2 was implemented (Blue).

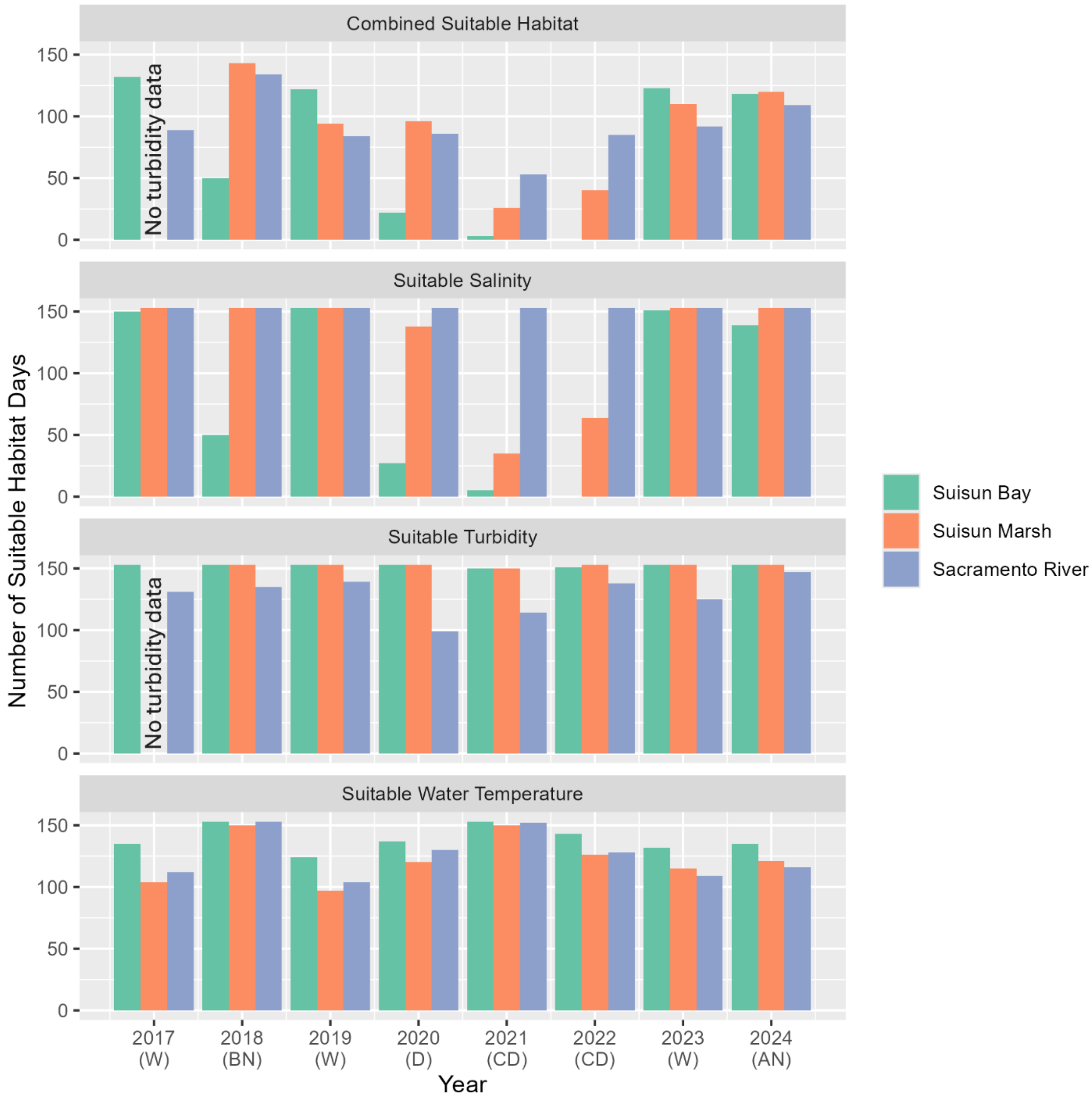

Figure 11. Number of days of the summer and fall (out of 153 total) where water quality conditions in the bay, marsh, and river met the suitable smelt habitat criteria (e.g., < 6 PSU salinity, < 22°C temperature, > 12 FNU turbidity) for 2017-2024. Water year type is indicated below the year.

Table 4. Number of days with optimal Delta Smelt habitat conditions in each region and year during the summer-fall time period (out of a total possible of 153).

Year	Region	Combined good smelt habitat days	Days >12 FNU	Days < 22 °C	Days < 6 PSU
2017	Bay	132	153	135	150
2017	Marsh	0	0	104	153
2017	River	89	131	112	153
2018	Bay	50	153	153	50
2018	Marsh	143	153	150	153
2018	River	134	135	153	153
2019	Bay	122	153	124	153
2019	Marsh	94	153	97	153
2019	River	84	139	104	153
2020	Bay	22	153	137	27
2020	Marsh	96	153	120	138
2020	River	86	99	130	153
2021	Bay	3	150	153	5
2021	Marsh	26	150	150	35
2021	River	53	114	152	153
2022	Bay	0	151	143	0
2022	Marsh	40	153	126	64
2022	River	85	138	128	153
2023	Bay	123	153	132	151
2023	Marsh	110	153	115	153
2023	River	92	125	109	153
2024	Bay	118	153	135	139
2024	Marsh	120	153	121	153
2024	River	109	147	116	153

Aquatic Vegetation

To determine the potential impacts of aquatic vegetation on Delta Smelt habitat in and around Suisun Marsh, we quantified the waterway area occupied by floating aquatic vegetation (FAV) and submersed aquatic vegetation (SAV) based on our hyperspectral maps. In 2018 and 2021, no FAV was detected (Figure 12). In 2022, FAV area became detectable in the imagery (1.5 ha across all regions) and increased to 6.5× and 11.4× of the 2022 levels by 2023 and 2024, respectively. The general pattern of increase in FAV area was similar in the East Marsh, West Marsh and Bay regions, but the proportion of the waterways occupied by FAV differed substantially among them (Figure 12). In the Bay region, FAV occupied the smallest proportion of waterways, likely because the waterway area included in the Bay region (12,206 ha) was one to two orders of magnitude greater than that of the West Marsh (1,328 ha) and East Marsh (733 ha) and included large areas that are faster flowing and saltier than the marsh regions. FAV covered much higher proportions of the two marsh regions compared to the Bay region with the West Marsh showing the highest levels (Figure 12). Most of the FAV area was the aquatic fern, azolla (*Azolla spp.*) (Figure 13), occupying 10.0 ha and comprising 58.6% of the total FAV area across all regions in 2024. The ongoing invasion of Suisun Marsh by alligatorweed (*Alternanthera philoxeroides*) (Figure 13), a non-native that was first discovered in 2017, contributed most of the remaining area (6.5 ha or 38.1% of 2024 total FAV area). Water primrose *(Ludwigia spp.)* occupied the small remaining area (0.5 ha or 3.2% of total FAV area in 2024).

Across all three regions, SAV occupied 192.0 ha, which is 1.3% of the total waterway area, and for just the two marsh regions, it occupied 132.0 ha, which is 6.4% of the waterways (Figure 15). These SAV area estimates are likely conservative because of the difficulty detecting SAV in turbid water, and as with FAV, much of the area of SAV in and around Suisun Marsh is not included in our calculations because it is found outside the main channels. The East Marsh region exhibited the highest proportion of waterway area occupied by SAV, while the Bay region exhibited the lowest (Figure 14). In the East Marsh, there were patches of SAV along the margins of many sections of eastern Montezuma Slough, but the greatest concentration of SAV was in the Nurse Slough complex, especially Little Honker Bay, adjacent to several tidal wetland sites (Bradmoor Island, Blacklock, and Arnold Slough) (Figure 16). In the West Marsh, SAV was most abundant in Suisun Slough, particularly along the margins where the slough curves, and in the Bay region, it was most abundant around the mouth of Suisun Slough and along the margins of the tidal wetland site Tule Red.

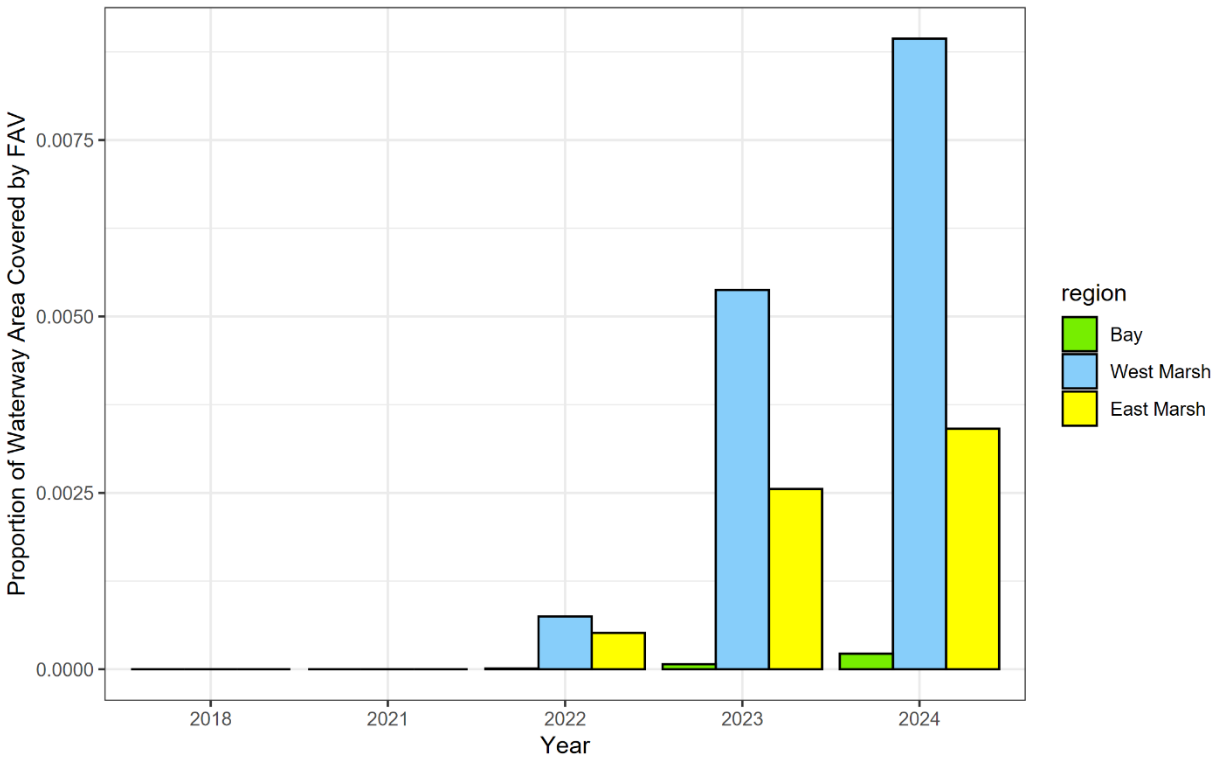

Figure 12. Time series of floating aquatic vegetation (FAV) area in and around Suisun Marsh by region.

Figure 13. Alligatorweed (left) and azolla (right) were the most common FAV species detected by the airborne hyperspectral imagery of Suisun Marsh.

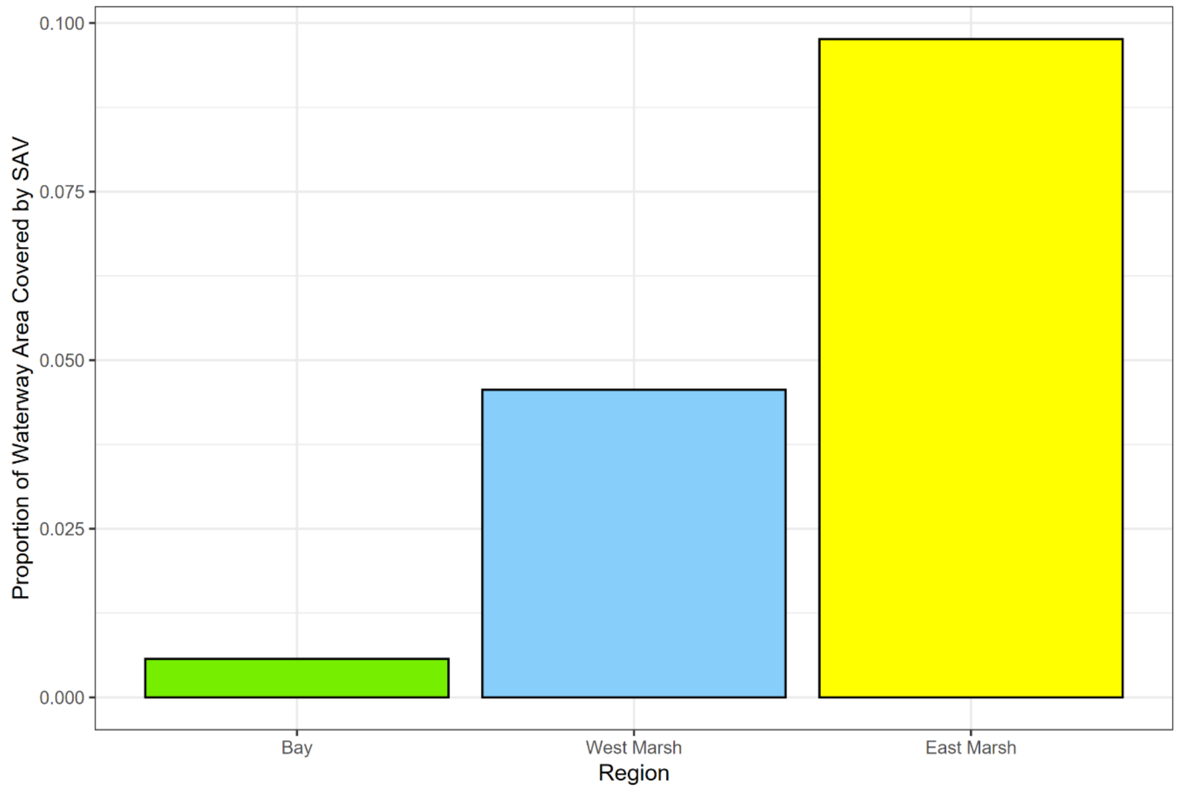

Figure 14. Submersed aquatic vegetation (SAV) area in and around Suisun Marsh during 2024 by region.

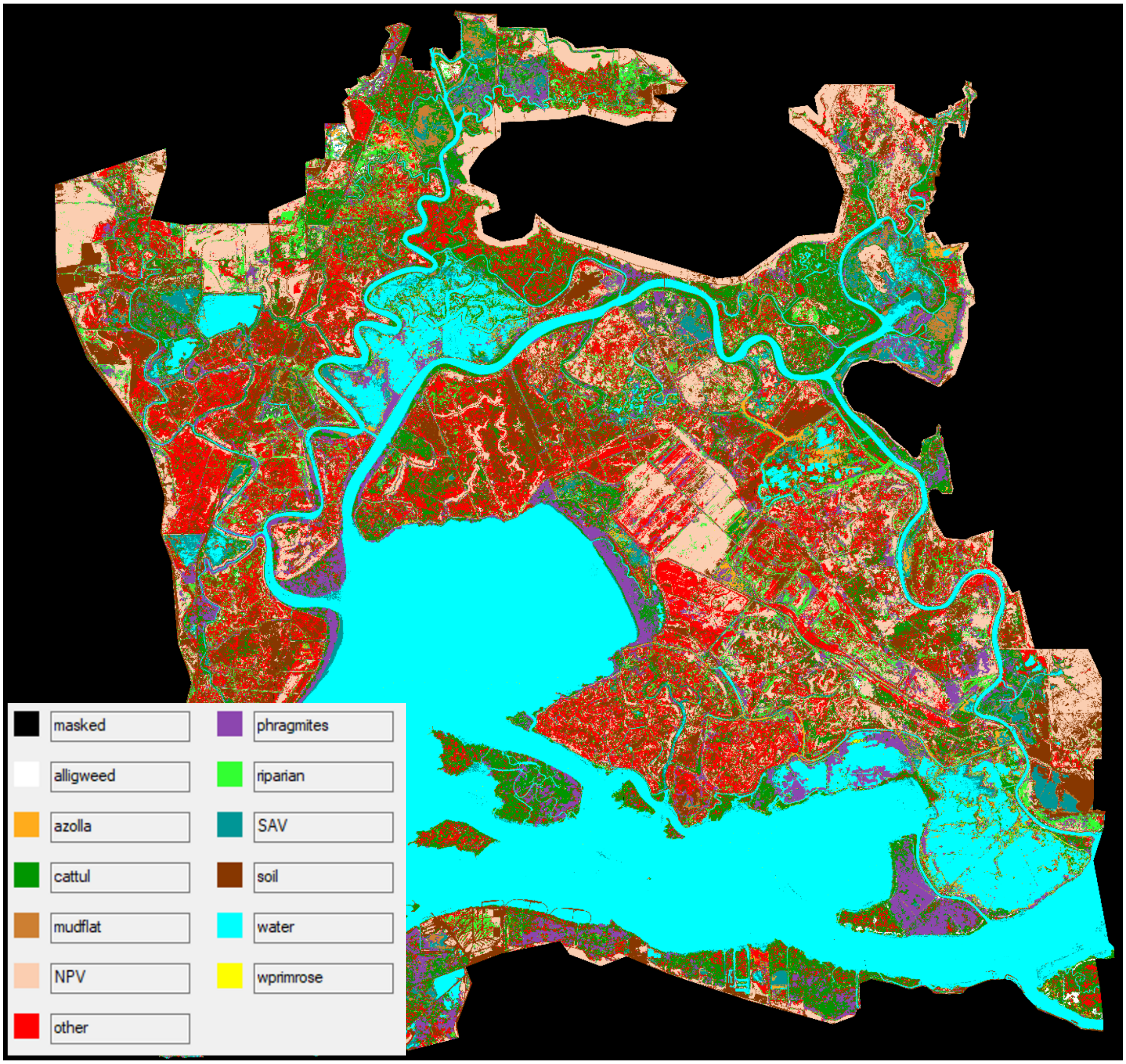

Figure 15. Aquatic vegetation map of Suisun Marsh from July 2024.

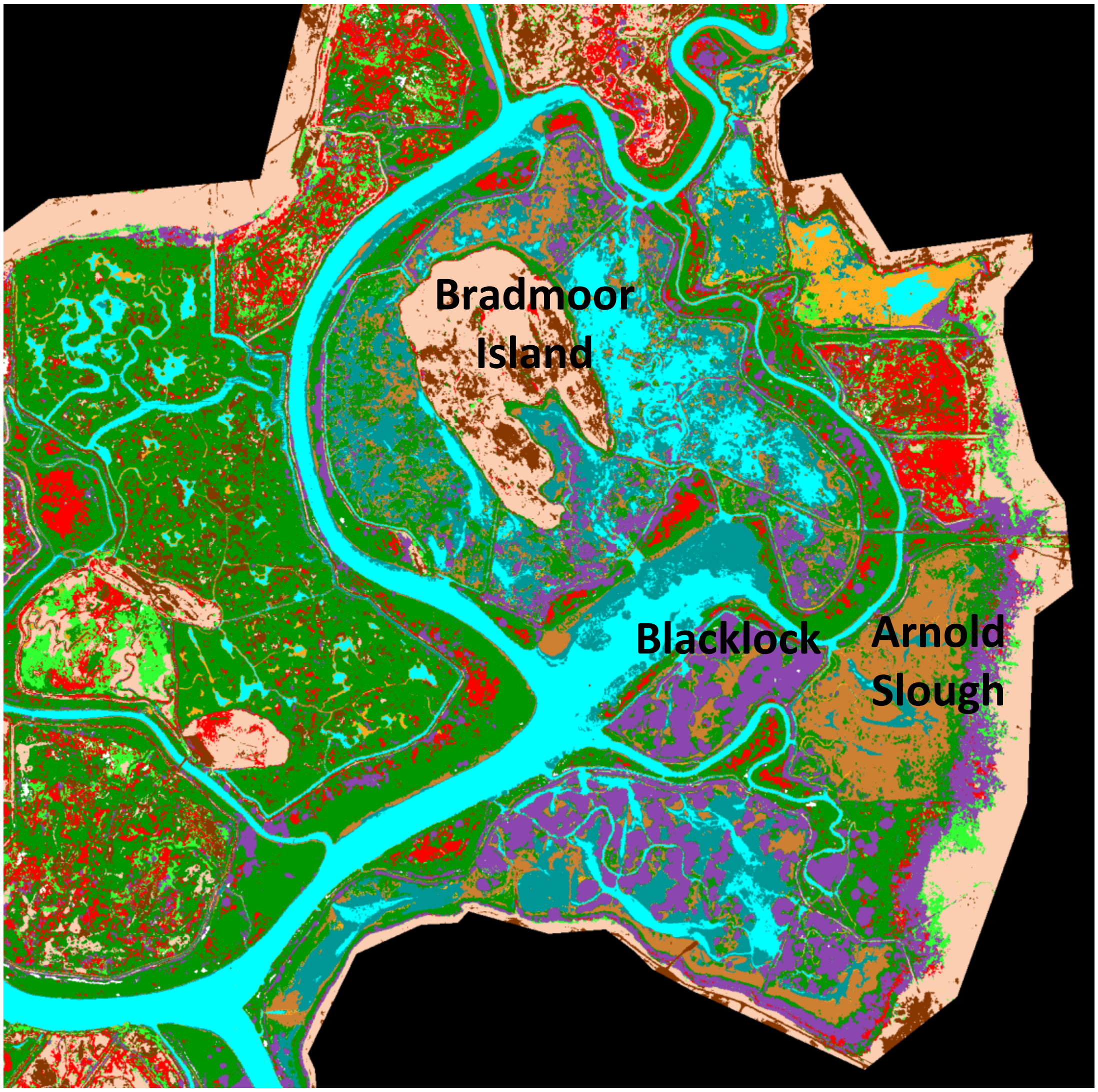

Figure 16. Northeastern area of Suisun Marsh where three tidal wetland sites are located and where significant amounts of submersed aquatic vegetation were observed in July 2024. See previous figure for the color key.

Hindcast Modeling

The SMSCG is known to effectively freshen the Suisun Marsh area. Figure 17 shows the Low Salinity Zone (LSZ) averaged over the first 14-day period in 2024 during August, September and October. The X2 actions end in September, but October is presented to highlight a post action period. The historical actions which included the SMSCG operations and X2 actions freshen the marsh by increasing the LSZ along the main stem of the estuary and slight change along a thin margin of Suisun Bay. The scenario with no SMSCG operations and no X2 actions resulted in the smallest acreage of the low salinity zone (Figure 18).

SMSCG operations along with the X2 action freshens the Suisun Marsh and has the potential to improve marsh habitat under suitable conditions. All other alternatives yielded lower habitat acreages in Suisun Marsh compared to the SMSCG and X2 actions. The LSZ acreages in Suisun Marsh are larger than in previous years since we added more tidal areas to our model around Hill Slough. The X2 actions kept the position of X2 within 80 km as shown in Figure 19.

