Delta Smelt Summer-Fall Habitat Seasonal Report for WY 2020

Central Valley Project, California
California-