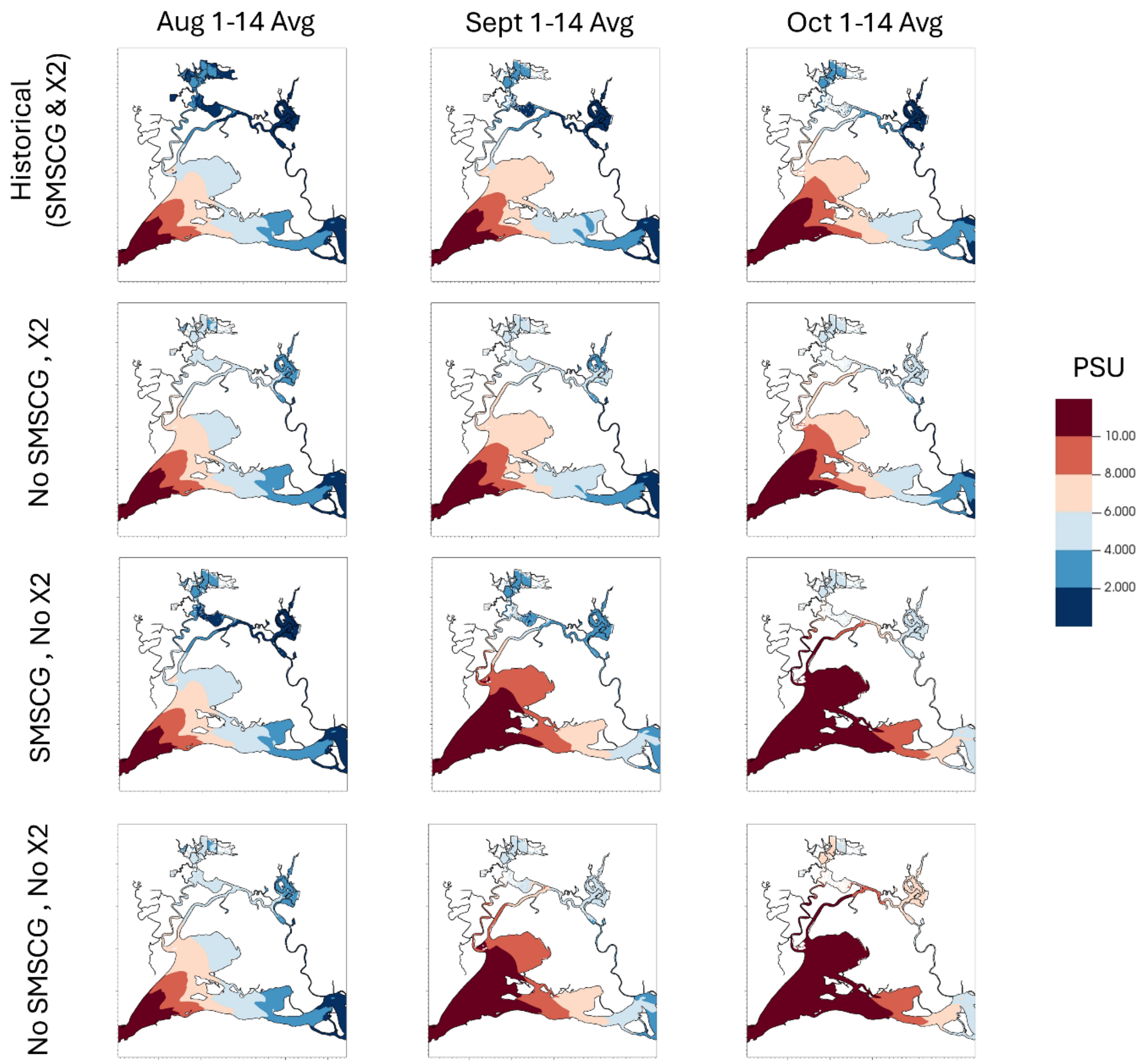

Figure 17. Maps of salinity in Suisun Marsh and Suisun Bay for each of the operational scenarios, averaged over the first half of August, September, and October. Blue indicates areas of appropriate smelt habitat, red indicates poor smelt habitat.

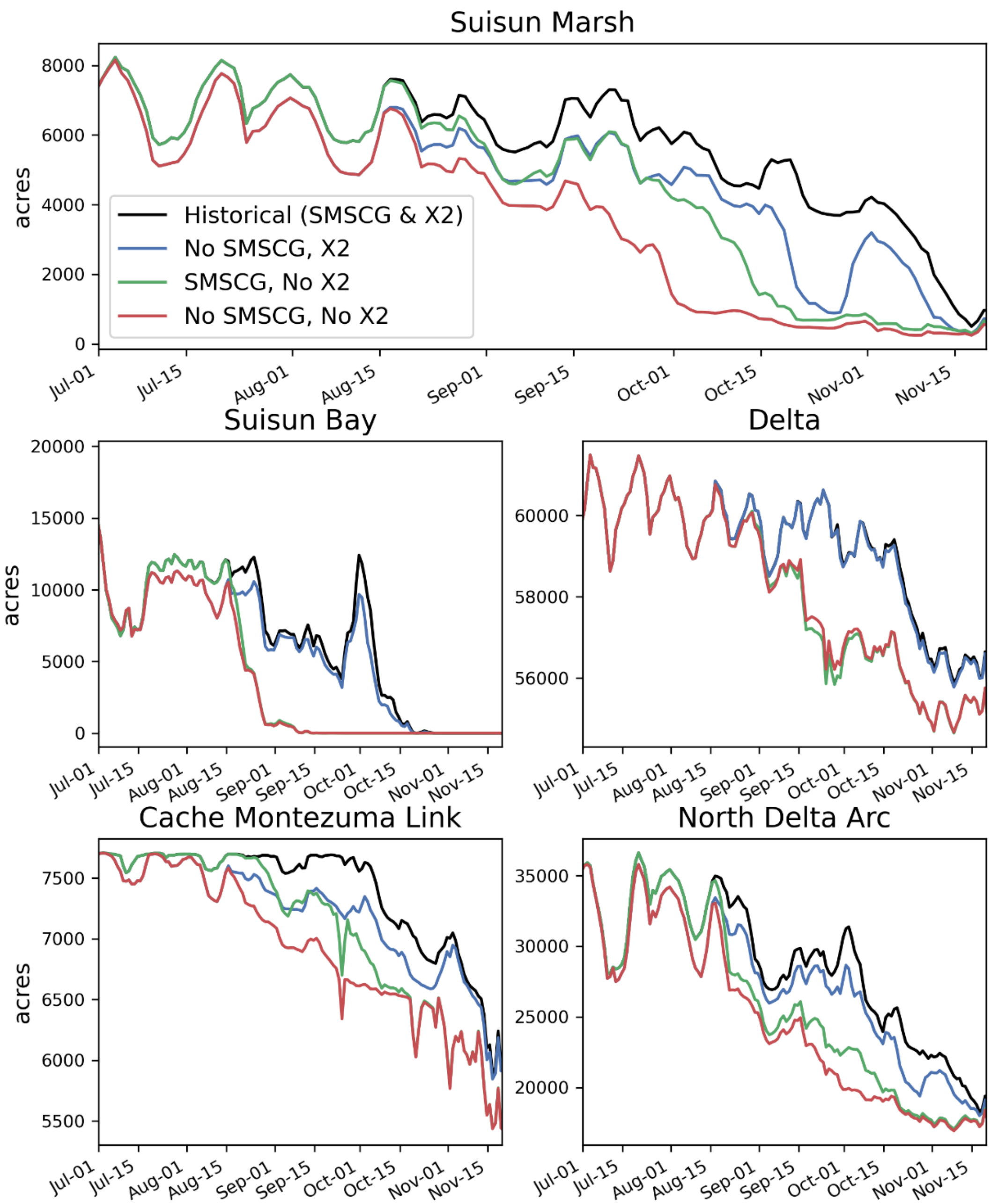

Figure 18. **Time series of LSZ within the Suisun Marsh and Suisun Bay regions shown in Figure 6.**

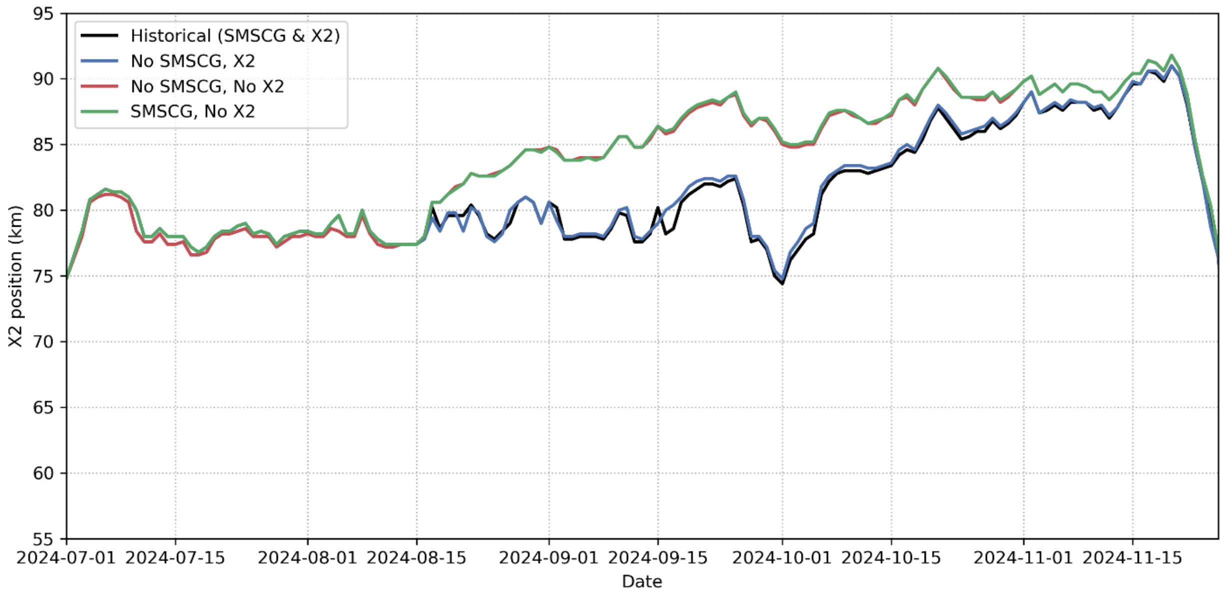

Figure 19. Position of X2 for the historical and alternate scenarios.

In addition to quantifying the LSZ habitat, the 14-day average of daily maximum temperature was computed for the historical and alternate scenarios shown in Figure 21. The SMSCG and X2 actions do not affect the temperature in Suisun Marsh as compared to the alternate scenarios. The temperature models are usually accurate to within 0.3-0.6 °C for deep, open-water areas, however shallow tidal habitats are subject to inaccuracies due to low volume impacting their heat balance. Therefore, low temperatures modeled in the recently restored tidal habitat on the edge of Grizzly Bay (Tule Red Restoration site), and the northern end of Suisun Slough (Hill Slough and Wings Landing restoration sites) are cooler than recorded by in-situ temperature sondes (Figure 20).

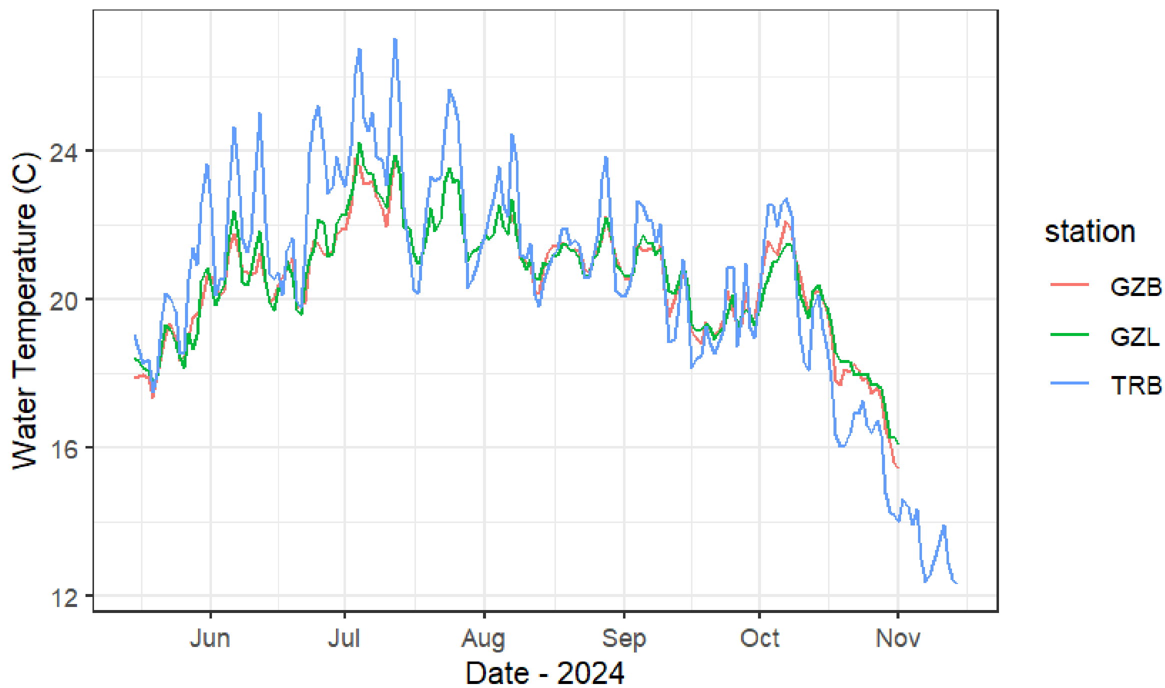

Figure 20. Daily mean water temperature at Tule Red (TRB) a tidal wetland site on the border of Grizzly Bay, and two sites in the open water center of Grizzly Bay (GZL and GZB). While the model results in the following figure predict temperatures in Tule Red to be cooler than Grizzly Bay, measurements suggest it is usually warmer, particularly in June, July and August.

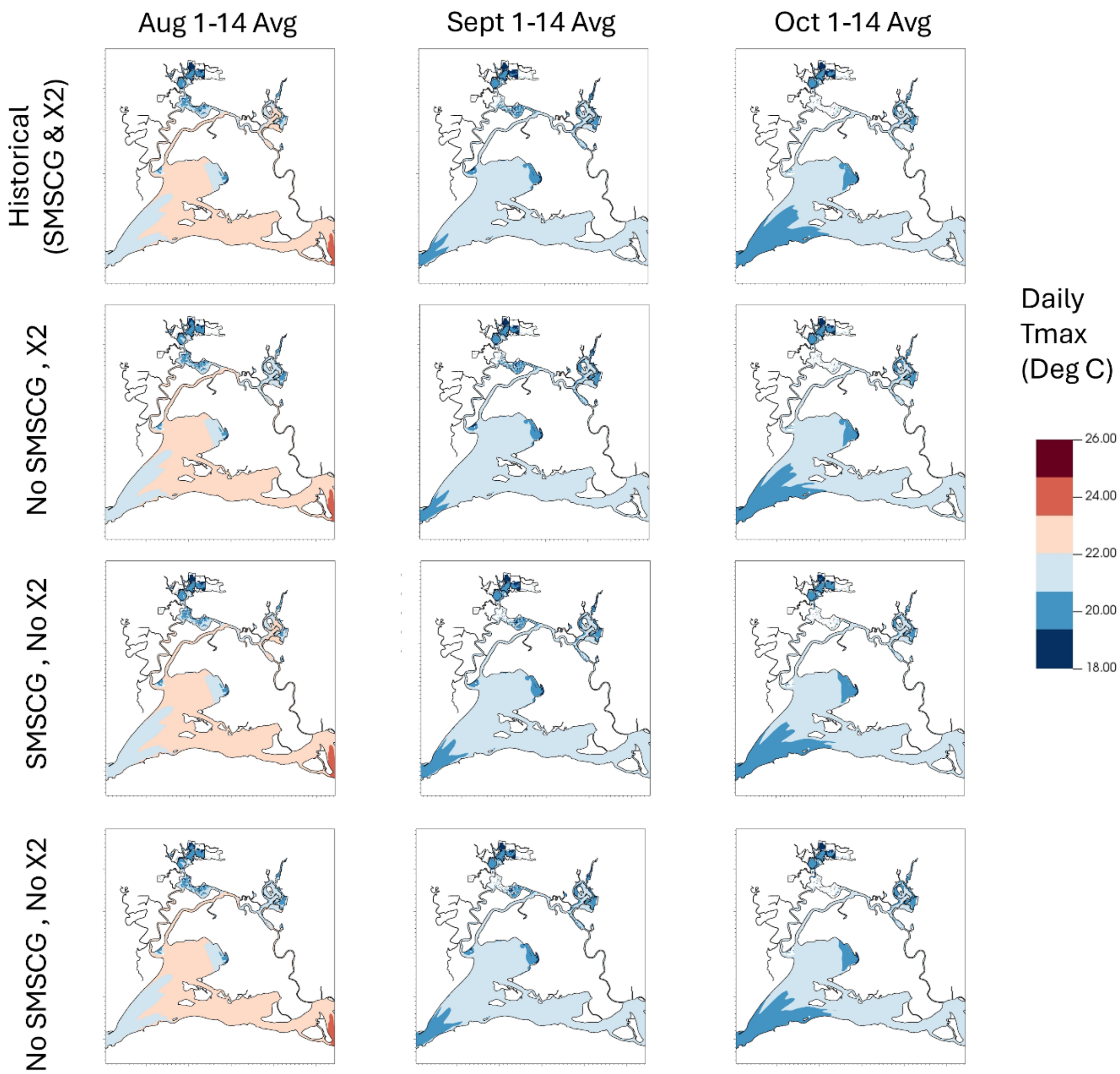

Figure 21. 14-day average of daily maximum temperature for the historical and alternate scenarios.

A spatial plot that combines the LSZ and spatial temperature was created by assigning 1 to elements that met the LSZ of 6 daily-average PSU and the temperature threshold of less than daily average 22 °C and 0 to when they are not met. A 14-day average of the combined habitat is shown in Figure 22. In this plot, one means 100 % time meets the criteria and zero otherwise during the 14 days. This shows increased habitat in western Montezuma slough, Suisun slough and Hill slough complex. Figure 23 shows a time series of the area appropriate for Delta Smelt habitat which meets the combined criteria of less than 6 PSU for salinity and less than 22 °C for temperature.

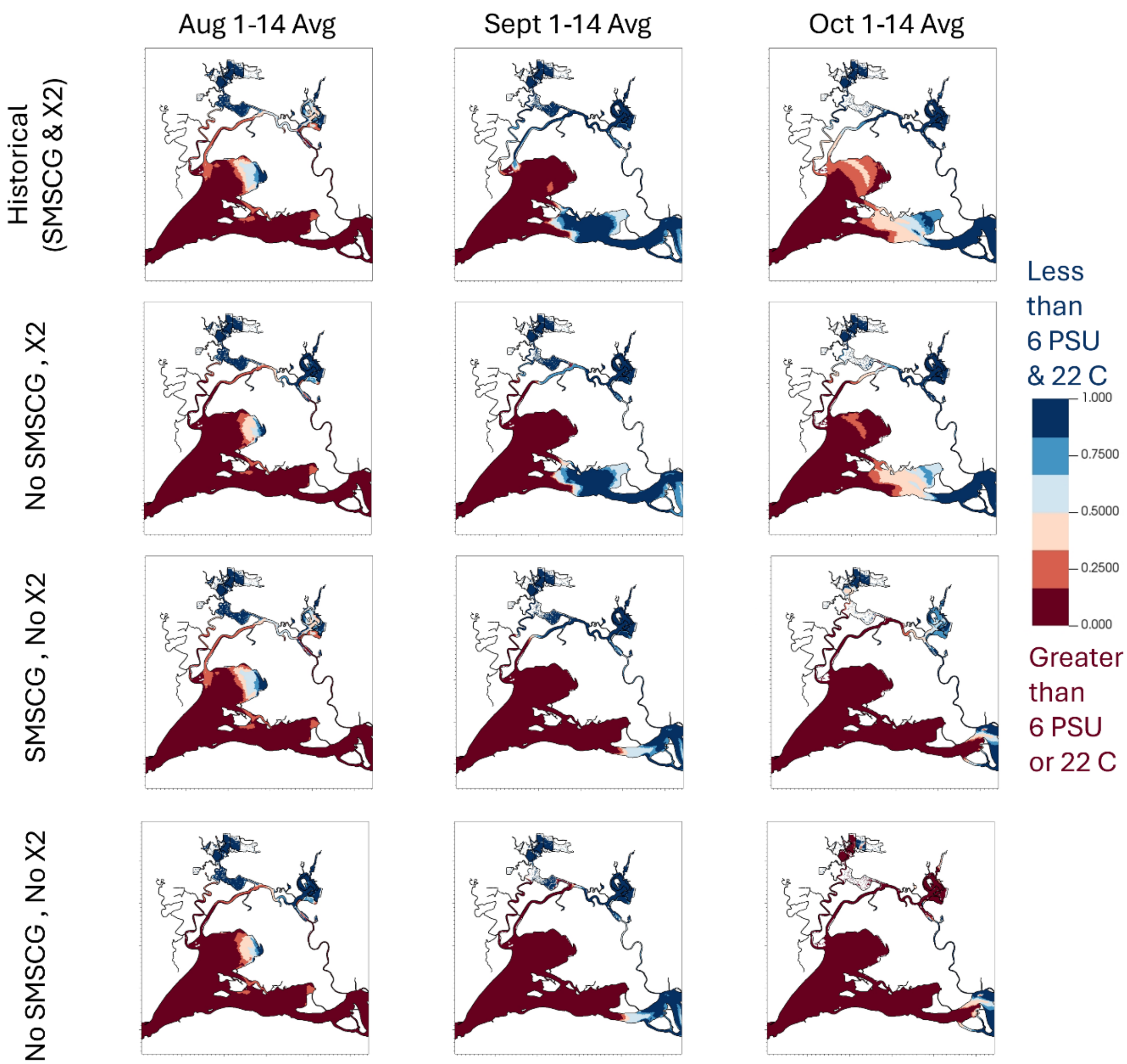

Figure 22. Map of appropriate Delta Smelt habitat (less than 6 PSU and less than 22°C) in the historical and alternate scenarios. Colors indicate proportion of the 14-day time period that both parameters were suitable, with 1 being 14 days and 0 being 0 days.

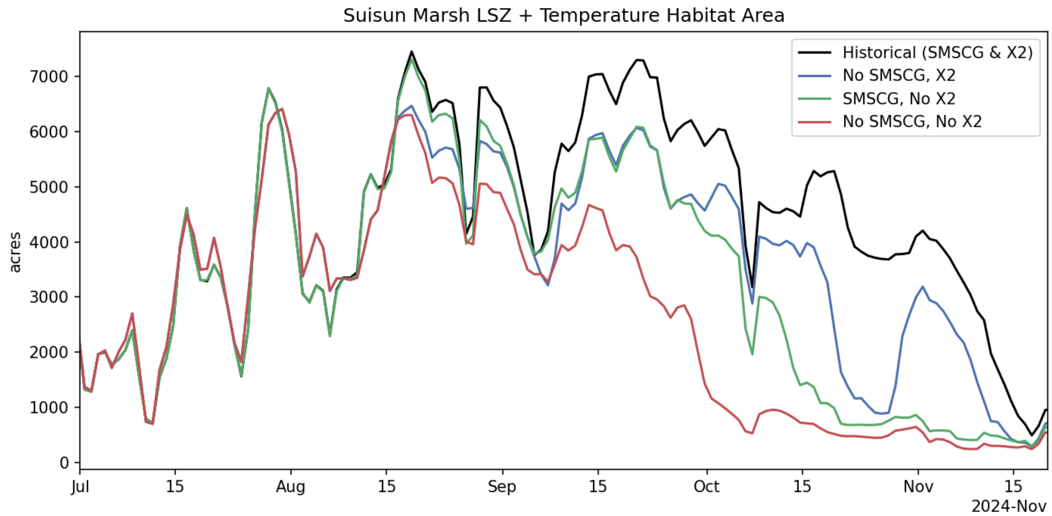

Figure 23. Area appropriate smelt habitat that is both less than 6 PSU and less than 22°C in Suisun Marsh for the summer-fall habitat action (July-October). Black line shows historical habitat area, blue, green and red line shows the alternate scenarios.

When comparing the LSZ area in 2024 to previous years (Figure 24), we can see that less habitat was available in both Suisun Bay and Suisun Marsh than previous action years (2023 and 2017), but more was available than in the non-action years of 2016 and 2020. Habitat area was similar to 2010, at times being higher, and at other times being lower. Please note that the modeling grid was updated in 2024 to include new areas of tidal wetland restoration, increasing the total area of the Suisun marsh region by approximately 3,000 acres. Therefore, we present the habitat comparison as a percentage of the total for that year, rather than the absolute acreage.

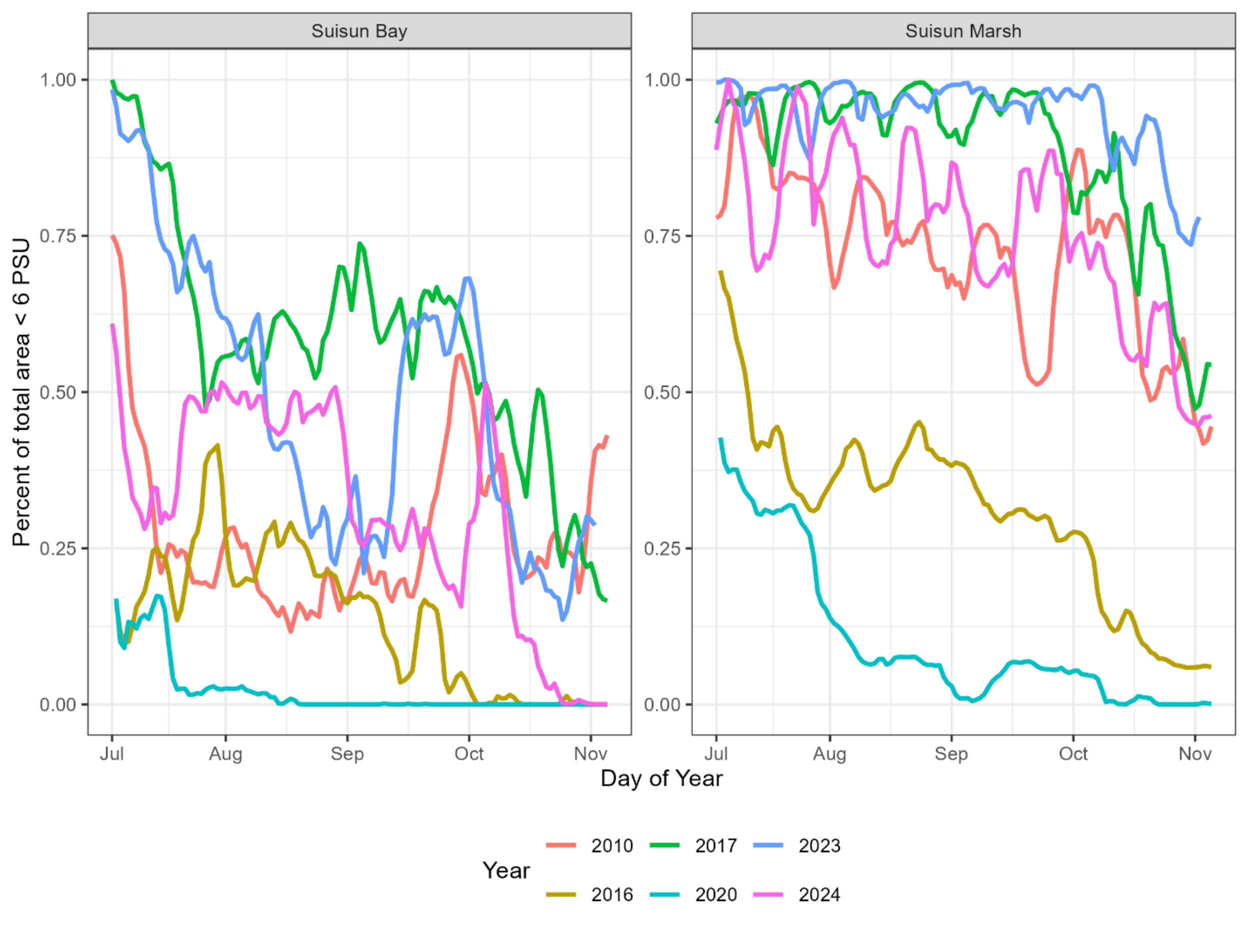

Figure 24. Percent of total wetted area less than 6 PSU in Suisun Bay and Suisun Marsh during the summer of 2010, 2016, 2017, 2020, 2023, and 2024.

Zooplankton

STN and FMWT collected 108 mesozooplankton samples in the SMSCG footprint in 2024. ICF collected an additional 32 mesozooplankton samples at Belden's landing and Grizzly Bay. Total zooplankton biomass was relatively low across all three regions, though was higher in the River than Suisun Bay or Suisun Marsh (Figure 25). *Pseudodiaptomus* biomass in 2024 was higher than previous dry years (2012-2016, 2020-2022), but lower than the wet year of 2023, and higher in the River region than Suisun Bay or Suisun Marsh (Figure 26, Table 5). The cyclopoid copepod, *Limnoithona tetraspina*, was extremely variable and not correlated with wet or dry years, with the highest biomass in Suisun Bay of 2017 (Table 6; Figure 27). Biomass of the calanoid copepod *Eurytemora carolleeae* was also highly variable, with the highest biomass in Suisun Marsh (Figure 28; Table 7). It did not show any clear responses to flow actions during the summer. Biomass of *Limnoithona sp*. and *Eurytemora* sp. were both several orders of magnitude lower than *Pseudodiaptomus sp.* (Figure 25).

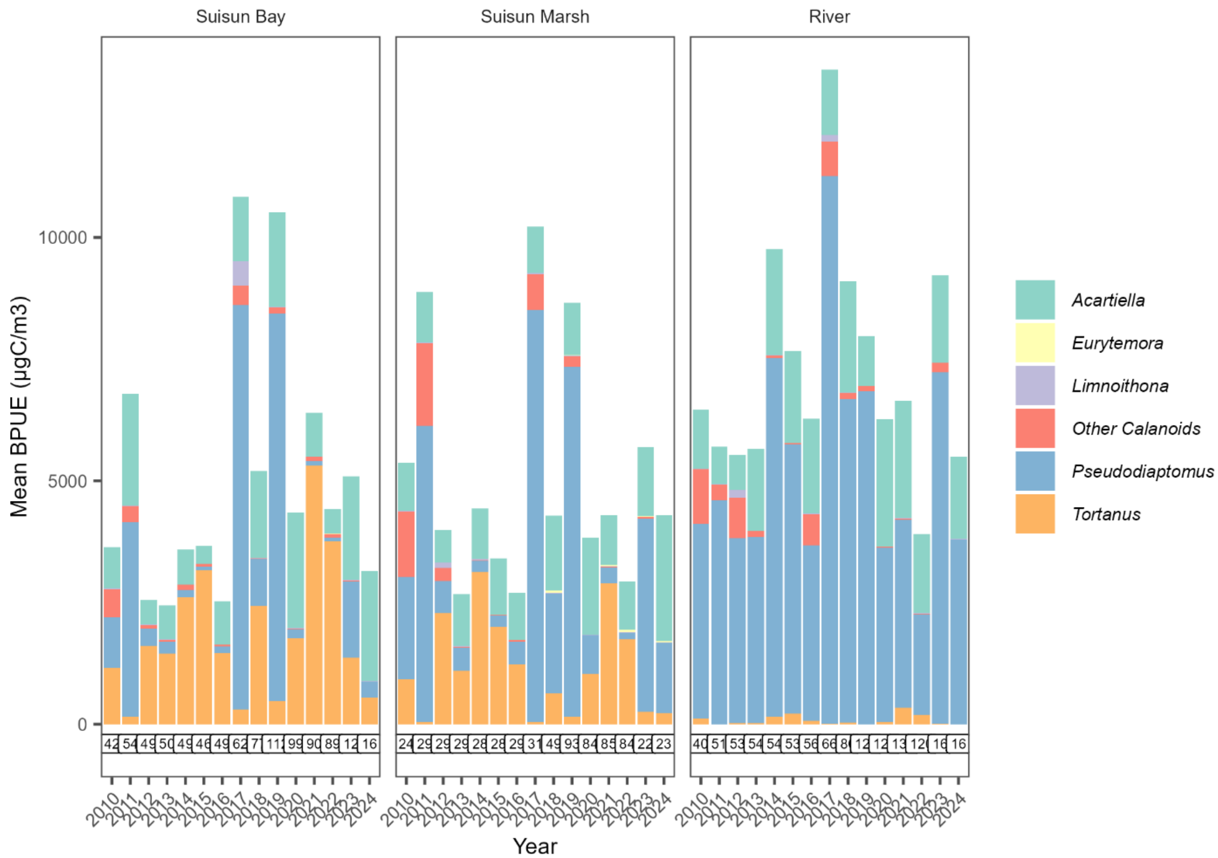

Figure 25. Mean biomass (Jun-Oct) of each of the major copepod taxa by region and year from 2010-2024. Number of samples is noted below each bar.

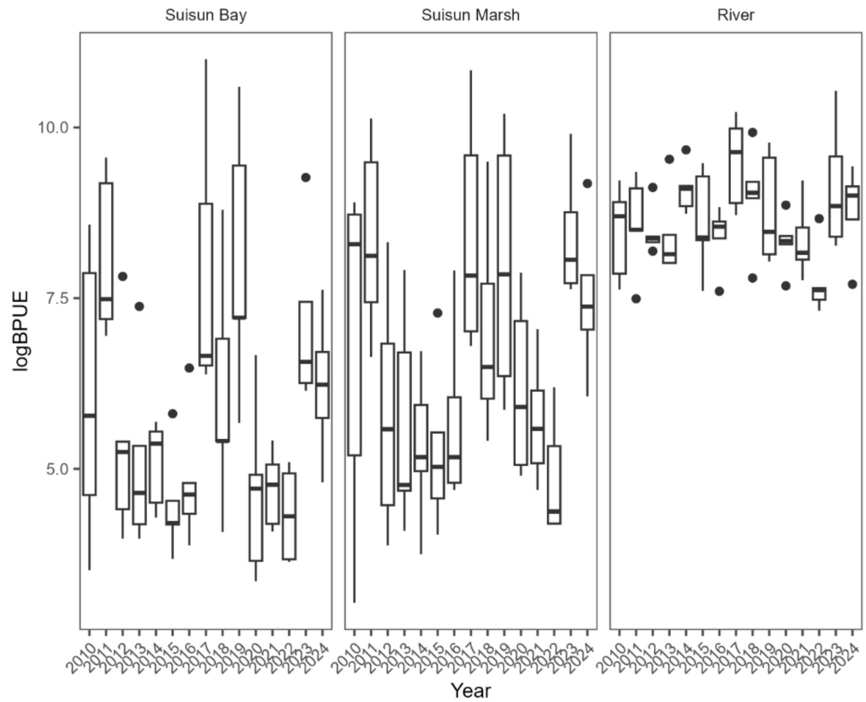

Figure 26. Box plots showing biomass of *Pseudodiaptomus sp*. by region and year.

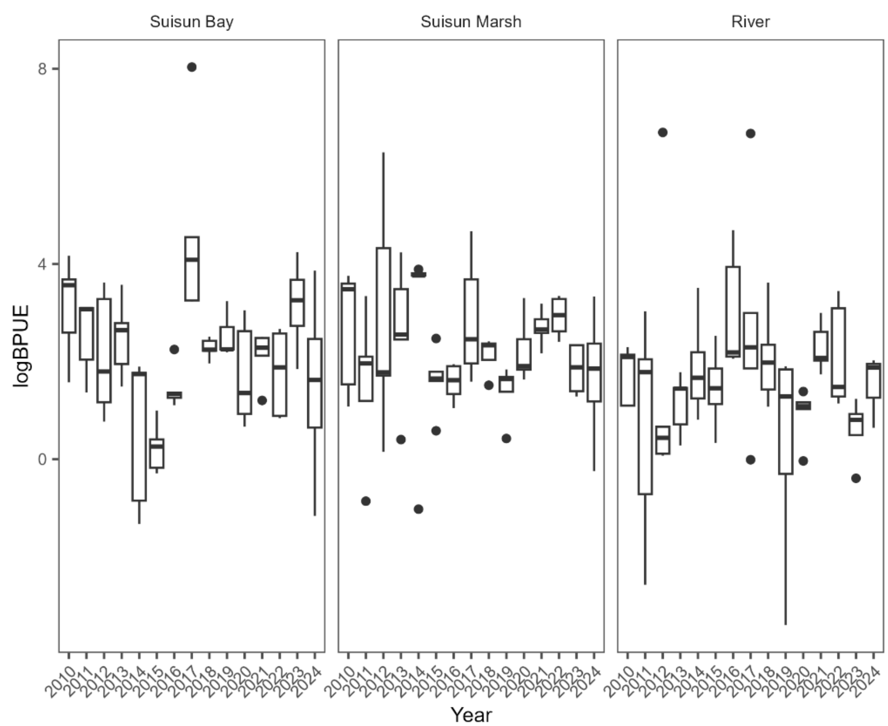

Figure 27. Box plots showing biomass of *Limnoithona sp*. by region and year.

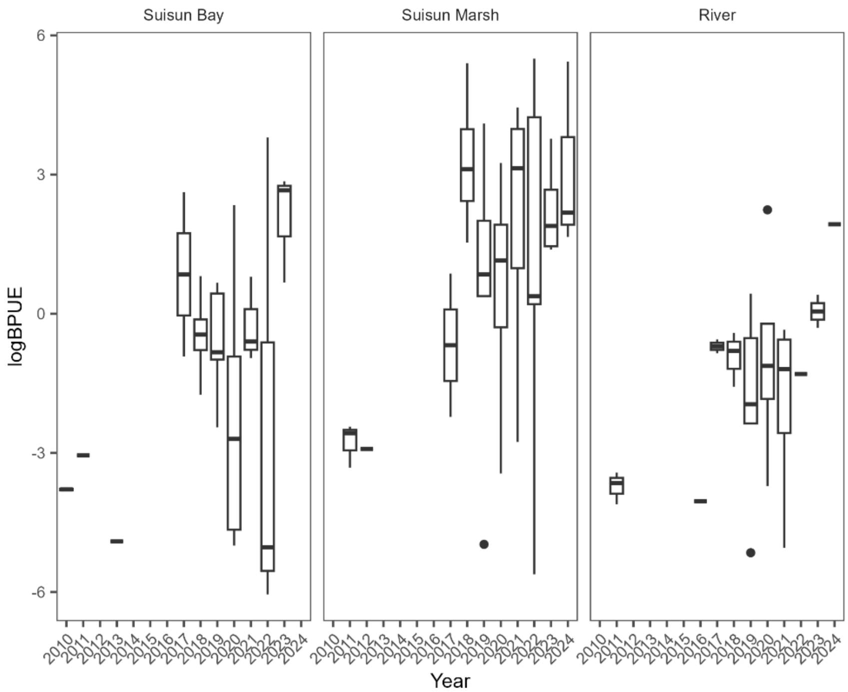

Figure 28. Box plots showing biomass of *Eurytemora carolleeae* by region and year.

Table 5. Results of linear mixed model of *Pseudodiaptomus sp*. biomass versus region, year, and the interaction of region and year. * = significant at the p<0.001 level. ** = significant at the p < 0.01 level. * = significant at the p < 0.05 level.**

	Estimate	Std. Error	df	t value	Pr(>|t|)	Sig.
(Intercept: 2024, Suisun Marsh)	7.58	0.51	10.68	14.77	<0.0001	***
Region- River	1.47	0.50	1679.01	2.93	0.0035	**
Region- Suisun Bay	-1.51	0.50	1679.05	-3.01	0.0027	**
Year- 2023	0.94	0.46	1679.01	2.05	0.0406	*
Year- 2022	-3.17	0.36	1679.11	-8.72	<0.0001	***
Year- 2021	-2.43	0.36	1679.10	-6.70	<0.0001	***
Year- 2020	-2.14	0.36	1679.14	-5.88	<0.0001	***
Year- 2019	-0.04	0.36	1679.13	-0.10	0.9173	
Year- 2018	-1.42	0.39	1679.07	-3.64	0.0003	***
Year- 2017	0.41	0.42	1679.12	0.97	0.3336	
River:2023	-0.67	0.71	1679.00	-0.94	0.3467	
Suisun Bay:2023	-0.32	0.75	1679.02	-0.43	0.6676	
River:2022	0.92	0.55	1679.00	1.69	0.0916	
Suisun Bay:2022	0.93	0.55	1679.02	1.68	0.0941	
River:2021	0.90	0.55	1679.01	1.65	0.0989	
Suisun Bay:2021	0.39	0.55	1679.04	0.71	0.4787	
River:2020	0.52	0.55	1679.01	0.96	0.3374	
Suisun Bay:2020	-0.12	0.55	1679.04	-0.22	0.8266	
River:2019	-0.73	0.54	1679.01	-1.35	0.1787	

	Estimate	Std. Error	df	t value	Pr(>|t|)	Sig.
Suisun Bay:2019	0.87	0.55	1679.07	1.58	0.1132	
River:2018	0.64	0.57	1679.01	1.12	0.2625	
Suisun Bay:2018	0.31	0.58	1679.03	0.54	0.5914	
River:2017	-0.55	0.60	1679.01	-0.92	0.3588	
Suisun Bay:2017	0.78	0.61	1679.06	1.29	0.1989	

Table 6. Results of linear model of *Limnoithona sp*. biomass by region and year, and the interaction between region and year.. * = significant at the p<0.001 level. ** = significant at the p < 0.01 level. * = significant at the p < 0.05 level.**

	Estimate	Std. Error	df	t value	Pr(>|t|)	Sig.
(Intercept: 2024, Suisun Marsh)	1.84	0.27	860.43	6.87	<0.0001	***
Region- River	-0.88	0.41	1679.37	-2.14	0.0324	*
Region- Suisun Bay	-0.06	0.41	1680.36	-0.15	0.8837	
Year- 2023	-0.34	0.37	1679.19	-0.90	0.3656	
Year- 2022	0.50	0.30	1681.62	1.69	0.0904	.
Year- 2021	0.47	0.30	1681.49	1.59	0.1128	
Year- 2020	-0.55	0.30	1682.23	-1.85	0.0649	.
Year- 2019	-0.82	0.29	1681.96	-2.79	0.0053	**
Year- 2018	-0.24	0.32	1680.75	-0.76	0.4482	
Year- 2017	0.64	0.35	1681.77	1.86	0.0637	.
River:2023	0.16	0.58	1679.10	0.28	0.7788	
Suisun Bay:2023	0.76	0.61	1679.45	1.24	0.2149	
River:2022	-0.28	0.45	1679.10	-0.62	0.5336	
Suisun Bay:2022	-0.73	0.45	1679.68	-1.62	0.1052	
River:2021	0.28	0.44	1679.19	0.63	0.5273	
Suisun Bay:2021	-0.63	0.45	1680.14	-1.39	0.1650	
River:2020	0.29	0.45	1679.35	0.65	0.5127	
Suisun Bay:2020	-0.25	0.45	1680.23	-0.56	0.5760	
River:2019	0.26	0.44	1679.39	0.58	0.5618	
Suisun Bay:2019	0.72	0.45	1680.79	1.61	0.1081	
River:2018	0.32	0.47	1679.25	0.69	0.4933	
Suisun Bay:2018	0.12	0.47	1679.94	0.26	0.7984	
River:2017	-0.08	0.49	1679.42	-0.16	0.8697	
Suisun Bay:2017	1.15	0.49	1680.69	2.33	0.0200	*

Table 7. Results of linear model of *Eurytemora carolleeae* biomass by region, year, and the interaction between region and year. * = significant at the p<0.001 level. ** = significant at the p < 0.01 level. * = significant at the p < 0.05 level.**

	Estimate	Std. Error	df	t value	Pr(>|t|)	Sig
(Intercept: 2024, Suisun Marsh)	1.58	0.23	46.61	6.81	<0.0001	***
Region- River	-1.27	0.31	1679.06	-4.13	<0.0001	***
Region- Suisun Bay	-1.62	0.31	1679.20	-5.30	<0.0001	***
Year- 2023	0.18	0.28	1679.03	0.63	0.5295	
Year- 2022	-0.85	0.22	1679.41	-3.81	0.0001	***
Year- 2021	-0.52	0.22	1679.38	-2.34	0.0196	*
Year- 2020	-0.91	0.22	1679.55	-4.10	<0.0001	***
Year- 2019	-0.87	0.22	1679.48	-3.99	0.0001	***
Year- 2018	-0.20	0.24	1679.26	-0.83	0.4091	
Year- 2017	-1.36	0.26	1679.44	-5.25	<0.0001	***
River:2023	-0.31	0.43	1679.02	-0.71	0.4760	
Suisun Bay:2023	0.80	0.46	1679.07	1.76	0.0781	.
River:2022	0.57	0.33	1679.02	1.71	0.0879	.
Suisun Bay:2022	1.09	0.34	1679.10	3.21	0.0013	**
River:2021	0.31	0.33	1679.03	0.92	0.3576	
Suisun Bay:2021	0.71	0.34	1679.16	2.09	0.0365	*
River:2020	0.75	0.33	1679.05	2.26	0.0242	*
Suisun Bay:2020	1.20	0.34	1679.18	3.56	0.0004	**
River:2019	0.70	0.33	1679.06	2.10	0.0361	*
Suisun Bay:2019	1.27	0.33	1679.26	3.79	0.0002	***
River:2018	-0.07	0.35	1679.04	-0.19	0.8498	
Suisun Bay:2018	0.52	0.35	1679.13	1.47	0.1411	
River:2017	1.15	0.37	1679.06	3.12	0.0019	**
Suisun Bay:2017	1.79	0.37	1679.25	4.85	<0.0001	***

Delta Smelt Status

The STN and FMWT have historically provided abundance indices for Delta Smelt in the summer and fall periods, respectively. However, Delta Smelt numbers have declined below the detection limits of both surveys. Neither the STN nor the FMWT surveys captured any Delta Smelt at their fixed index stations in 2024, making a 0 index for both surveys.

EDSM Delta Smelt catch and abundance estimates in summer-fall period 2024 were lower than the summer-fall period of 2023 (Table 8, Figure 30) Several larval osmerids were caught in the Sacramento Ship Channel in June (Figure 29). However, preliminary genetic confirmation data show that many of the larval fish preliminarily identified as Delta Smelt in 2024 were actually Wakasagi (*Hypomesus nipponensis)*, so all larval fish without genetic confirmation have been reported as "*Hypomesus* sp." Due to preservation in formalin, the remaining fish cannot be verified.

Only one juvenile Delta Smelt was caught in the Suisun Region during the summer-fall action period (June-October) of WY 2024 (Figure 29, Table 8).

Table 8. Delta Smelt catch, from June 1-October 31, 2024. Genetic identification of some of the osmerid larvae collected in 2024 showed that they were Wakasagi, not Delta Smelt as originally reported. Due to preservation in formalin, the remaining fish cannot be verified.

Date	Survey	Fork Length	Location	Identity
2024-06-04	USFWS EDSM	12.5	Sacramento Ship Channel	*Hypomesus* sp
2024-06-04	USFWS EDSM	15	Sacramento Ship Channel	*Hypomesus* sp
2024-06-04	USFWS EDSM	13.8	Sacramento Ship Channel	*Hypomesus* sp
2024-06-06	USFWS EDSM	12	Sacramento Ship Channel	*Hypomesus* sp
2024-06-11	USFWS EDSM	12.1	Cache Slough	*Hypomesus* sp
2024-06-11	USFWS EDSM	11.8	Sacramento Ship Channel	*Hypomesus* sp
2024-06-13	USFWS EDSM	12.8	Sacramento Ship Channel	*Hypomesus* sp
2024-06-13	USFWS EDSM	14.8	Sacramento Ship Channel	*Hypomesus* sp
2024-06-13	USFWS EDSM	21.5	Sacramento Ship Channel	*Hypomesus* sp
2024-06-13	USFWS EDSM	13.6	Sacramento Ship Channel	*Hypomesus* sp
2024-06-13	USFWS EDSM	11.5	Sacramento Ship Channel	*Hypomesus* sp
2024-06-13	USFWS EDSM	11.9	Sacramento Ship Channel	*Hypomesus* sp
2024-06-13	USFWS EDSM	13	Sacramento Ship Channel	*Hypomesus* sp
2024-06-13	USFWS EDSM	14	Sacramento Ship Channel	*Hypomesus* sp
2024-06-13	USFWS EDSM	12.3	Sacramento Ship Channel	*Hypomesus* sp
2024-06-13	USFWS EDSM	13.1	Sacramento Ship Channel	*Hypomesus* sp
2024-06-13	USFWS EDSM	15	Sacramento Ship Channel	*Hypomesus* sp
2024-06-13	USFWS EDSM	10	Sacramento Ship Channel	*Hypomesus* sp
2024-06-13	USFWS EDSM	12.1	Sacramento Ship Channel	*Hypomesus* sp
2024-06-13	USFWS EDSM	12.6	Sacramento Ship Channel	*Hypomesus* sp
2024-06-13	USFWS EDSM	13.2	Sacramento Ship Channel	*Hypomesus* sp
2024-06-21	USFWS EDSM	27	Sacramento Ship Channel	*Hypomesus* sp
2024-07-07	USFWS EDSM	50	Suisun Bay	Delta Smelt

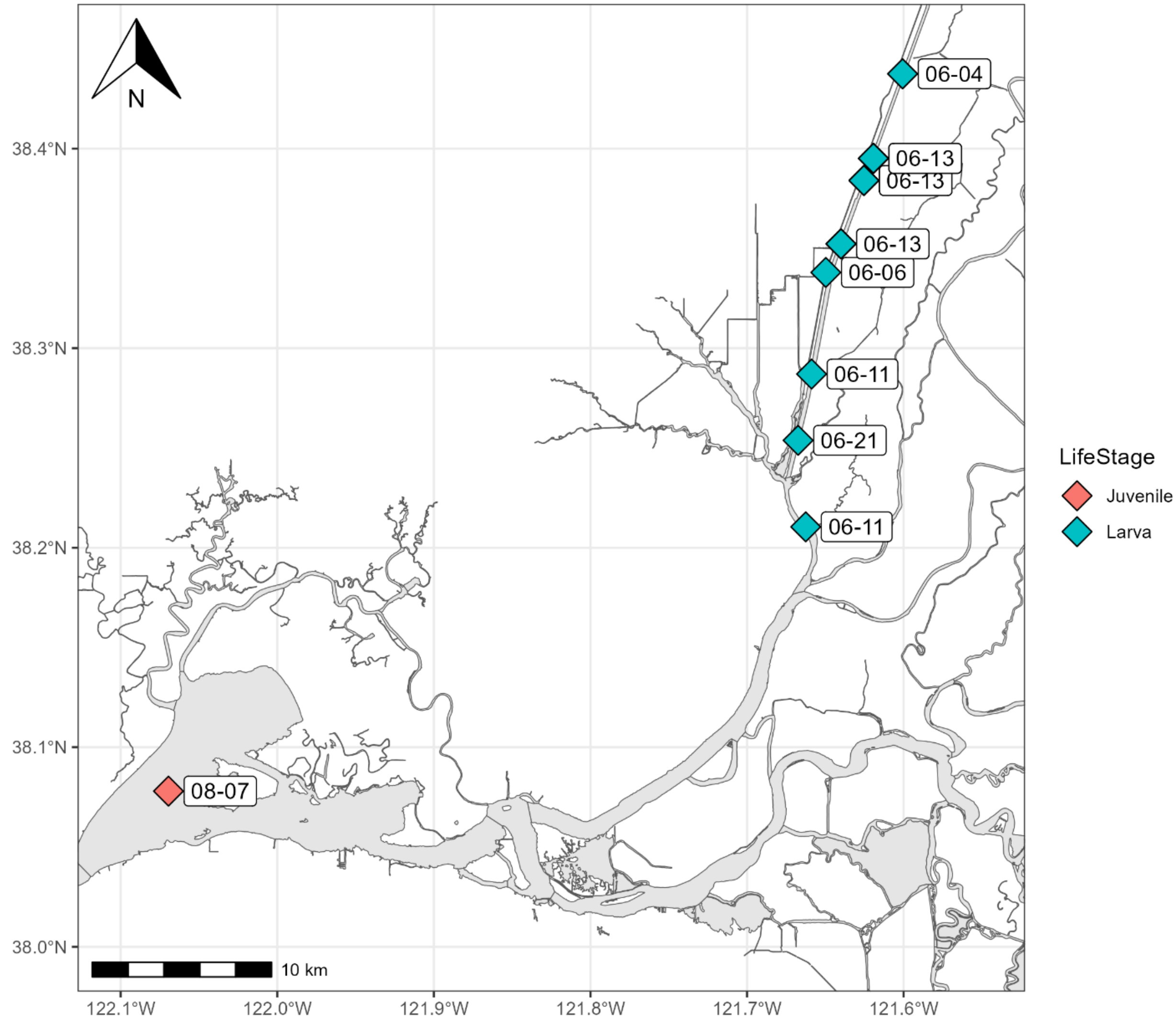

Figure 29. Map of EDSM osmerid catch during the summer-fall action period (June 1 - October 31, 2024). The date of each capture (Month-Day) is indicated next to the point. Note that larval osmerids caught in June of 2024 were not genetically identified and may be Wakasagi, not Delta Smelt.

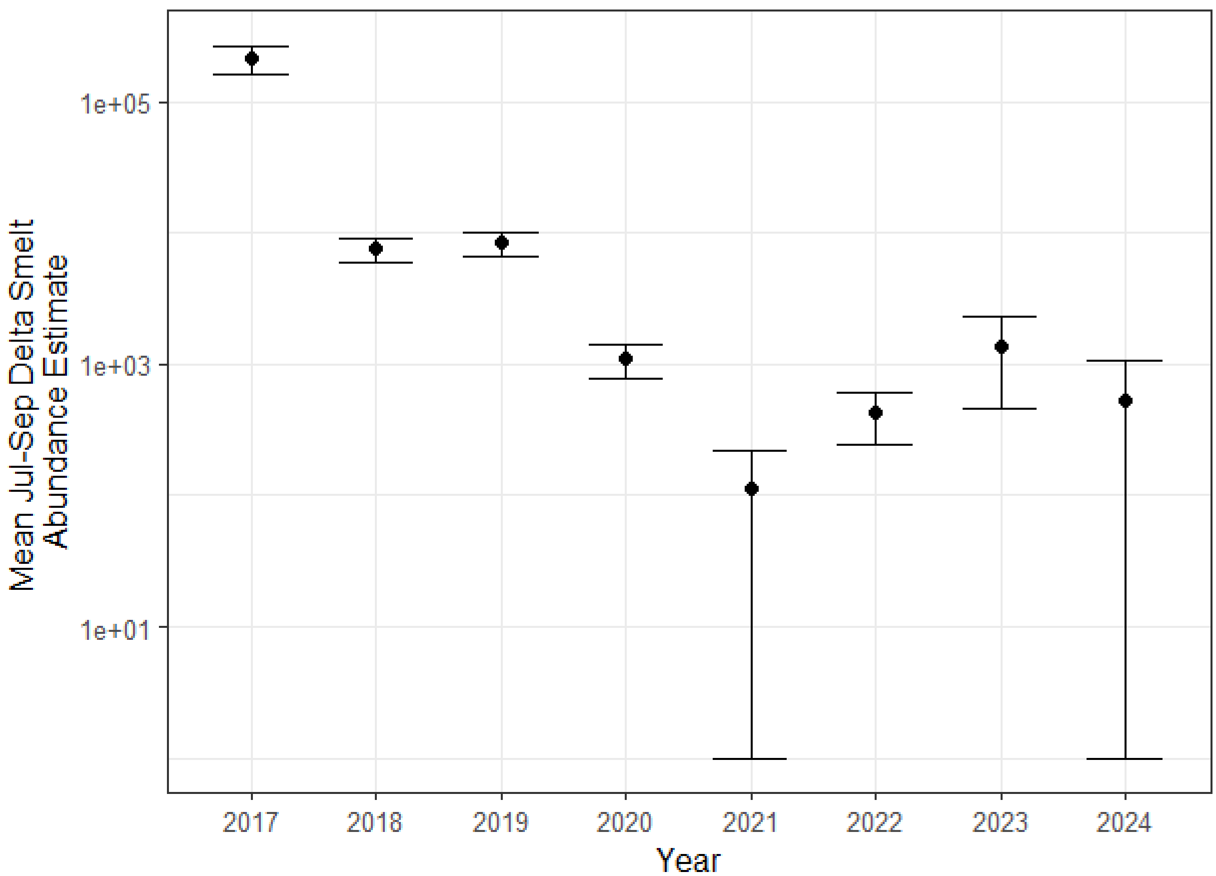

Figure 30. Average Delta Smelt abundance estimate for July 1 through September 30. Abundance estimates are calculated by EDSM on a weekly basis, then summarized by calculating the average and standard error over the summer-fall habitat season. Plot courtesy of Lara Mitchell, USFWS.

Delta Smelt Cage Deployments

The results presented here should be considered preliminary and will be updated in a separate enclosure report after all data are fully analyzed. The cages deployed at Belden's Landing were anchored with the same 130-pound pyramid anchors as in 2023. However, in 2024 the anchors did not stay in place, moving several times over the course of the deployment. This resulted in smelt potentially experiencing more banging, impingement on the cages, and other sources of stress than the fish at Rio Vista. After three attempts to secure the cages, the deployment was cut from 6-weeks to 4-weeks. Therefore, differences between sites may have been partially due to differences in handling stress rather than from habitat conditions. Biofouling of cages in 2024 was similar to 2023, but because results from 2023 indicated no difference in smelt responses from biofouling treatments, we only scrubbed the cages from the outside to reduce biofouling and did not exchange the cages.

Survival was highly variable, ranging from 52% to 90% of fish remaining in the field enclosures after four weeks (Figure 31). Survival tended to be lower in cages at Montezuma than at Rio

Vista (ANOVA p-value 0.03), and all field enclosures had lower survival than the control at FCCL (which had 98% survival). Only a single FCCL replicate was used, so statistical comparisons are not available. Fish in enclosures at Rio Vista also had significantly higher condition factor than fish at Montezuma (ANOVA F-value 32.599, p-value <0.0001; Figure 32), and fish in both field enclosures had significantly lower condition factor than FCCL (tukey post-hoc p-value <0.0001).

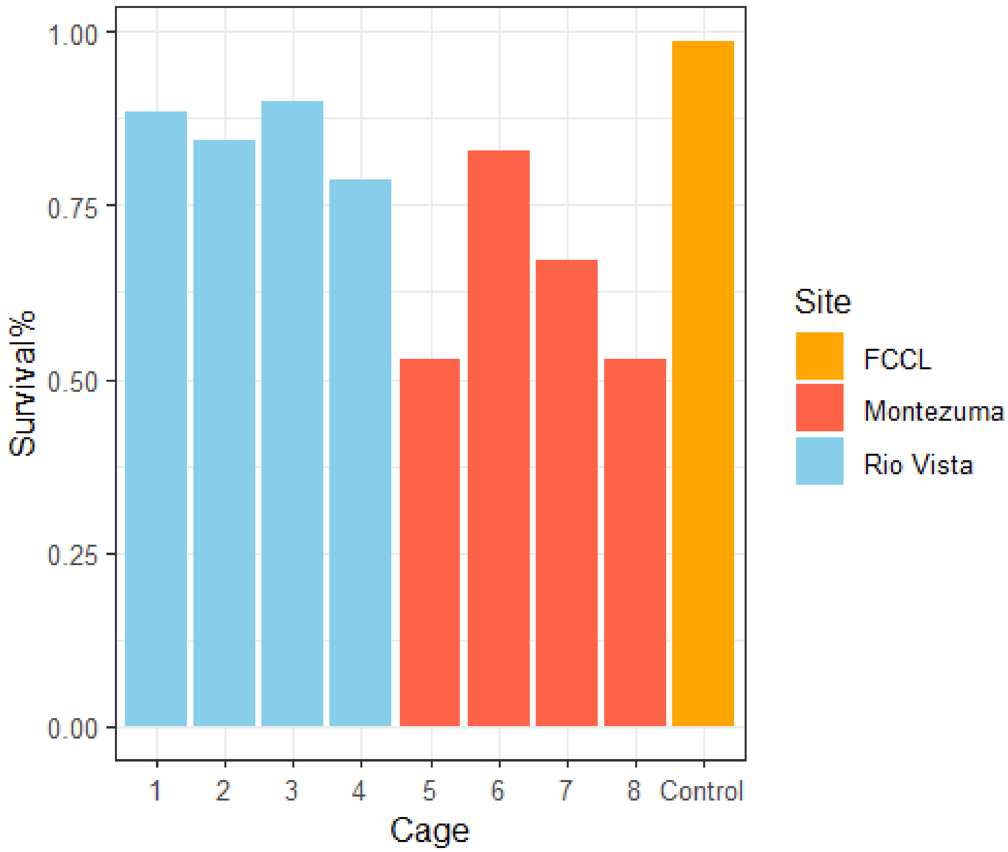

Figure 31. Survival of Delta Smelt in cages by site (Rio Vista, Belden's Landing or FCCL control).

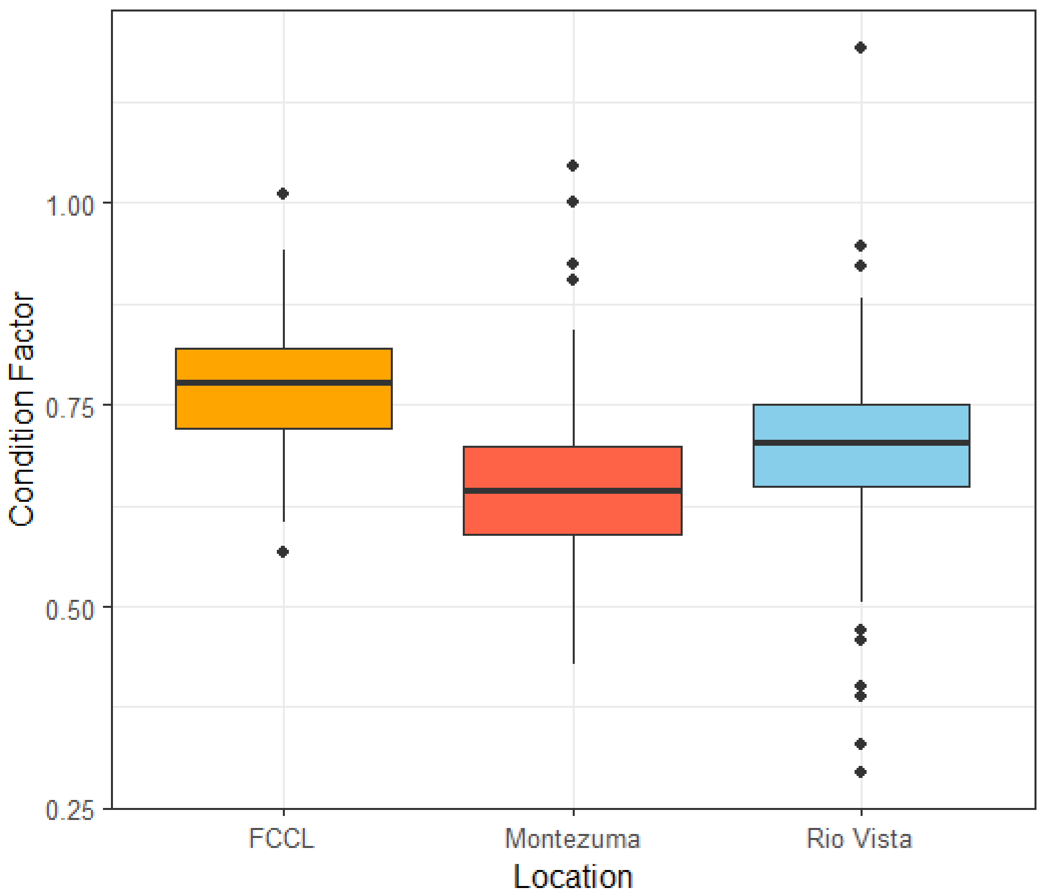

Figure 32. Box plots of Delta Smelt condition factor after four weeks at the Fish Conservation and Culture facility (FCCL), Montezuma Slough at Belden's Landing (Montezuma) and Rio Vista (Condition factor = Weight in mg/Fork Length cubed * 100).

Flow Action Discussion

The 2024 Sacramento Valley Water Year designation was Above Normal, and the summer-fall SMSCG and Fall X2 actions occurred. In wetter years, Delta Smelt habitat is expected to have higher quality and quantity than in drier years due to the increased Delta outflow. Most of this increase in outflow is from increased snowmelt, increased reservoir releases for flood control, and an increase in runoff from below the major reservoirs rather than from higher outflow requirements listed in regulatory permits (Gartrell et al. 2022). However, the Fall X2 and SMSCG actions, when taken in wetter year types, add to this higher flow in order to maintain the benefits caused by high precipitation throughout the summer and fall. In 2024, flow during the beginning of the summer was lower than in the other action years, which were all wet years, but higher than below normal, dry, or critically dry years, indicating that some amount of increased outflow may have been due to higher precipitation.

Suitable Delta Smelt habitat measured at continuous stations across the monitoring region demonstrated that the number of days with suitable salinity in Suisun Marsh in 2024 was similar to other years with an X2 action (2017 and 2019, 2023) or a SMSCG action (2018, 2023). Hindcast modeling showed that the area of LSZ habitat in Suisun Marsh increased during the SMSCG action, adding an additional 500 acres in July, 800 in August, and 1100 in September (on average) versus an X2-only scenario. Even in October, after the gate actions had been completed, salinity in Suisun Marsh remained lower than in an X2-only scenario. The X2 action also improved habitat in Suisun Marsh, adding 270 in August, 1,500 acres in September, and 2400 acres in October, on average. This increase is somewhat lower than was seen in 2023 (Figure 24) due to the shorter Fall X2 action and drier conditions overall.

Submerged and floating aquatic vegetation in the Marsh was variable, with almost 10% of the East Marsh covered by SAV, but only 4.5% of the west marsh covered by SAV. This may be due to the lower salinity in the East Marsh which provides better habitat for many aquatic invasive species. Coverage was particularly high in the Nurse Slough Complex, an area with several tidal wetland restoration sites (Figure 16). The high density of SAV in this area may have limited its effectiveness in providing habitat for Delta Smelt this year. Floating vegetation was much lower, less than 1% of the total tidal area, so was unlikely to have impacted availability of smelt habitat.

Number of days of suitable salinity and area of the LSZ in Suisun Bay were lower than previous action years because the X2 standard was only in place in September, not September and October as in previous years. Area of the LSZ in Suisun Bay did improve with the X2 action in in August, September, and October (average increase of 2,500, 5700 and 2421 acres. respectively). While no X2 standard was in place in October, holdover effects of the September action served to keep salinity lower than it would have been with no September action (Figure 22). Operation of the SMSCG also decreased salinity in Suisun Bay, primarily in the north-west end of Grizzly Bay, near the mouth of Montezuma Slough, seeing an increase of 400 acres in July, 1,400 acres in August, 680 acres in September, and 1500 acres in October (Figure 22).

Submerged and floating aquatic vegetation in the Bay was much lower than in the Marsh, with less than 1% of total area covered by SAV (Figure 14), and a lower percentage of FAV (Figure 12). This low percentage was unlikely to have significantly impacted availability of smelt habitat.

Despite the improved salinity, high water temperatures (>22°C) likely limited the benefits of the actions. There were 18 days where temperatures were too hot for positive Delta Smelt growth in Suisun Bay and 32 days where temperatures were too hot for positive Delta Smelt growth in Suisun Marsh. This is similar to 2022 and 2020, though slightly better than 2023, 2019, and 2017 (Figure 11, Table 4). There were more days of overlap of all three key abiotic factors in Suisun Marsh and the Sacramento River (e.g., salinity, turbidity, and water temperature) than 2023, but less overlap in Suisun Bay (Figure 11, Table 4). There was less overlap of habitat in Suisun Marsh than 2018 and less overlap in Suisun Bay than in 2019 or 2017 (Figure 11, Table 4). Hindcast modeling indicated that the actions did not directly affect temperature in the region (Figure 21). However high temperatures did limit the available habitat more than salinity alone (Figure 22), with very little habitat in the Marsh or Bay less than 22°C in August. An analysis of the Fall X2 action of 2017 also concluded that high water temperatures may have limited the effectiveness of that action (FLOAT-MAST 2021; Smith and Nobriga, 2023).

The sudden increase in FAV during the past two years was largely driven by the aquatic fern, azolla, but invasion of Suisun Marsh by alligatorweed (*Alternanthera philoxeroides*) also played a role. Azolla is a freshwater genus with limited salinity tolerance, and although alligatorweed tolerates brackish water, it grows faster in freshwater. It seems likely that fresher conditions in the marsh during 2023 and 2024 contributed to the increase in FAV, though it is difficult to determine the relative contributions of naturally higher outflows versus management actions. While FAV area increased markedly during the past two years, it still occupied a very small overall proportion of the waterway area (Figure 12, Figure 15). Specifically, FAV covered 0.2% of the waterways across all three regions and 1.0% across the two marsh regions. Much of the area occupied by FAV in and around the marsh consisted of backwater areas likely inaccessible or otherwise unsuitable for Delta Smelt habitat and therefore not included in our area calculations (Figure 7, Figure 15).

For SAV, we focused our analysis and discussion on 2024, and cannot currently show patterns over time due to some recently-identified problems with differentiating mud flats from submersed vegetation. However, we are currently working on re-analyzing data from previous years to provide a time series of SAV coverage to be included in the SFHA synthesis report in fall of 2025. There was higher coverage of SAV in the East Marsh than West marsh, which may be due to lower salinity in the East Marsh, or the higher density of smaller sloughs with lower velocities. SAV species cannot be distinguished from the imagery, though additional analysis of ground truthing field data could provide some information about species composition. The most common SAV species across Suisun Marsh is sago pondweed *(Stuckenia pectinata),* a native that tolerates brackish water. In future reports, we hope to include more discussion of patterns through time for SAV area, but we need to disentangle the algae-covered mudflat class from the SAV class in maps prior to 2024 first.

Biomass of the calanoid copepod, *Pseudodiaptomus sp*, in Suisun Marsh and Suisun Bay was higher in 2024 than previous dry years (2020-2022), but lower than in 2023 (Figure 25). This may have been due to the shorter extent of the X2 action, the generally lower outflow over the entire year, or a combination of the two. Despite being higher than previous no-action years, biomass of *Pseudodiaptomus* in Suisun Marsh and Suisun Bay was still lower than upstream in the lower Sacramento River Region. This pattern of increased *Psuedodiaptomus* biomass in the LSZ during flow action is corroborated by multiple other studies showing increased subsidy of *Pseudodiaptomus* during higher flow conditions (Kimmerer et al. 2018; Hassrick et al. 2024). We did not see clear patterns in biomass of *Eurytemora carolleea*e *or Limnoithona sp*. associated with flow actions, and these taxa had much lower biomass than *Pseudodiaptomus* across all regions. *E carolleeae* has generally low biomass during the summer and fall, though it is an important food source for Delta Smelt in the spring (Merz et al. 2016; Slater and Baxter 2014). *Limnoithona sp.* is frequently consumed by Delta Smelt in high numbers in the LSZ during the summer (Slater et al. 2019), but it is much smaller than the calanoid copepod taxa, so does not provide as much energy per individual (Rose et al. 2013), and is not sampled quantitatively with the 150-micron mesh net used in this study (Bashevkin et al. 2022).

We could not attribute changes in the distribution and abundance of Delta Smelt to the SFHA operations due to extremely low catch. Only one Delta Smelt was caught in Suisun Bay during the action period, and the salinity at which it was caught was above the 'low salinity zone' threshold of 6 PSU (Figure 29), so it is not clear whether the actions increased the likelihood of catching smelt in this area.

Ongoing attempts to determine whether Delta Smelt have higher growth and survival in Suisun Marsh or Sacramento River (Rio Vista) continued in WY 2024. We repeated the enclosure experiments from 2023, with four enclosures at Rio Vista and four at Belden's Landing to see whether smelt responded similarly. We found smelt survival and growth was higher at Rio Vista than Belden's Landing, similar to the results from 2023. The difference in growth and survival could be partially due to the specific locations where the enclosures were placed and biofouling on the surface of the cages rather than indicative of the habitat as a whole. Furthermore, the detachment of cages at Belden's landing this year may have influenced the results. However, the repeated trends in cage experiments in these two locations in 2019, 2023, and 2024 call into question the underlying hypothesis that Suisun Marsh is "better" habitat than upstream in the Sacramento River near Rio Vista.

Conclusions

Our findings only partially inform our hypotheses, with some benefits to Delta Smelt habitat and food availability, but potentially limited effectiveness due to high temperatures. Limited Delta Smelt catch data prevented us from fully evaluating our fundamental hypothesis about the impact of these actions on smelt growth and survival.

1. **Hypothesis: Maintaining and X2 of 80 km will increase the area and duration of Delta Smelt habitat in Suisun Bay with appropriate water temperatures, turbidity, and salinity, which will result in higher Delta Smelt growth and survival.**
   This hypothesis was partially supported.
   a. We found that the number of days with salinity less than 6 PSU in Suisun Bay in 2024 was lower than previous years with longer X2 actions and actions with lower X2 standards (2017, 2019, 2023). Temperatures again limited total number of suitable habitat days, but not as much as in 2023.
   b. Area of LSZ modeled with and without the action found that the action added several thousand acres of LSZ within Suisun Bay, though much of this area was warmer than desirable for smelt growth (> 22°C) in July and August. Area of the LSZ was lower than in previous years, most likely due to the shorter duration of the action.
   c. We did not have enough Delta Smelt catch data to assess the impact of better habitat on Delta Smelt growth and survival.

2. **Hypothesis: Maintaining and X2 of 80 km will increase biomass of calanoid copepods in the low salinity zone through increased transport of freshwater species from upstream, which will result in higher Delta Smelt growth and survival.**
This hypothesis was partially supported.
    a. Biomass of the calanoid copepod *Pseudodiaptomus sp.* was higher in 2024 than previous non-action years, though not as high as during the wetter action year of 2023 when the X2 action was longer.
    b. We did not have enough Delta Smelt catch data to credibly assess the impact of increased food on wild Delta Smelt growth and survival.

3. **Hypothesis: Operating the SMSCGs during the summer and fall will increase the duration and area of Delta Smelt habitat in Suisun Marsh with appropriate temperatures, turbidity, and salinity that can be accomplished with 100 TAF of water, which will result in higher Delta Smelt growth and survival.**
This hypothesis was partially supported.
    a. We found that the number of days with salinities below 6 PSU in Suisun Marsh was similar to other high-flow years (2017, 2019, 2023) and the 35-day SMSCG action in 2018, and high temperatures were less limiting than in 2023. Temperatures were higher in Suisun Marsh than Rio Vista in 2024, similar to 2023 but different from 2020-2022.
    b. Area of LSZ modeled with and without the action found that the action added several thousand acres of LSZ within Suisun Bay, though much of this habitat was warmer than desirable for smelt growth (> 22°C) in July and August. Area of the LSZ was lower than in previous years, most likely due to the shorter duration of the action.
    c. We did not have enough Delta Smelt catch data to credibly assess the impact of better habitat on wild Delta Smelt growth and survival. Cultured Delta Smelt in enclosures had lower growth and survival at Belden's Landing than Rio Vista, similar to 2023, which may refute the hypothesis that the marsh is better smelt habitat than the river; however, these results are likely due to cage effects rather than a broader indication of habitat quality.

4. **Hypothesis: Operating the SMSCGs during the summer and fall will increase biomass *of P. forbesi* in Suisun Marsh through increased transport from upstream, which will result in higher Delta Smelt growth and survival.**
This hypothesis was partially supported.
    a. Biomass of the calanoid copepod *Pseudodiaptomus sp.* was higher in 2024 than previous non-action years, though not as high as during the wetter action year of 2023.
    b. We did not have enough Delta Smelt catch data to assess the impact of increased food on wild Delta Smelt growth and survival.

5. **Hypothesis: Operating the SMSCGs will increase the area of appropriate Delta Smelt habitat in Grizzly Bay.**

   This hypothesis was partially supported.

   a. We found that low salinity zone habitat in Grizzly Bay was increased by several hundred acres during the SMSCG action in July and August. During August much of the low salinity habitat was above 22°C, meaning Delta Smelt growth was most likely low if they were occupying this area, however temperatures were mostly below the lethal limit (25-26°C), so fish would not experience direct mortality from these high temperatures.

Additional Food Web Actions

No food web actions were implemented in 2024, but monitoring and special studies were conducted to help inform their implementation in future years.

North Delta Food Subsidy

Background

Past North Delta Food Subsidies (NDFS) managed flow actions redirected agricultural drainage water or Sacramento River water into the Yolo Bypass Toe Drain to create positive net flow during the summer or fall when flows are typically net negative. These actions were intended to transport nutrients and upstream-produced phytoplankton and zooplankton (fish food) to increase the quality of habitat for Delta Smelt into the North Delta, including Cache Slough Complex (CSC) and potentially the lower Sacramento River. The flow actions have been accomplished by generating a flow pulse of approximately 15-30 thousand acre-feet in the Yolo Bypass Toe Drain during the summer or fall period for a period of 4-6 weeks. Those actions have been shown to transport lower trophic resources locally and potentially trigger a phytoplankton bloom downstream in some years (Frantzich et al. 2018, 2021), though results are potentially circumstantial with high variability across years (Davis et al. 2022).

Past flow actions fall into two categories: Sacramento River flow action (2016) and agricultural drainage flow actions (2018, 2019). The Sacramento River flow action involved rerouting Sacramento River water through the Colusa Basin to the Yolo Bypass Toe Drain (Frantzich et al. 2021). The agricultural drainage actions involved coordinating and redirecting agricultural drainage water from the Colusa Basin (primarily rice agriculture) through the Yolo Bypass (Davis et al. 2022). During flow actions, DWR altered the operation of the Knights Landing Outfall Gates (KLOG) and Wallace Weir (near Knights Landing, CA) to divert the flow pulses into the Yolo Bypass Toe Drain. The Sacramento River action occurred in July, a necessary timing constraint, which happened after rice field flooding and before drainage starts in mid-August. This action was coordinated among DWR, U.S. Bureau of Reclamation, and local irrigation and reclamation districts and required increased pumping of Sacramento River water in the Colusa Basin near Hamilton City, CA and through the Colusa Basin Drain and Knights Landing Ridge Cut (hereafter referred to as the Ridge Cut). Agriculture flow actions began in mid- to late-August, depending on timing of agricultural field drainage within the Colusa Basin Drain, and Yolo Bypass as determined by DWR and reclamation and irrigation districts. Coordinated draining amongst landowners as well as routing of water with the existing infrastructure was used to direct the agricultural tailwaters through the Yolo Bypass Toe Drain. In non-action years, a non-managed flow pulse can be observed due to local (Yolo Bypass) agricultural drainage in late-August and early-September. These non-managed pulses are generally of low magnitude (Davis et al. 2022).

Each year, DWR monitored continuous and discrete water quality parameters, phytoplankton, and zooplankton before, during, and after the NDFS flow actions at sites along a transect starting at the terminus of the Colusa Basin Drain, through the Ridge Cut, along the Yolo Bypass Toe Drain, and downstream into the Cache Slough Complex and lower Sacramento River (Figure 33). Sampling generally began in July or August and continued through November in years with non-managed flow pulses or agriculture actions. In 2016 with the Sacramento River action, sampling occurred earlier from June through September. Water quality parameters included temperature, dissolved oxygen (DO), conductivity, pH, turbidity, and secchi depth. Water samples for nutrients, phytoplankton, and zooplankton were collected concurrently with water quality measurements.

Introduction

Assessing Delta Smelt habitat quality is a vital component of designing appropriate conservation measures for recovery of the species. Any future summer-fall habitat management action in the North Delta must consider whether the action has the potential to positively impact the primary habitat quality factors and if the habitat has the capacity to remain suitably cool, provide ample food resources, and maintain low contaminant exposure. Failure to meet any of these habitat quality standards could negate gains in habitat quality from management actions and threaten the persistence of Delta Smelt.

The primary components of habitat suitability considered here include thermal stress, food availability, and contaminant exposure. Though not an exhaustive list, these components are thought to directly affect Delta Smelt growth and survival during stressful summer months (Mahardja et al. 2019, Stillway, et al. 2024). Additionally, food web components which could indirectly affect habitat quality are considered to assess the productive potential across the study area.

The present study differed from past years with increased focus on the Cache Slough Complex (CSC) rather than the traditional longitudinal transect which covered the Knights landing Ridgecut, through the Yolo Bypass Toe Drain and along the east margin of the CSC. The new sampling locations included areas in the northern and western CSC (Shag Slough, and Liberty Cut), as well as the Deepwater ship channel. This expansion came in response to work by Stumpner et al. (2020) which showed a high degree of spatial variability in nutrients and phytoplankton in these areas of the CSC which were not investigated under the traditional NDFS sampling transect. The expansion was also driven by a desire to capture conditions prior to the new tidal marsh restoration occurring in the CSC at Lookout Slough since we expect localized hydrodynamic and food web responses following restoration. Furthermore, given the consistency of the zooplankton community dominated by small-bodied cladoceran and cyclopoid zooplankton taxa, high thermal stress, and contaminant loading across past years in the Yolo Bypass Toe Drain (which is not habitable to Delta Smelt in the summer), sampling effort in the northern sites was reduced and shifted to downstream sites.

Methods

Sampling Locations:

Legacy sites along the longitudinal axis of the Yolo Bypass, through the CSC, and into the Lower Sacramento River were monitored with continuous sondes in 2024 to match previous years of NDFS sampling (RCS, RD22, I80, LIS, STTD, BL5, LIB, RYI, RVB; Table 9, Figure 33). However, sites in the Yolo Bypass Toe Drain were monitored with only continuous sondes while sites in the CSC and Lower Sacramento River included lower trophic sampling and experimental Delta Smelt enclosures (Table 9, Figure 33). New sampling sites for 2024 were added in Shag Slough (SHAS, SHAN), Liberty Cut (SSE), and in the Deepwater ship channel (DWSS, DWSN) and included lower trophic sampling as well as experimental Delta Smelt enclosures. A control site in the adjacent Sacramento River at Sherwood Harbor (SHR) was also concurrently sampled as in past seasons.

Table 9. Associated metadata pertaining to the sampling sites. Regions represent spatial groupings of sites. Solid squares indicate data type collected, open squares indicated no data collected.

Site	Name	Latitude	Longitude	Region	Lower Trophic	Encl. Smelt	Continuous WQ
RCS	Ridgecut Slough	38.7932	-121.726	Colusa Basin Drain	□	□	■
RD22	Toe Drain at Road 22	38.6775	-121.644	Yolo Bypass	□	□	■
I80	Toe Drain at I80	38.5747	-121.583	Yolo Bypass	□	□	■
LIS	Toe Drain at Lisbon	38.4759	-121.589	Yolo Bypass	□	□	■
STTD	Toe Drain terminus	38.3534	-121.643	CSC	■	□	■
SSE	Liberty Cut north end	38.3358	-121.668	CSC	■	□	□
SHAN	Shag Slough north	38.3220	-121.690	CSC	■	■	■
SHAS	Shag Slough south	38.2837	-121.692	CSC	■	■	■
DWSS	Deepwater Ship channel south	38.28813	-121.659	DWSC	■	■	■
DWSN	Deepwater Ship channel north	38.4171	-121.6104	DWSC	■	■	■
BL5	Prospect slough - Below Lisbon 5	38.2746	-121.665	CSC	■	■	□

Site	Name	Latitude	Longitude	Region	Lower Trophic	Encl. Smelt	Continuous WQ
LIB	Liberty Island at south breach	38.2404	-121.686	Confluence	■	■	■
RYI	Cache slough at Ryer Island	38.2143	-121.668	Confluence	■	▫	■
RVB	Rio Vista Bridge	38.1581	-121.683	Confluence	■	■	■
SHR	Sac. River at Sherwood Harbor	38.2746	-121.665	Sac River	■	■	▫

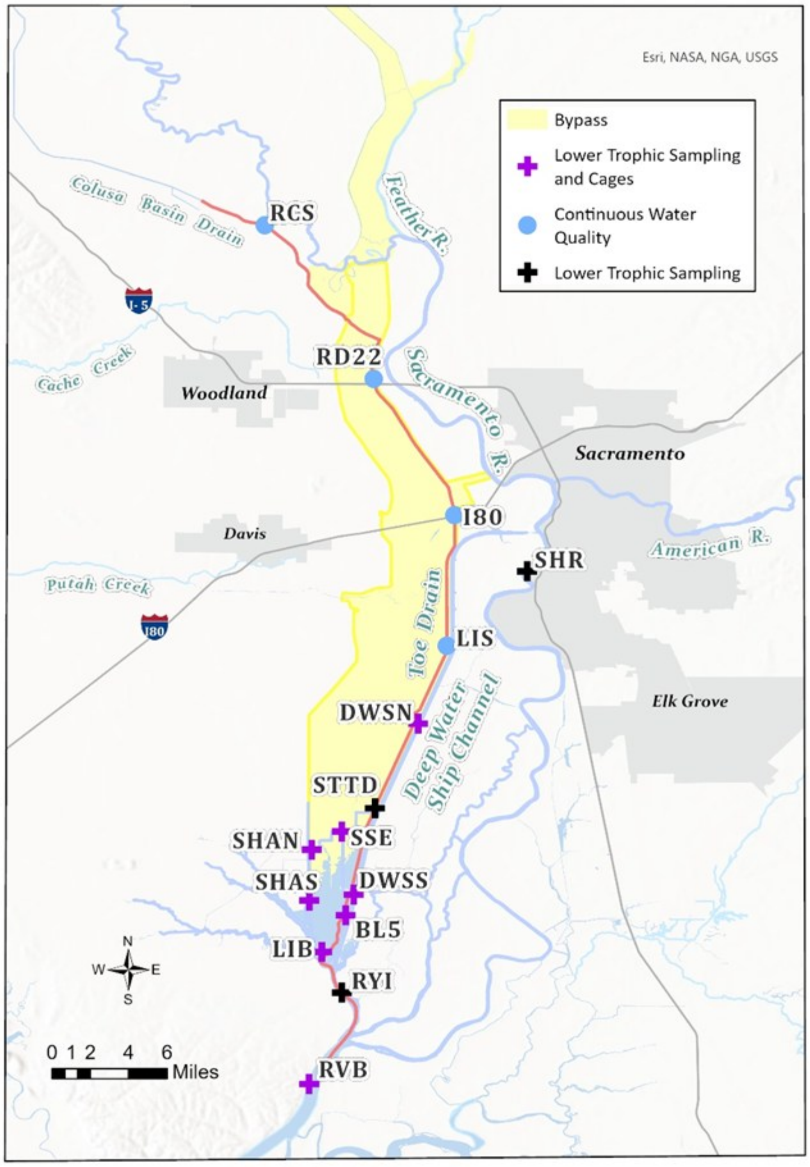

Figure 33. Map of North Delta Flow Action Study Area, including the Yolo bypass and Cache Slough complex.

Sample and data collection:

The discrete sampling period included six transects which began on June 17th and ended on Oct 13th. Sampling transects in the North Delta were conducted once every two weeks with all sites except for SHR collected on a single day. The samples collected during each transect included surface point water quality, nutrient and chlorophyll-α grab samples, phytoplankton grab samples, and zooplankton tows. Detailed sampling methods are described in the NDFS Workplan (DWR 2023).

Point water quality parameters collected with a YSI ProDSS sonde including temperature (°C), dissolved oxygen (mg/L), electrical conductivity (µS/cm), specific conductivity (µS/cm), pH, and turbidity (FNU) were collected at a biweekly interval with a YSI ProDSS handheld sonde. Nutrient and chlorophyll grab sample parameters included Chlorophyll a (µg/L), Pheophytin (µg/L), Dissolved Ammonia (mg/L), Dissolved Chloride (mg/L), Dissolved Nitrate Nitrite (mg/L), Dissolved Organic Phosphorous (DOP, mg/L), Dissolved Organic Nitrogen (DON, mg/L), Dissolved Organic Carbon (DOC, mg/L), Total Organic Carbon (TOC, mg/L), Total Organic Phosphorus (TOP, mg/L), Total Kjeldahl Nitrogen (TKN mg/L), Total Dissolved Solids (TDS mg/L), Total Suspended Solids (TSS mg/L), and Volatile Suspended Solids (VSS, mg/L) and were collected via a Van Dorn sampler at 1m depth. Samples were processed by the Bryte water quality laboratory within 24 hours of field collection. Due to unforeseen complications with a change in the Bryte Lab information management system, the data are not available at the time of this report creation. Phytoplankton samples were collected from the same Van Dorn water grab samples and preserved in 10% Lugol's solution. Zooplankton samples were collected with a 50cm diameter and 150µm mesh net towed near the water surface for 5 minutes from a motorized boat with a flow meter to estimate volume sampled and standardize values on a catch per unit volume scale.

Continuous water quality monitoring at a 15-min interval was conducted at legacy sites in the Yolo Bypass Toe Drain and are available from the DWR Water Data Library (Sites: RCS, RD22, I80, STTD, LIS, RVB; https://wdl.water.ca.gov/waterdatalibrary) and the USGS National Water Information System (TOE = STTD, LIB, RYI; https://waterdata.usgs.gov/nwis). Additionally, at each experimental enclosure site, we deployed a Precision Micro Engineering (PME) MiniDOT logger which recorded water temperature and dissolved oxygen at a 5-minute interval.

Ambient water contaminant samples were collected at a subset of sites in 1L brown glass bottles opened and filled underwater at a depth of approximately 0.5m. Suspended particle contaminant samples were collected at a subset of sites with a 50cm diameter 150µm mesh zooplankton net towed from a motorized boat for 10 minutes. All contaminant samples were kept refrigerated and assays were conducted at the USGS Sacramento State laboratory within 48 hours of field collections.

Delta Smelt were obtained from the UC Davis Fish Conservation and Culture Laboratory (FCCL) and were deployed in an enclosure study for two and a half weeks at sites across the North Delta. Two enclosures were deployed at each of the 7 sites in the CSC, DWSC, and Confluence regions. Smelt enclosures were cylindrical in shape with 20" diameter and 36" height and constructed of 1/8" perforated aluminum walls with solid aluminum bottom and top caps.

Table 10. Grid of data and samples collected at each site. Cell codes and colors represent status of the data (YY (green) = samples collected and data available, YP (blue)= samples collected and data partially available, YN (yellow) = samples collected but data not yet available, N (red) = no samples collected). Data are provisional and subject to change.

Sample type	RVB	RYI	LIB	BL5	SHAS	SHAN	SSE	STTD	DWSS	DWSN	SHR
Continuous WQ	YY	YY	YY	YP	YP	YP	YP	YY	YY	YY	N
Point WQ	YY	YY	YY	YY	YY	YY	YY	YY	YY	YY	YY
Nutrients	YN	YN	YN	YN	YN	YN	YN	YN	YN	YN	YN
Phytoplankton	YN	YN	YN	YN	YN	YN	YN	YN	YN	YN	YN
Zooplankton	YY	YY	YY	YY	YY	YY	YY	YY	YY	YY	YY
Contaminants WQ	N	N	YY	YY	YY	YY	YY	YY	YY	N	YY
Contaminants susp.	N	N	YY	YY	YY	YY	YY	YY	YY	N	YY
Smelt enclosures	YY	N	YY	YY	YY	YY	N	N	YY	YY	N

Images were collected on Delta Smelt from half of the enclosures at deployment as well as all surviving fish collected at interim time points and at the end of the experiment. Smelt fork length (mm), weight (g), and Fulton's condition factor (K) were estimated using an image-based approach (Holmes and Jeffres, 2020, Figure 34). The approach utilized a training set of 48 images with measured fork lengths and weights to establish a multiple linear regression using Procrustes scaled and rotated morphometric characters as predictor variables and fish condition (K) as the response variable. When the model was applied to fish with no weights (unstable boat platform prevents traditional weight measurement), the estimated condition was used to back calculate the weight. Model performance was assessed on the training set following methods in Holmes and Jeffres (2020) and resulted in an unbiased prediction (Figure35), with a mean average percent error (MAPE) of 3.37% and mean absolute error of 0.07g.

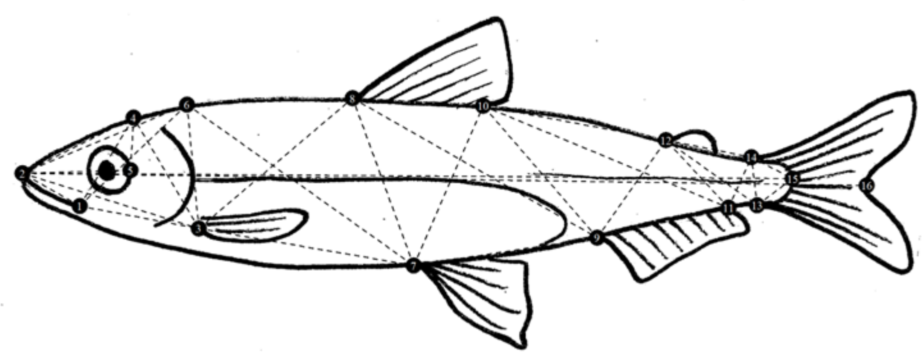

Figure 34. Delta smelt diagram with 15 landmarks (black dots) and 34 morphometric characters (dashed lines) overlaid. Delta Smelt drawing credit: Nicole Kwan (DWR).

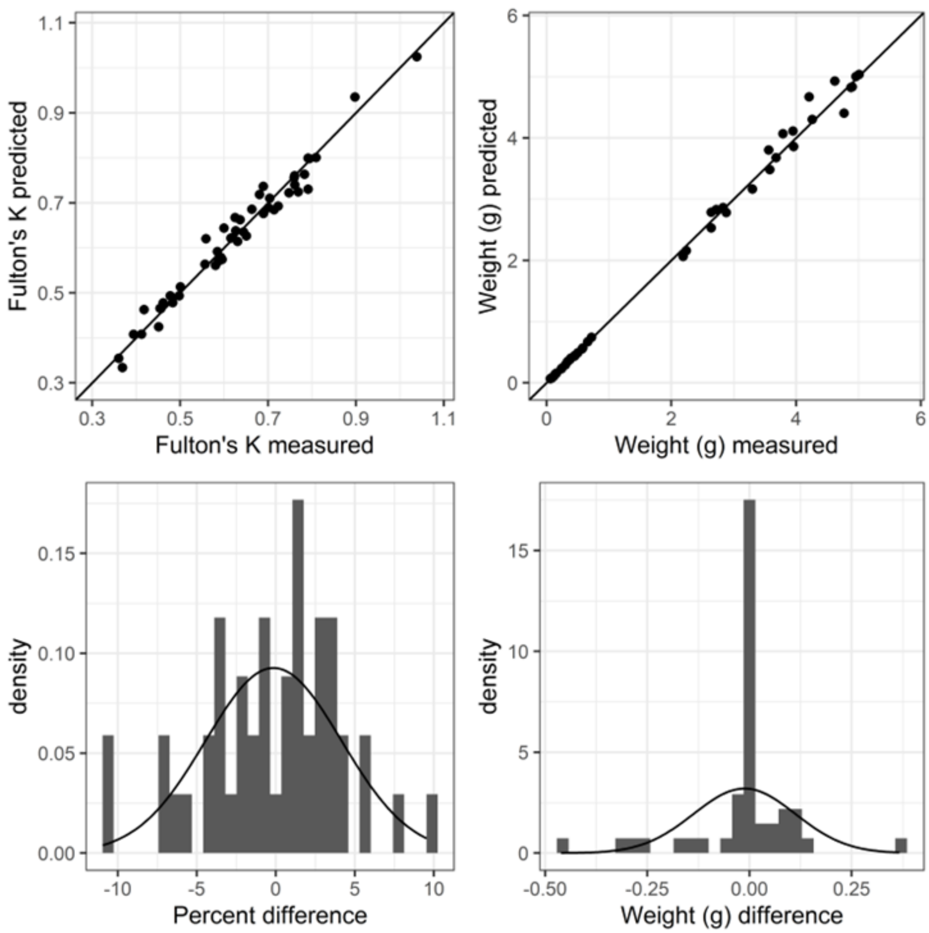

Figure 35 Panel A: estimated Fulton's condition factor on the y-axis versus the measured Fulton's condition factor, KC, on the x-axis. Panel B: Predicted weight in grams on the y-axis versus measured weight on the x-axis, with regression lines denoted with solid lines and 1:1 reference lines represented with dashed lines. Panel C: Histogram of the percentage of error in the weight prediction. Panel D: Histogram of the weight difference (predicted minus measured) in grams. Histograms have normal curves overlaid.

Results

Water quality

General patterns in physical water quality parameters measured with the handheld sonde were apparent across the study area (Figure 36). Sites closest to the Sacramento River confluence tended to have the lowest turbidity and highest Secchi values (highest visibility). These sites also tended to have the lowest specific conductivity (freshest water). In contrast, sites on the periphery of the CSC (SHAN, SSE, STTD) and in the Deepwater ship channel (DWSS, DWSN) tended to have murkier water (higher turbidity) and higher conductivity. Patterns in pH indicated that sites around lower Liberty Island (LIB, BL5, SHAS) had the highest pH (more alkaline) which was likely due to the high abundance of macrophytes in Liberty Island which extract CO_2 from the water during photosynthesis reducing the prevalence of carbonic acid. The increase in pH at

STTD may be due in part to the same process occurring in Little Holland tract and Lower Yolo Ranch restoration areas but may also be due to the presence of elevated phytoplankton which can also uptake CO_2 and increase pH. We are awaiting results from phytoplankton analysis and lab chlorophyll-a analysis to provide additional information about the primary drivers.

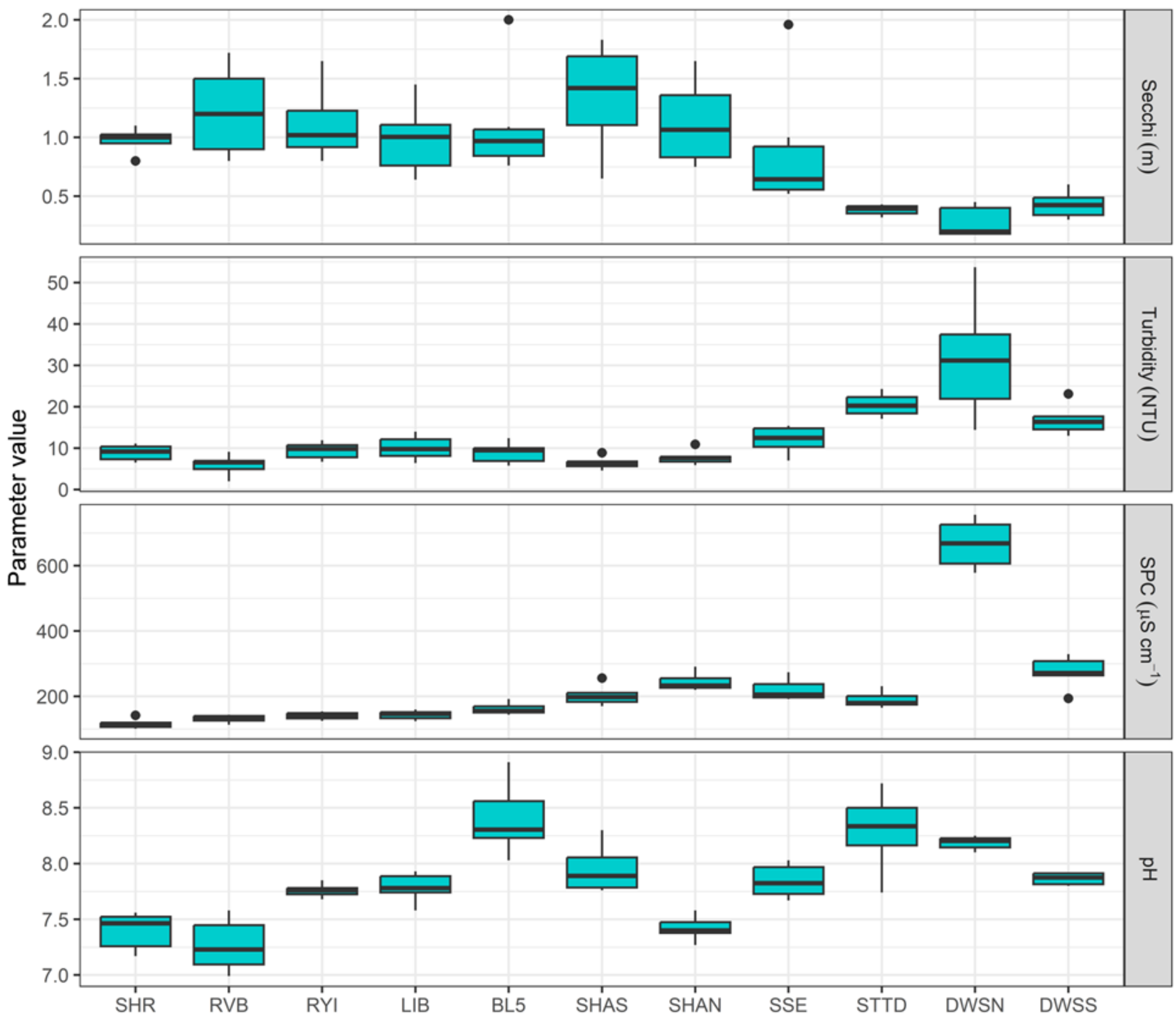

Figure 36. Discrete water quality parameters (turbidity, specific conductivity, Secchi depth, and pH) collected with a handheld sonde or Secchi disk and plotted in boxplots by station on the X axis.

Continuous water quality

Continuous water quality monitoring in the Yolo Bypass Toe drain yielded patterns similar to past seasons. In general, the Toe Drain sites are often warm with water temperatures above 25°C, relatively turbid (>20 FNU), and productive with chlorophyll-a concentrations generally in the 5 to 40 ug/L range (Figure 37). These sites also tend to have low dissolved oxygen (2.5-6 mg/L range) and higher specific conductivity compared to sites in the CSC. The exception to these patterns occurs near the end of the Toe Drain at the STTD site where the influence of Sacramento River water coming through the CSC can be observed due to landward flows from water diversions. This results in this region having higher dissolved oxygen, greater water clarity, lower conductivity (fresher), and low accumulation of chlorophyll-a (Figure 37).

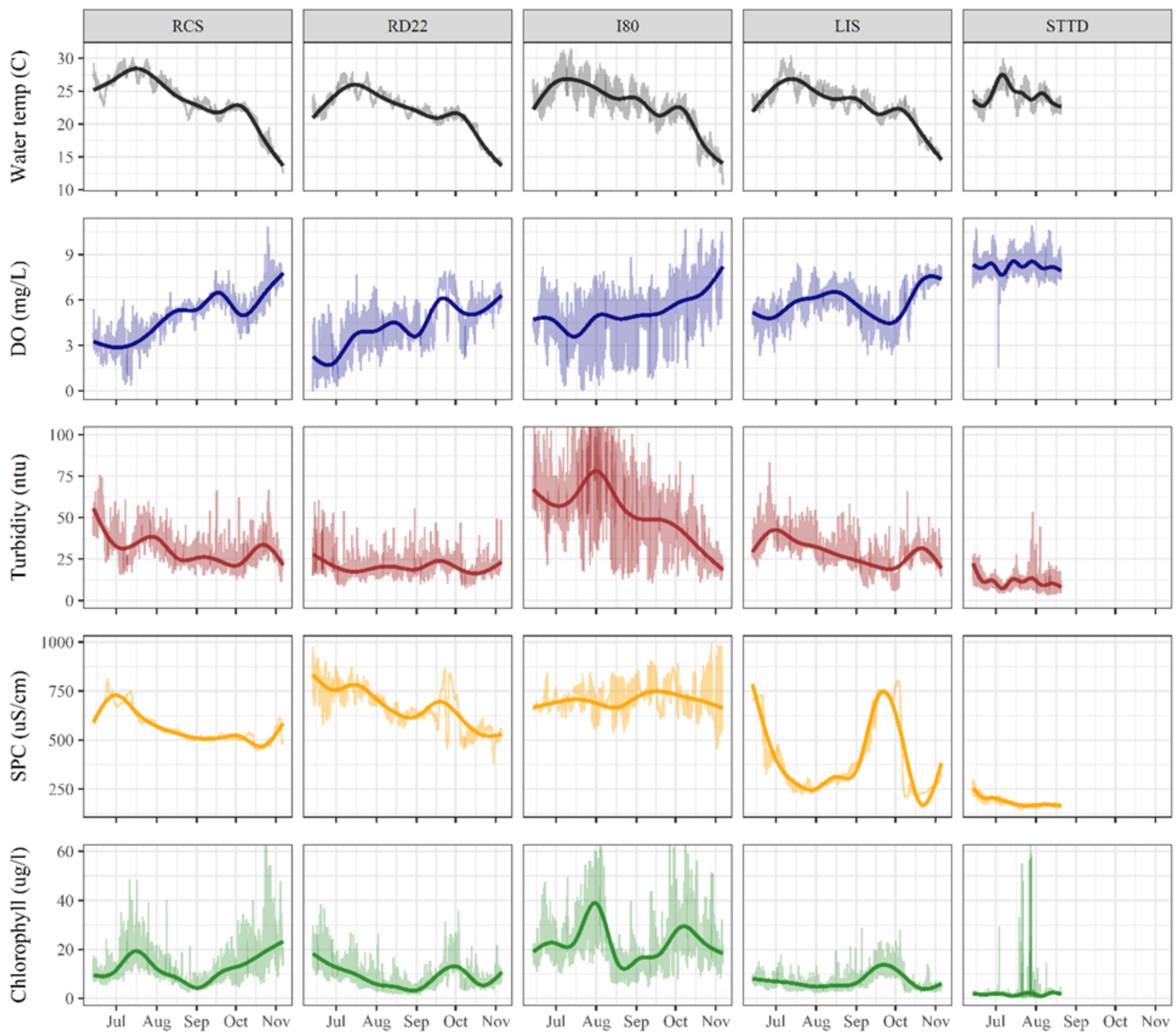

Figure 37. Continuous water quality parameters for sites in the Yolo Bypass region collected at a 15-minute interval (thin transparent lines) with loess smooth lines (thick solid lines) overlaid.

Continuous water quality monitoring in the CSC and adjacent habitats also yielded some general regional and seasonal patterns (Figure 38). These patterns included a gradient in certain parameters with increasing distance and hydrologic isolation from the confluence of the CSC and the Sacramento River and distributaries (i.e. Miner Slough and Steamboat Slough). This was evident in the Deep Water Ship Channel with higher turbidity, chlorophyll and specific conductivity. Surface water temperature also followed a similar pattern with cooler temperatures at sites near the CSC and Sacramento River Confluence and warmer temperatures on the periphery of the CSC and up the Deep Water Ship Channel. The sites near the confluence had similar water quality parameters with one notable exception. The Shag Slough sites showed lower dissolved oxygen conditions than neighboring areas for the majority of the summer season, and experienced a substantial decrease in dissolved oxygen and a concomitant increased in turbidity at the end of September and beginning of October. This coincided with the breaching of the levee at the Lookout Slough tidal restoration project. Satellite imagery from around the date of the breach showed a plume of turbid water emanating from the newly flooded area into Shag Slough and mixing into Liberty Island which was corroborated with a slight increase in turbidity at the LIB station at the south end of Liberty Island.

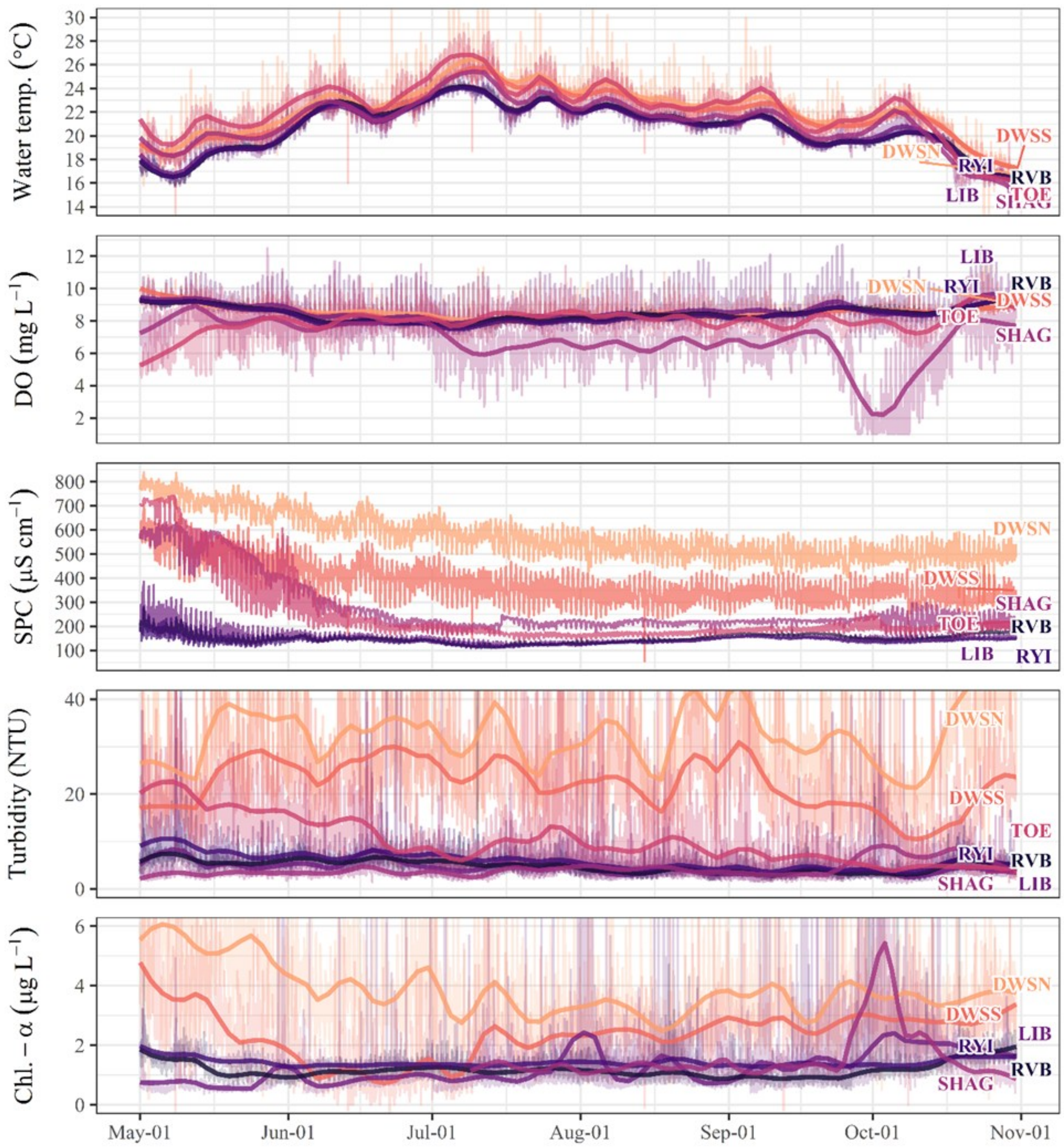

Figure 38. Continuous water quality parameters collected at a 15-minute interval (thin transparent lines) with loess smooth lines (thick solid lines) overlaid.

Zooplankton

Zooplankton trends in the CSC were similar to previous years with a generally low total abundance of zooplankton and dominance by the calanoid copepod, *Psuedodiaptomus forbesi*. Across all sites and sampling periods, *P. forbesi* copepodites comprised 52.7% while adult *P. forbesi* comprised 9.9% of all zooplankton catch per unit effort. We observed some spatial heterogeneity of the dominant zooplankton taxa in the periphery of the CSC and in adjacent water bodies. For example, on the western and northern margins of the CSC (SHAS, SSE) and in the transition zone of the deepwater ship channel (DWSN) we observed a larger proportion of

Cladoceran taxa (Figure 39). The Cladoceran taxa were primarily composed of small-bodied species including *Diaphanosoma sp*., *Chydorus sp*., and *Bosmina sp*. An overarching temporal trend was not apparent across sites, but there was a pattern of high variability within sites. Notably, zooplankton densities across the CSC were extremely low during the second sampling transect on July 1st. The driver of this variability is unknown but could include some combination of circulation patterns as a result of the spring/neap tidal cycle and/or atmospheric pressure and temperature fluctuations associated with the onset of an extreme heat event which took place in early July.

Figure 39. Panel A: Bar graph indicating proportion of zooplankton taxonomic group for each station and date combination. B) Bar graph indicating total zooplankton group density (individuals per cubic meter) for each station and date combination colored by zooplankton group.

Contaminants

Patterns in ambient water contaminant levels were apparent across the study area and throughout the season (Figure 40, Figure 41). In general, contaminant concentrations were low compared to past years. For instance, in 2023 we observed 3-times more contaminant detections than at the same sites in 2024. We also observed peak contaminant concentrations for the most prevalent compound, azoxystrobin, which were 15-times higher in 2023 compared to 2024.

From a spatial perspective, concentrations were relatively consistent across the CSC (Figure 40, Figure 41). Interestingly, while the SHR site in the Sacramento River had the lowest total number of detections (N = 11) this site had the highest individual concentrations of the major pesticide groups (Fungicides, Herbicides, and Insecticides) and the only detection of the synergist, piperonyl butoxide. The site at the terminus of the Toe Drain, STTD, had high total pesticide compound detections (N = 15), however total concentrations were the lowest of all sites sampled this season.

From a seasonal perspective, there was an apparent increase in contaminants in the last two sampling transects in late-July and mid-August. This increase may correspond to agricultural runoff into the Sacramento River and other local point sources.

Detection of contaminant compounds in zooplankton samples showed similar patterns to the ambient water samples. However, some compounds with only trace amounts in the ambient water were not detected in the zooplankton samples. Conversely, some hydrophobic compounds such as the legacy DDT degradate, p,p'-DDE, were detected in the zooplankton samples but were not detected in the water samples.

For the fish tissue analysis on the caged Delta Smelt, only three compounds were detected, p,p'-DDE, propanil, and propiconazole. The compound p,p'-DDE was detected at every site, while propanil and propiconazole were present in 4 out of 5, and 2 out of 5 sites respectively. The control fish showed no contaminant detections, indicating that there was no detectable exposure due to aquaculture at FCCL or accumulated during their stay at the UC Davis CABA facility.

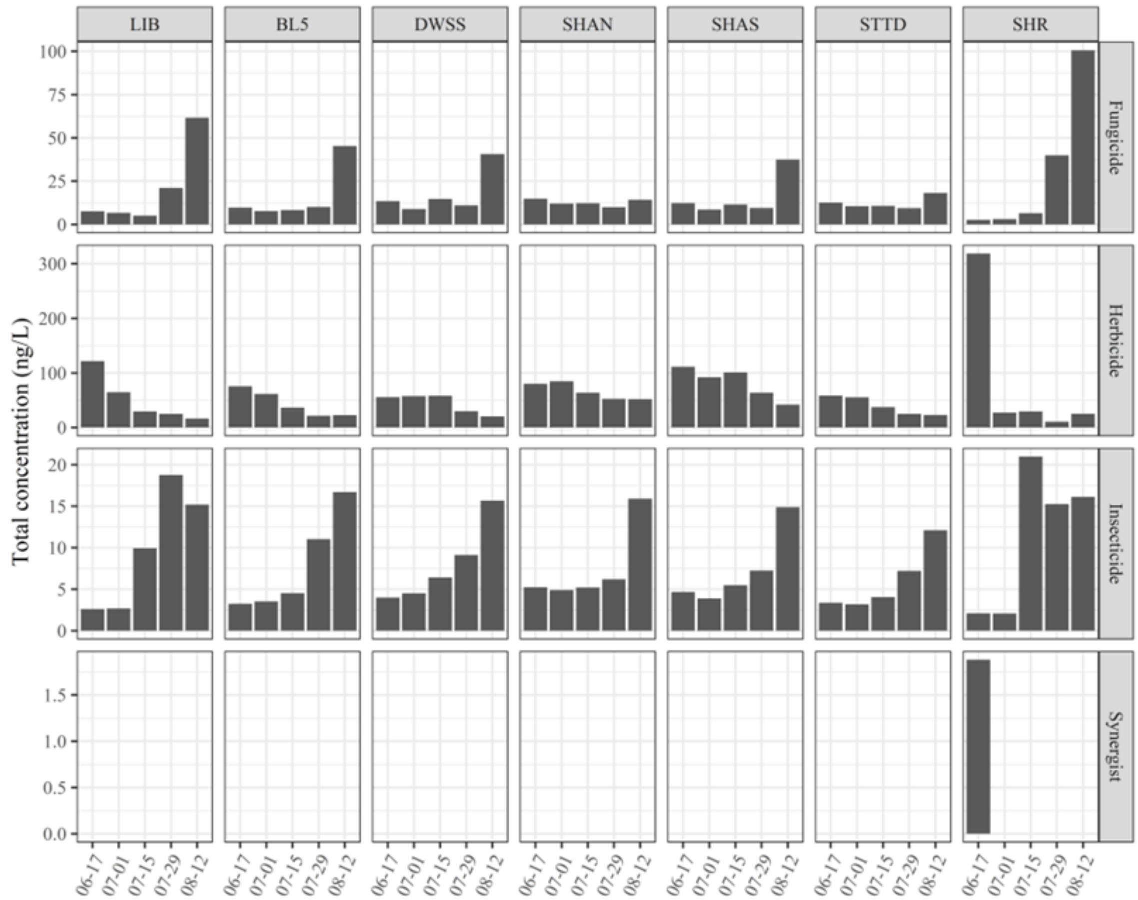

Figure 40. Ambient water contaminant concentrations at each site (top margin) summed for each pesticide class (right margin) for each sampling transect (x-axis) during 2024.

zooplankton

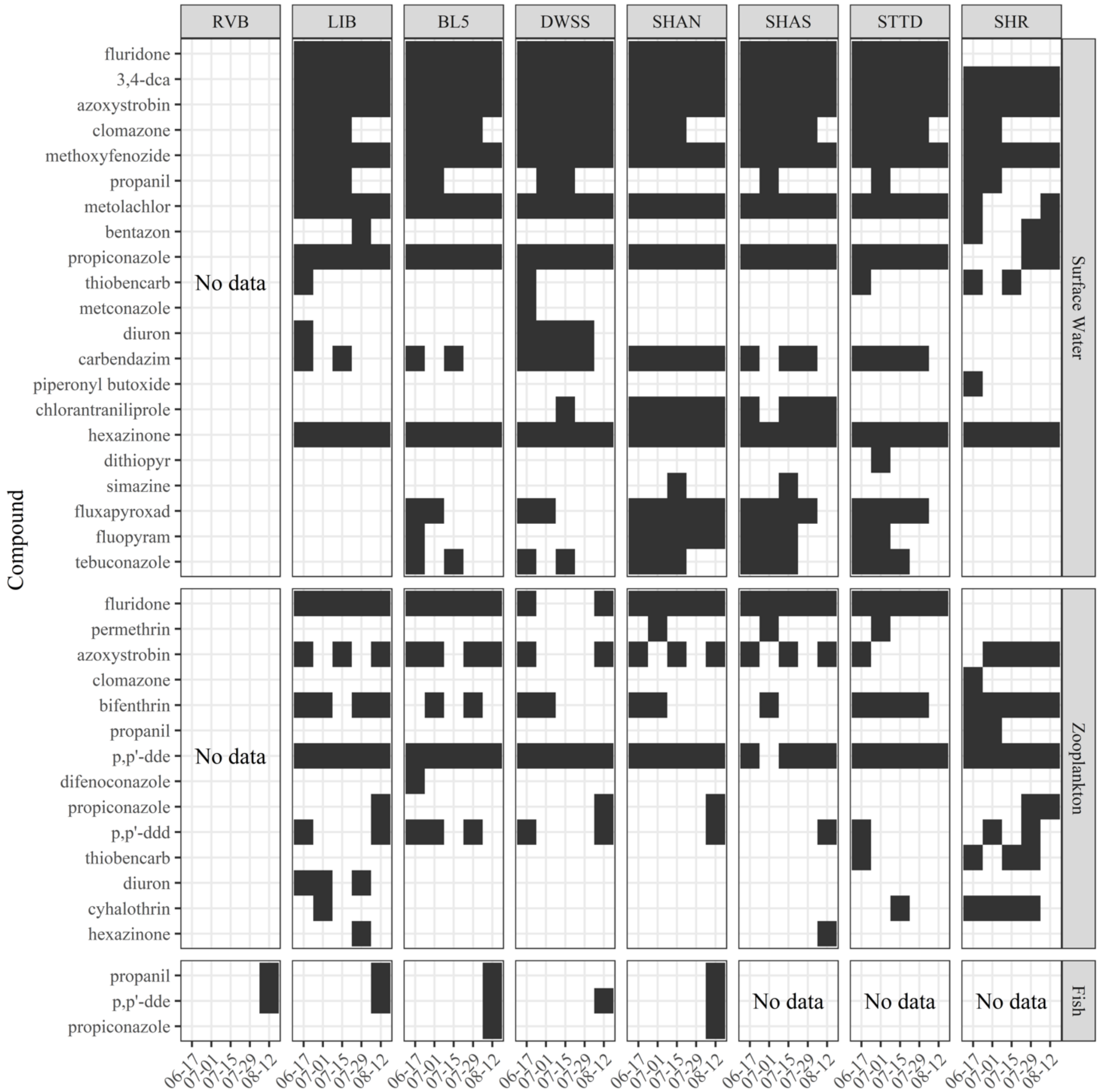

Figure 41. Individual contaminant compound detections (y-axis) for each type of medium, surface water, zooplankton, and fish tissues (right margin), at each site (top margin) and transect (x-axis). Black tiles represent detection of contaminant compound, white tiles represent no detection.

Habitat suitability across multiple axes

Results of the multi-axis habitat suitability assessment indicated some gradients in potential suitability that shifted from south to north. As expected, we noted that the lowest surface water temperatures were present in the southern sites nearest to the confluence with the Sacramento River. Additionally, we noted evidence of the highest adult *P. forbesi* densities in the lower

Sacramento River at Rio Vista, Cache Slough at Ryer Island, and southern end of the Liberty Island (Figure 42). This combination leads us to infer that these areas with the lowest thermal stress and highest available zooplankton would have the highest suitability for Delta Smelt (Figure 43). The contaminant distribution displayed a more irregular spatial pattern as noted above, and was lower than past years of the study (Figure 40).

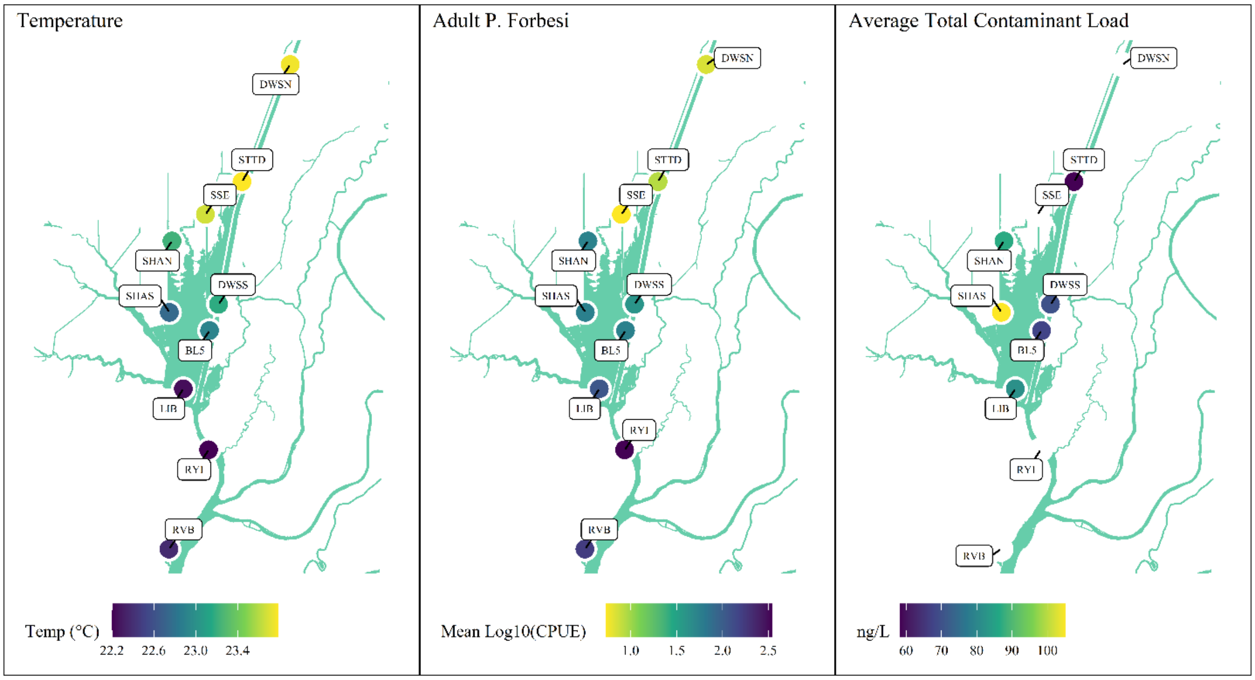

Figure 42. Map of study sites with data in panels corresponding to the primary habitat suitability metrics (Water temperature, *P. forbesi* CPUE (individuals per cubic meter), and contaminant concentration). Warmer/lighter colors on the color scale indicate more stressful conditions relative to the cooler/darker colors. White circles indicate no sample collected.

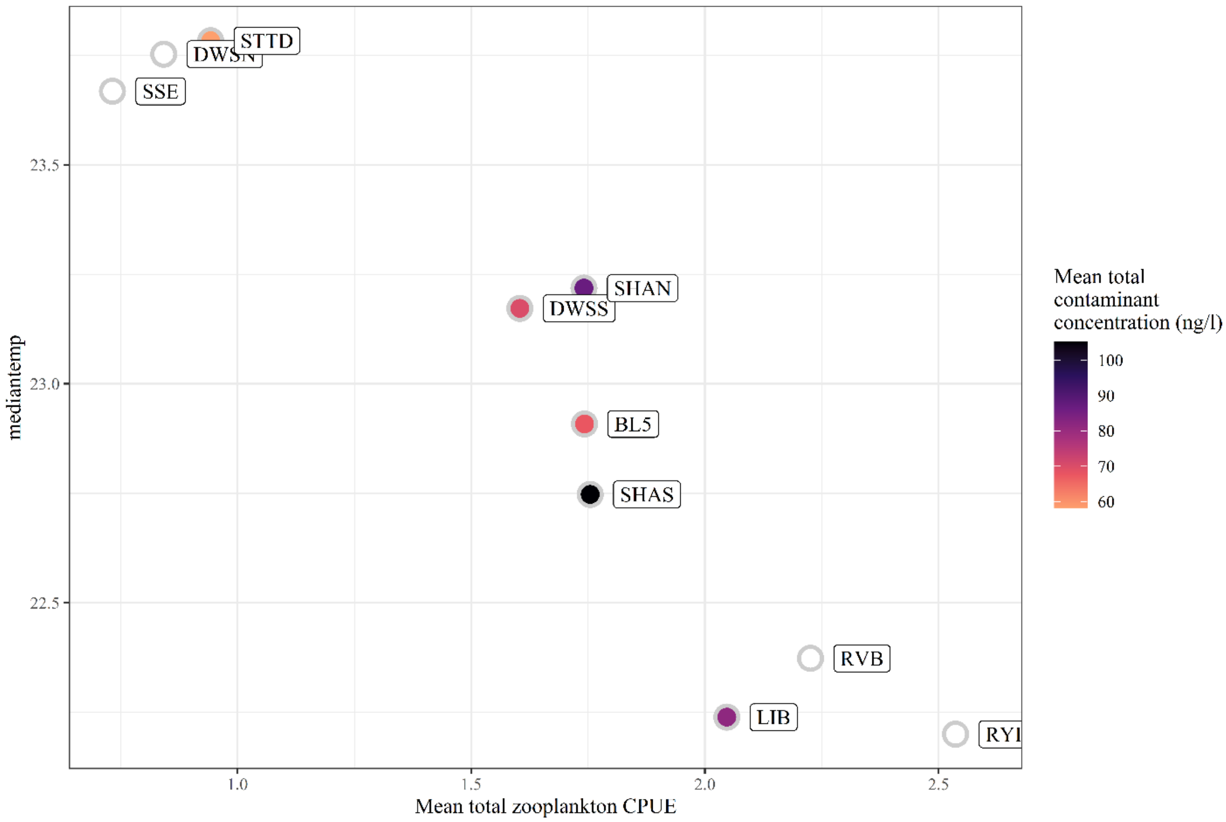

Figure 43. Biplot of median water temperature (y-axis) and mean zooplankton score (x-axis). Areas in the upper left indicate higher thermal stress and lower food availability. Conversely, the lower right region of the plot indicates sites with lower thermal stress and higher food availability.

Pilot Delta Smelt Enclosure Study

Survival of enclosure Delta Smelt was low during this experiment with most mortality occurring immediately after enclosure deployment. Mean survival across all 7 sites was 10.7% ± 9.7% SD with a range from 0-30% (Figure 44). Surviving fish appeared to lose weight and condition over the course of the experiment with Fulton's condition (K) values outside of the initial range (Figure 45). However, since we cannot be sure which individual fish survived, a growth rate or body condition change rate is not presented due to potential bias.

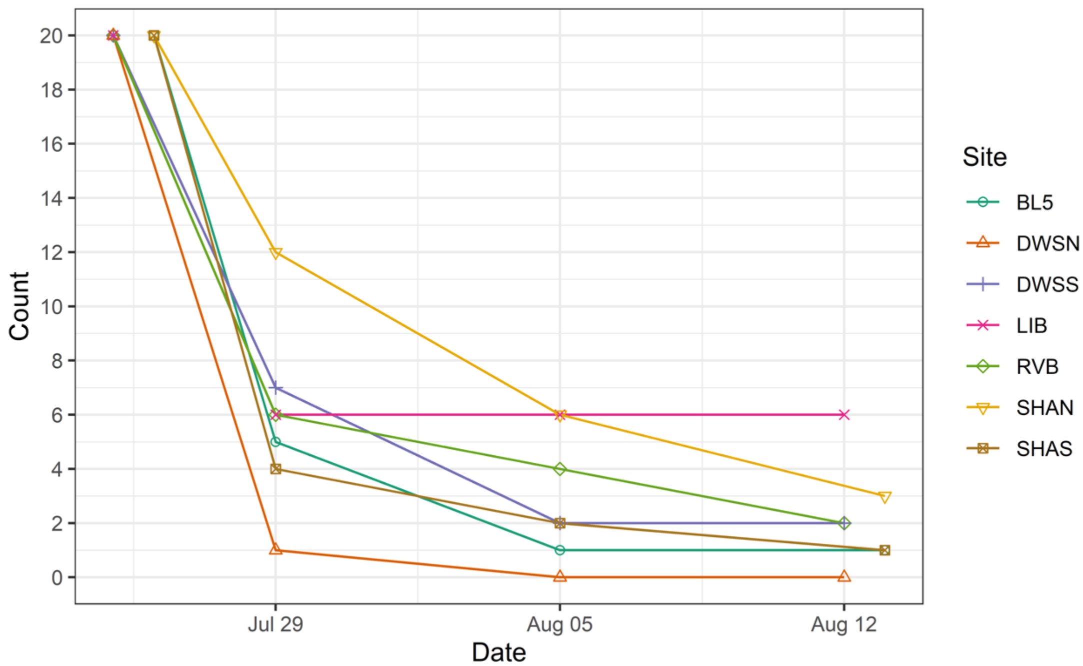

Figure 44. Survival over time of Delta Smelt in experimental enclosures.

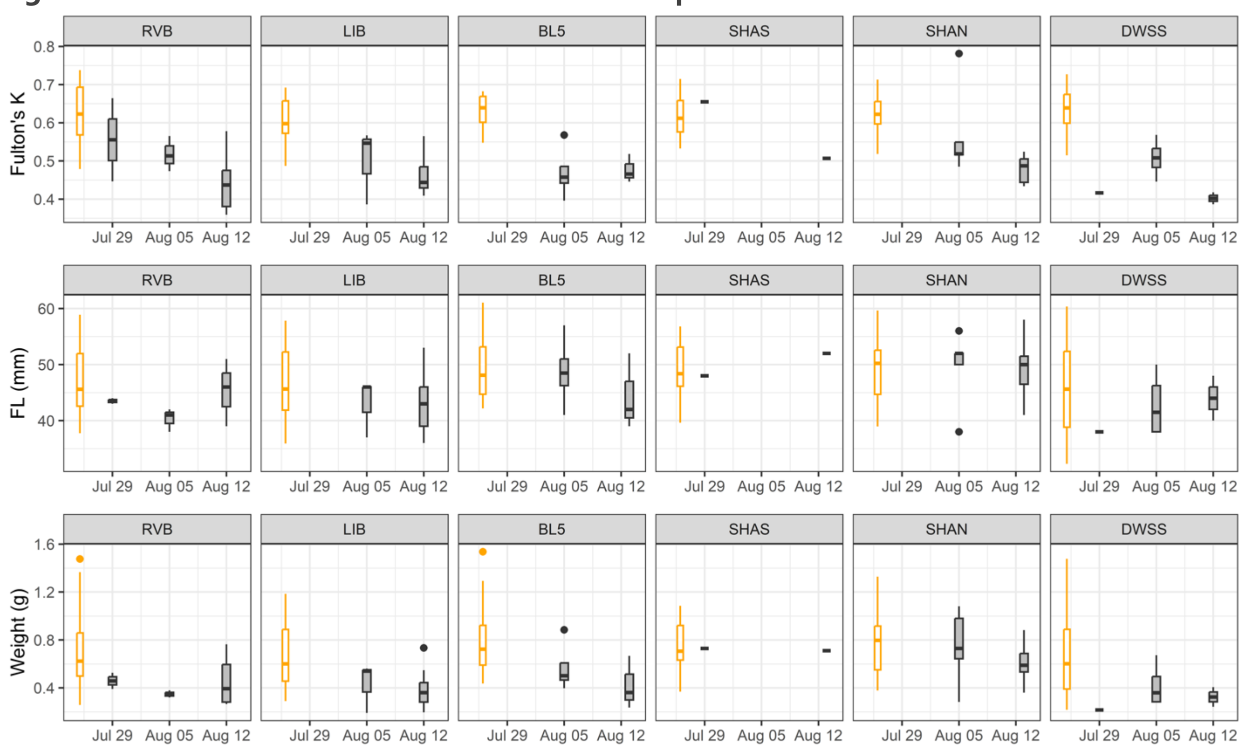

Figure 45. Delta Smelt size and condition across sites. Orange boxplots indicate initial predicted size and condition, whereas grey boxplots indicate fish measurements from the end of the experiment. The top panel indicates Fulton’s condition factor. The middle panel indicates fork length in millimeters. The bottom panel indicates weight in grams.

Discussion

This season of the North Delta Food Subsidy study was focused on characterizing habitat suitability for Delta Smelt in the Cache Slough Complex (CSC) and adjacent areas of the North Delta to inform the potential baseline conditions for a future summer flow action. Priority was given to existing CSC sampling sites while secondary priority was given to new sites in adjacent areas (Shag Slough and the Deepwater ship channel) to provide additional regional context as well as possibly inform upcoming restoration activities (Lookout Slough). This shift in priorities and increase in spatial scope was in response to a lack of compelling insights resulting from repeated sampling of the Toe Drain which is not habitable in the summer by Delta Smelt (Davis et al. 2022). High temperature, low food availability and high concentrations of contaminants have been identified as major limiting factors for Delta Smelt in the CSC. Thus, we sought to characterize the gradients in these limiting habitat suitability factors within the CSC and adjacent habitats.

Like Stumpner et al. (2020) we observed a gradient in some factors across the CSC and adjacent habitats. Generally, this included gradients in temperature, conductivity, and zooplankton. These observed gradients in water quality and lower trophic parameters across the study region, as well as their interactions, could have important consequences for Delta Smelt growth and survival. Preliminary results indicate that the highest *P. forbesi* densities and lowest temperatures occur at the southern extent of the CSC and lower Sacramento River (LIB, RYI, RVB), while the upper CSC and deepwater ship channel site consistently had lowest adult *P. forbesi* zooplankton densities and stressful surface water temperatures throughout the experiment. Unfortunately, drawing strong conclusions about Delta Smelt physiological response from the pilot enclosure study was compromised by experimental effects. We observed high mortality after two transport events, the first occurred when moving fish from FCCL to UC Davis CABA facility, and the second occurred when deploying fish from CABA to enclosure sites. We attributed the first mortality event to moving the fish at an immature age at which time they are less capable of handling stress. The second mortality event was due to high temperatures at deployment following a severe July heat wave. This series of events leaves the pilot study at an existential crossroad since there is only a tiny window of opportunity in most years when the fish are large/hardy enough to transport and before the habitat has reached seasonal temperature increases beyond the tolerance of these fish. Despite these challenges which impeded our ability to model survival and growth and draw conclusions about Delta Smelt response to variable environmental conditions, there are a few observational takeaways: 1) after the initial mortality upon deployment, juvenile survival was high for the remaining study duration, indicating that the new smaller cage design was feasible and likely functional, 2) the site with the highest survival post-deployment, was also one of the hottest sites (SHAN), and 3) fish appeared to be stressed by temperature and possibly lack of available food generally across the whole study area resulting in an apparent trend of weight loss and associated decline in body condition.

Results from this season in combination with a lack of reproducible efficacy following past monitoring efforts, leave the future of habitat actions in the northern Delta uncertain. The effects of flow actions (positive or not) are limited in spatial scope to the periphery of the CSC which appears to be too thermally stressful to support Delta Smelt in the summer. Even if net positive effects for lower trophic productivity can be achieved through coordinated summer-fall flow actions, habitat in this region and season is compromised by thermal stress which cannot be ameliorated by the flow actions. Therefore, the North Delta Food Subsidy action will be terminated in effort to explore other adaptive management strategies that have potential to improve the food web for native fish species.

Sacramento Deep Water Ship Channel Food Web study

The Sacramento Deepwater Ship Channel (SDWSC) is one of the few areas in the Delta in which Delta Smelt are detected fairly consistently. Understanding why and how this region can support Delta Smelt throughout the year is important for identifying the potential for management actions to further enhance Delta Smelt support. Ongoing research in the Sacramento Deepwater Ship Channel continues to focus on understanding how water exchange and residence time mediate abiotic and biotic drivers of phytoplankton and zooplankton dynamics.

In 2023, DWR and USGS initiated a bioenergetics modeling study to better understand the relatively consistent occurrence of Delta Smelt in the SDWSC. USFWS, Reclamation, and UC Davis are collaborators in this study. Analysis for the study is ongoing and preliminary results will be shared at the appropriate venues when ready (e.g., conferences, project work teams).

Reclamation also continued to work with UC Davis to study ecosystem metabolism, benthic nutrient pools and fluxes, and zooplankton grazing rates in the SDWSC with the ultimate goal of developing flow and nutrient enhancement management actions. This project was initiated in 2021 and published studies associated with the project were highlighted in the previous seasonal report. UC Davis continued to sample water chemistry and zooplankton, and maintained field instruments to measure ecosystem metabolic rates in 2024. UC Davis also continued to carry out laboratory incubation and sediment nutrient flux experiments to model the SDWSC ecosystem metabolism and dynamics.

Suisun Marsh Food Subsidy Studies

Introduction

Studies suggest that managed wetlands–principally operated by duck hunting clubs– have the potential to locally enhance plankton productivity in Suisun Marsh within the San Francisco Estuary (SFE) (Aha et al. 2021; Phllips et al. 2024; Tung et al. 2021; Williamshen et al 2021). Plankton have declined throughout much of the SFE, largely because of an introduced clam that disrupts the food web, creating food limitation in native planktivorous fish, including Delta Smelt. Managed wetland operations may pose a useful tool in subsidizing plankton abundance in adjacent tidal habitats because they are free of clams and allow for increased growth and concentration of plankton. However, a mechanistic understanding of how managed wetlands influence food webs remains limited, and optimal management regimes for promoting plankton abundances at critical times for pelagic fish are unknown.

We are comparing several wetlands with different hydrologic management regimes to understand how managed wetland practices affect phytoplankton and zooplankton production. The two-year study encompasses two complete flood cycles (typically fall through spring) in managed wetlands, and will be compared to data previously collected at restoration sites in their pre-restoration state. We hypothesize that seasonally flooded wetlands will promote high plankton biomass, perennially flooded wetlands will promote intermediate plankton biomass, and unrestricted tidal habitats (tidally restored wetlands and reference tidal sloughs) will have comparably low biomass production likely due to flood-pulse effects and differences in water residence time.

Data presented here are preliminary. We are still processing zooplankton and phytoplankton community samples from the study, as well as incubation samples for both.

Methods

From October 2022 to June 2024, we collected monthly data on chlorophyll-*a* concentrations, zooplankton densities, and water quality at five seasonally managed wetlands, three tidally restored wetlands, and reference sloughs associated with each wetland distributed throughout Suisun Marsh (Figure 47). Of the managed wetlands, Denverton Duck Club (DDC) stayed perennially flooded for the duration of our study, while the rest flooded seasonally in keeping with typical duck club operations. Whole water grabs were collected for measurements of chlorophyll a, nitrate, ammonium, phosphate, dissolved organic carbon, total suspended solids, and volatile suspended solids. Additional water quality data included chlorophyll fluorescence, dissolved oxygen, temperature, conductivity, turbidity, pH, and fluorescent dissolved organic matter (taken with a YSI EXO sonde), Secchi depth measurements, and rapid-assessment zooplankton abundance estimates. Monthly zooplankton rapid-assessment estimates were collected, alongside tow-net samples that are being evaluated for species ID, life stage and egg counts (in progress). Rapid zooplankton assessments are a three-liter sample of pond water concentrated by a 150 micron mesh net into a small live well and estimate the number of visible copepods, cladocerans, and ostracods. Formal counts of zooplankton abundance are later collected in a laboratory under a microscope, and preliminary results suggest the rapid assessments provide a decent estimate of more quantitative results (Figure 46).

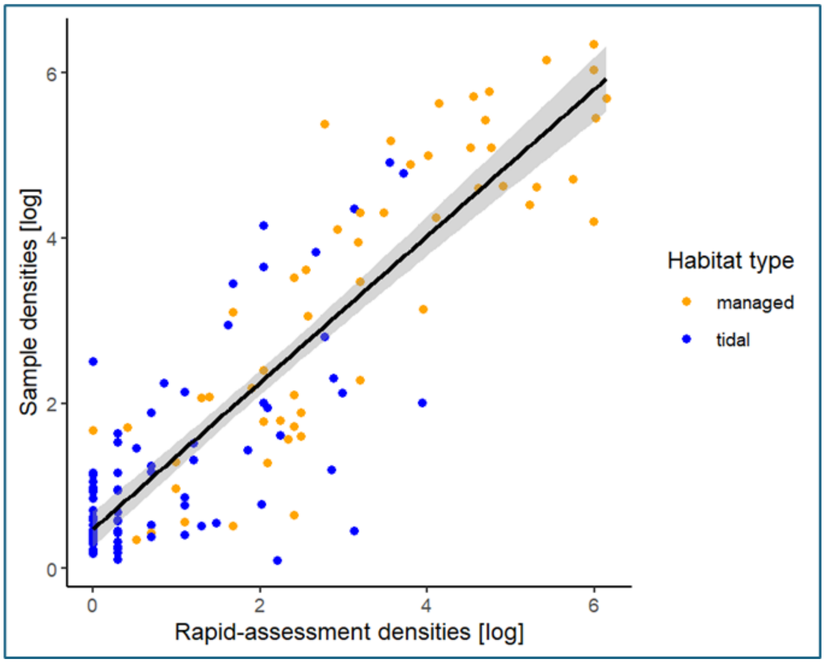

Figure 46. Relationship between rapid assessment densities and sample densities in a liner model comparing zooplankton sampling methods. Points represent raw estimates for each sampling method, while colors represent the habitat type sampled.

Quarterly, we conducted in vitro incubation trials to estimate phytoplankton and zooplankton growth rates in water collected from different wetlands in controlled temperature and light environments. Field sampling and incubation trials concluded in early summer 2024 after all managed wetlands were drained, followed by sample post-processing and analysis (pending). During data analysis, we will also compare pre- and post-restoration plankton monitoring data from Wings Landing (restored in 2020) to compare before-after effects of tidal restoration on plankton abundances. These analyses are not complete as of March, 2025, but will be available in several peer-reviewed journal articles currently in development.

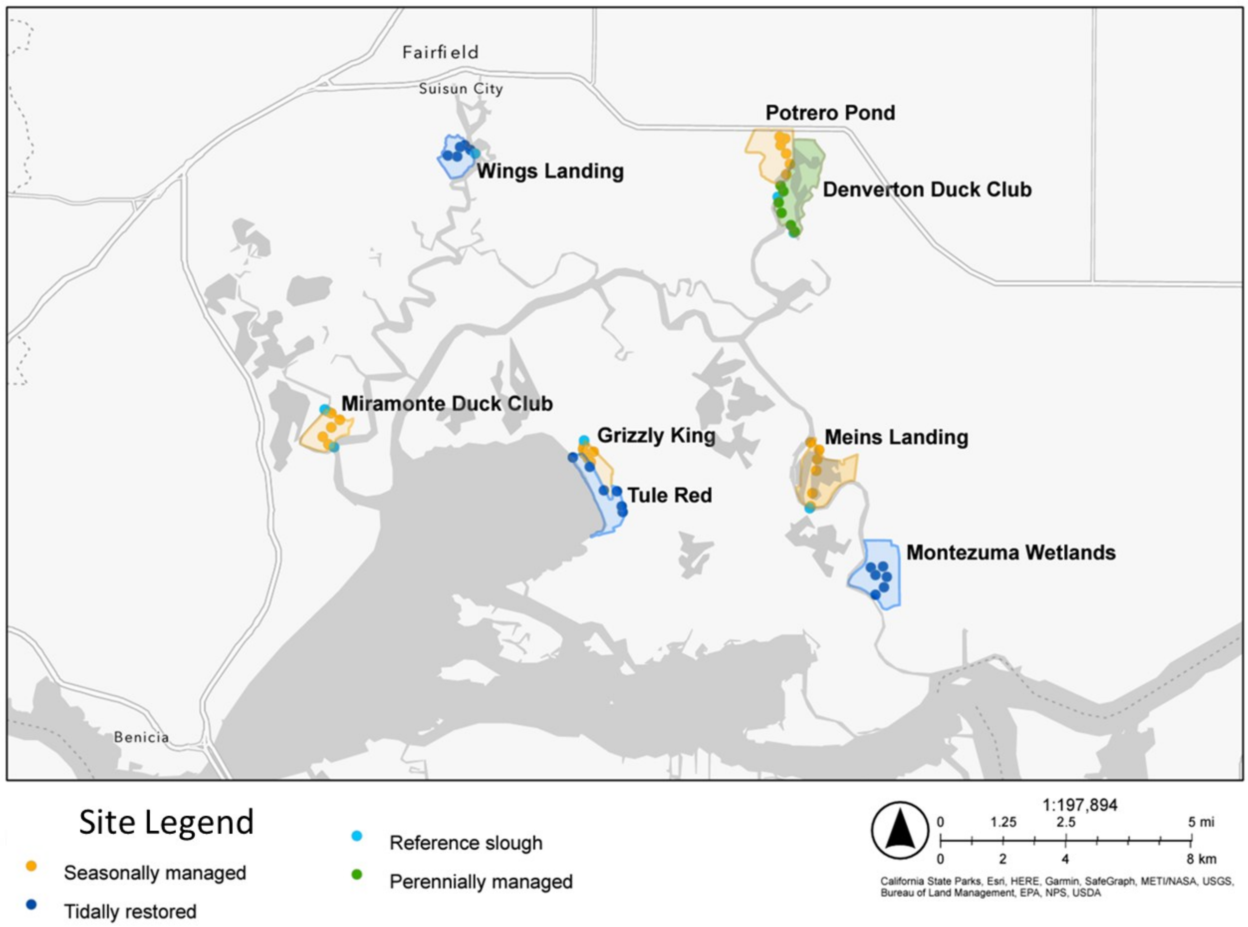

Figure 47. Map of monitoring stations for a plankton productivity study in Suisun Marsh. Stations were located withing seasonally managed wetlands (orange), perennially managed wetlands (Green) tidally restored wetlands (dark blue) and adjacent references sloughs (light blue).

Preliminary Results

We provide a preliminary summary of sonde and rapid-assessment zooplankton data from Water Years 2023 and 2024, with water years defined as the period between October 1st and September 30th and which also align with typical flood cycles in managed wetlands. Other sample processing and data QA/QC are still in progress. We report on each treatment group (seasonally managed, perennially managed, tidally restored, and reference tidal sloughs). No statistical analyses have been completed to date.

Daytime dissolved-oxygen (DO) trends were consistent between the two water years. DO trends were most variable in seasonally managed wetlands, particularly in the fall flood-up months where DO levels reached hypoxic levels at some stations and supersaturated levels elsewhere (Figure 48, Figure 52A). Meanwhile, the range of DO levels in the perennially managed wetland were comparable to tidal habitats. DO levels were relatively stable in all wetland treatment groups during winter, spring, and summer, and rarely decreased to levels <5 mg/L in the tidal environments. Because we only measured DO levels during the day, DO in all habitat types could have dropped lower at night when respiration may outpace photosynthesis. This is most concerning in the seasonally managed wetlands where even daytime DO levels were low.

Phytoplankton biomass–as measured by chlorophyll-*a* concentration–was highest in seasonally managed wetlands throughout the study period during flooded periods, with peak concentrations occurring in the months following fall flood-up (Figure 49). The perennially managed wetland promoted intermediate chlorophyll-a concentrations between seasonally managed and tidal habitats. Zooplankton abundances were patchy and highly variable, although elevated densities were generally restricted to managed wetlands. Copepod abundances were higher in managed wetlands during the flooded months and on two occasions were high in reference sloughs (Figure 50, Figure 52C). Cladocerans were restricted to only a few sites, but abundances were higher in managed wetlands during the winter and spring months and were sparse in all wetland treatments during the fall months (Figure 51, Figure 52D). Both copepod and cladoceran abundances decreased in the perennially managed wetland after the first year of flooding (Figure 52C, D).

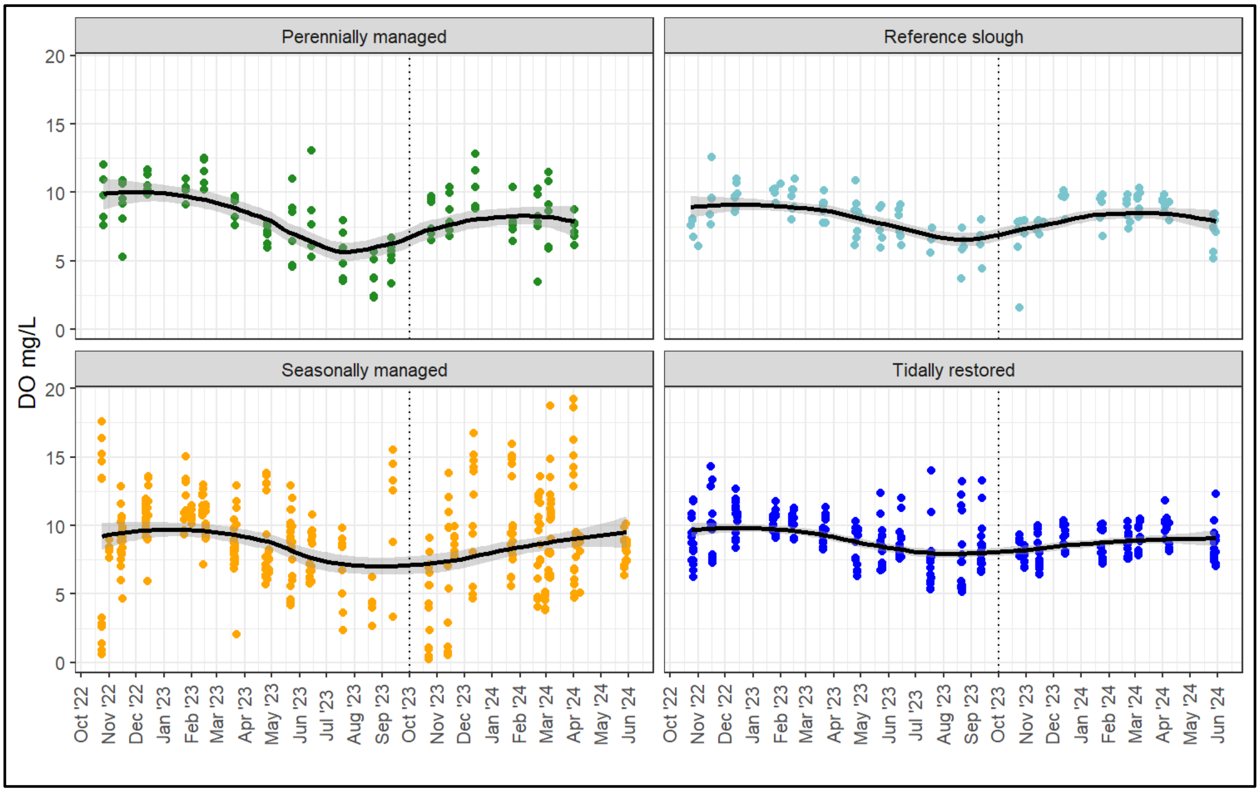

Figure 48. Point and LOESS regression plots of daytime dissolved-oxygen trends in wetlands and adjacent reference sloughs in Suisun Marsh. Dotted vertical line delineates water years 2023 and 2024.

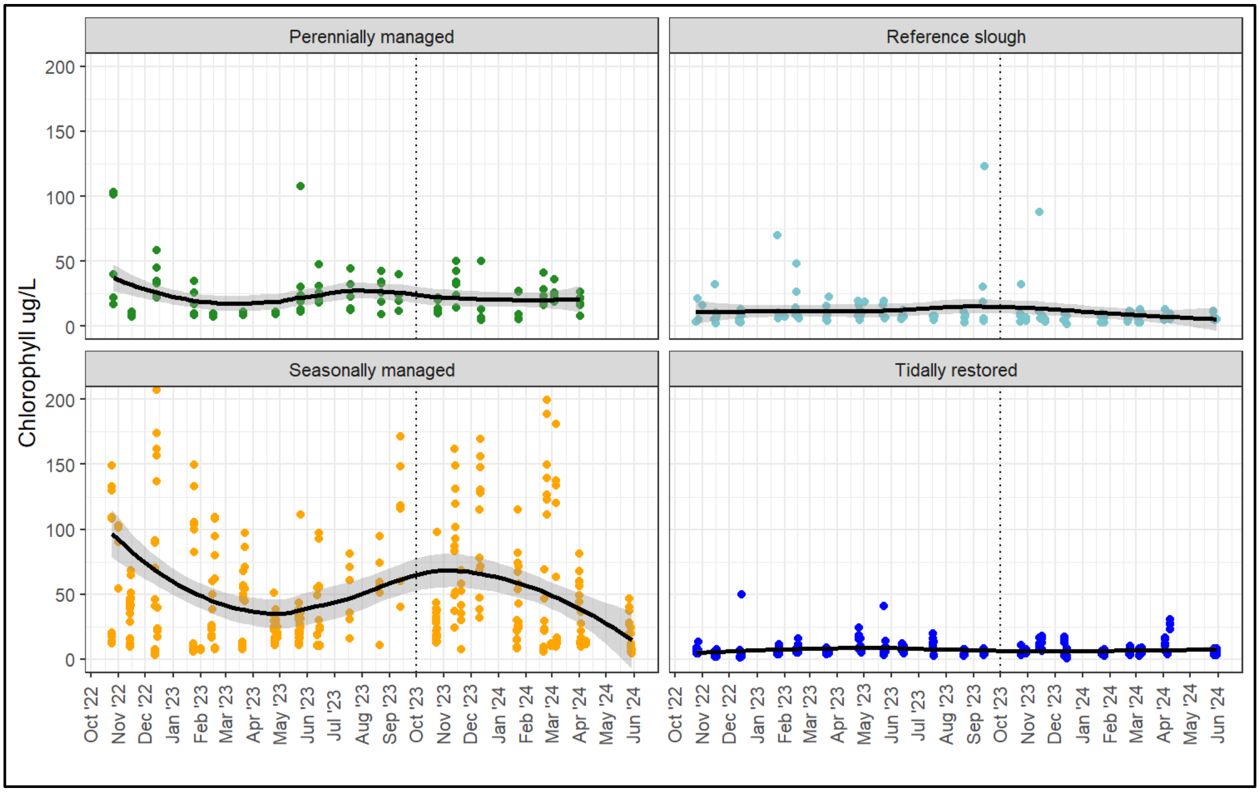

Figure 49. Point and LOESS regression plots of chlorophyll sonde measurement trends in wetlands and adjacent sloughs in Suisun Marsh. Observations above 200 µg/L are not shown (N = 12 in seasonally managed wetlands), but are included in LOESS regression. Dotted vertical line delineates water years 2023 and 2024.

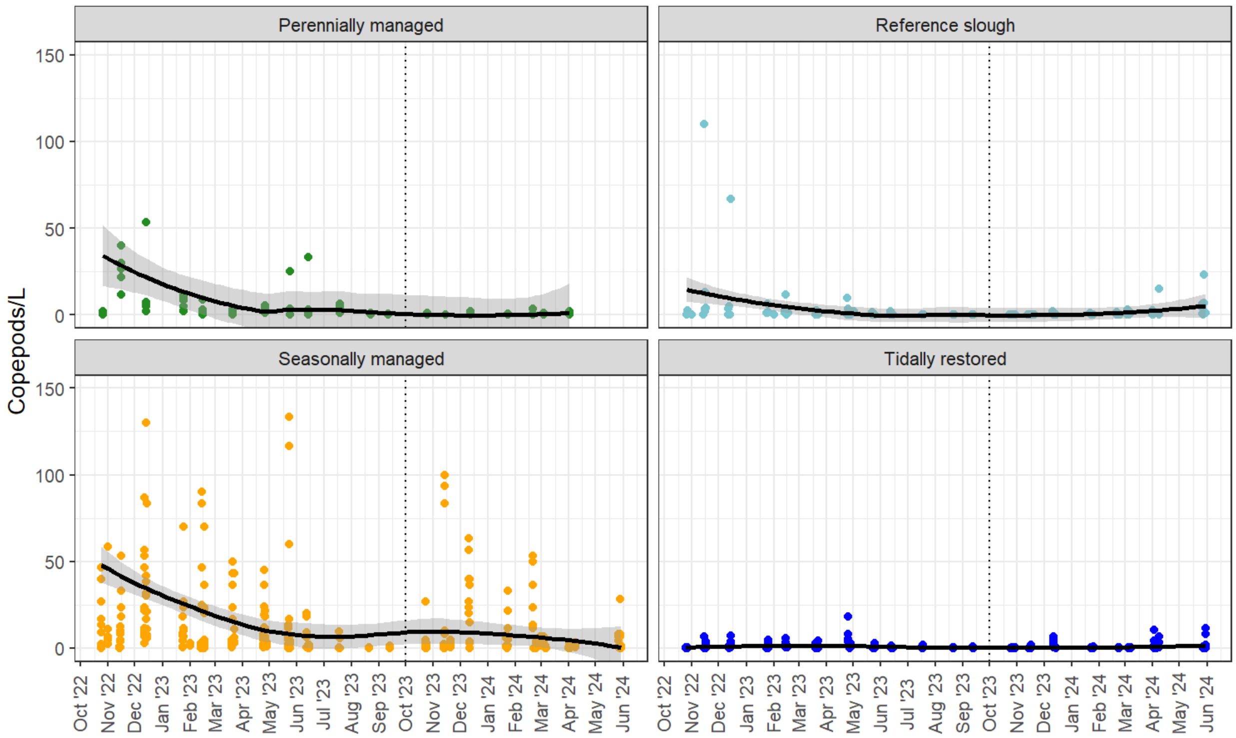

Figure 50. Point and LOESS regression plots of all copepod abundance trends in wetlands and adjacent sloughs. Observations above 150 counts/L are not shown (N = 1 in perennially managed and N=6 in seasonally managed), but are included in LOESS regressions.

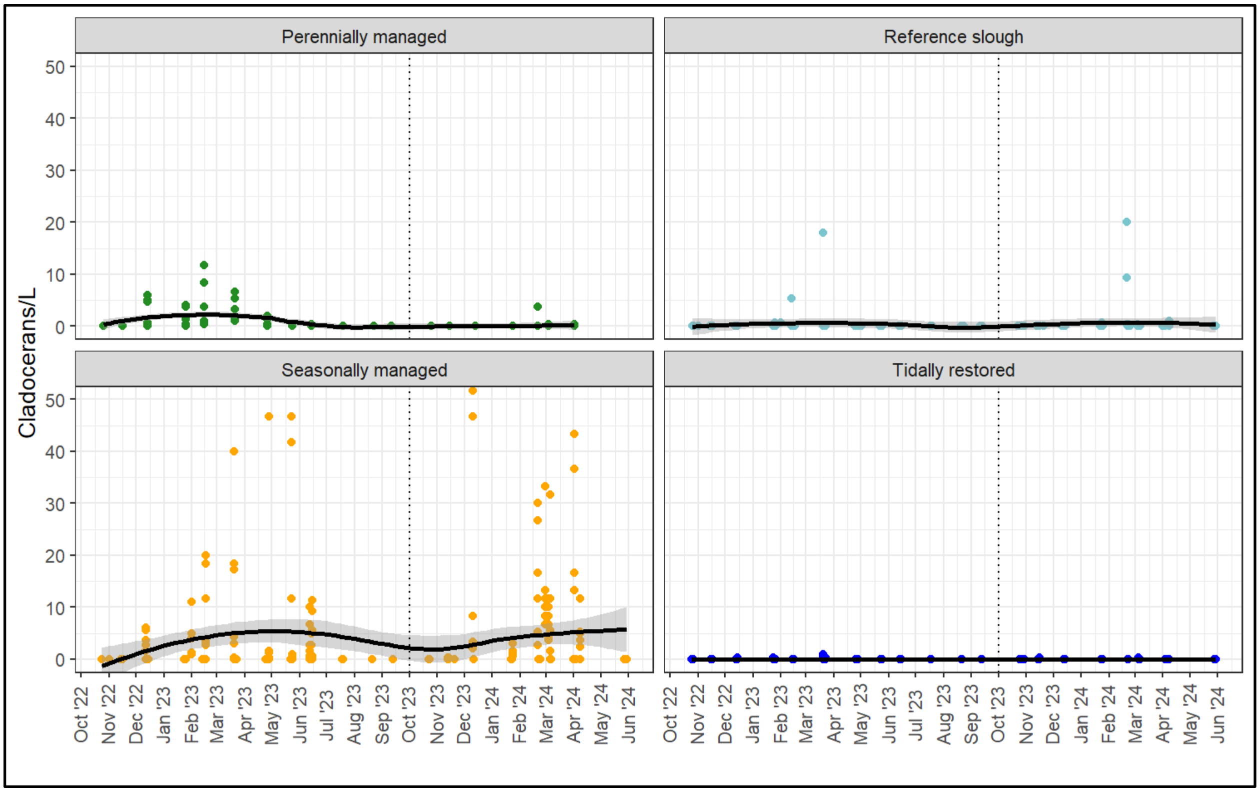

Figure 51. Point and LOESS regression plots of cladoceran abundance trends in wetlands and adjacent sloughs in Suisun Marsh. Observations above 50 counts/L are not shown (N = 8 in seasonally managed) but are included in LOESS regression.

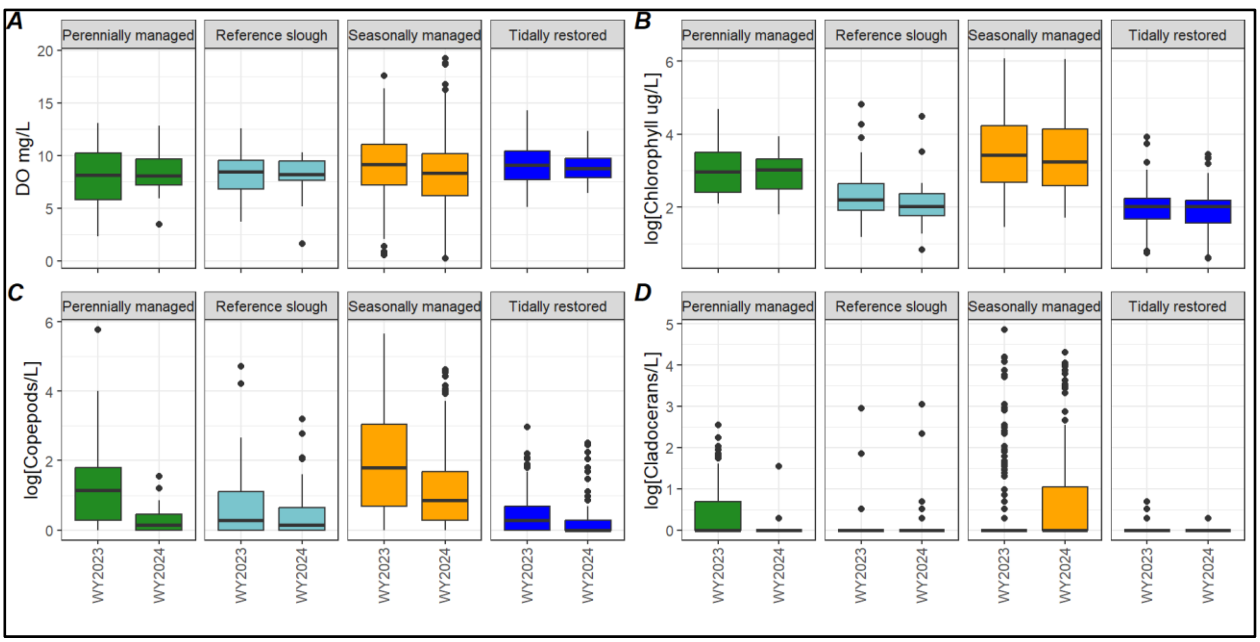

Figure 52. Box plots comparing water year 2023 and 2024 for A) Daytime dissolved oxygen, B) Chlorophyll-a concentration, C) Copepod abundance and D) cladocera abundance across treatment types. Plankton abundances are log-transformed.

Discussion

To date, our study shows that managed wetlands during flooded periods support higher plankton concentrations than tidal channels and restorations but that water quality trade-offs likely exist. Phytoplankton and dissolved oxygen trends were similar for water years 2023 and 2024, while zooplankton abundances changed between water years in the two managed wetland treatments. Low chlorophyll concentrations and low daytime DO in some seasonally managed wetlands occurred shortly after fall flood-up, while other seasonally managed wetlands were associated with high and supersaturated daytime DO. Chlorophyll concentrations and zooplankton abundances responded positively to fall flooding in seasonally managed wetlands, likely due to increased food availability and expected increases in water residence times. Copepods rapidly responded to flooding, often reaching peak abundances within two months, suggesting tight coupling with phytoplankton blooms. Larger-bodied cladocerans were slower to respond to flooding, but tended to dominate the zooplankton biomass once established, possibly because they are efficient grazers and may outcompete copepods. Despite supporting similar phytoplankton concentrations in the second year, the perennially managed wetland had lower zooplankton abundances, possibly due to accumulating predators, such as fish and macroinvertebrates. Trends in reference sloughs and tidally restored wetlands were similar for both water years and supported comparatively low zooplankton abundances, possibly due to lower phytoplankton availability and higher tidal mixing. The occasional high abundances in the reference sloughs were observed near managed-wetland outfalls and were possibly produced and exported from managed wetlands.

Overall, our findings are consistent with our hypotheses, but we observed unexpected trends at the perennially managed wetland, Denverton Duck Club (DCC), and one of the seasonally managed wetlands, Miramonte Duck Club (MDC). We predicted that DCC would respond to the initial fall flood pulse in the first year with high phytoplankton *and* zooplankton density that diminished thereafter, and that MDC would respond with high plankton densities for both years, but instead, both wetlands supported relatively few plankton after initial flooding. We suspect that hydraulic connectivity to the slough channels at DCC and MDC wetlands were higher than other managed wetlands, resulting in low water residence times that limited plankton accumulation. While this provides new insights into water management implications on plankton production, it also confounds our examination on how perennial management affects plankton production when residence time is not a limiting factor. The effects of water management on plankton production may be highly variable depending on the site-specifics of a managed wetland (e.g., site elevation, hydrologic infrastructure, etc.). Growth rate data for phytoplankton and zooplankton is pending but may provide more insight on the effects of wetland management on plankton production.

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Attachments

Attachment A: **Summer Fall Habitat Action Monitoring and Science Plan** (Separate Document)

Attachment B: **2024 Summer Fall Habitat Action Plan** (Separate Document)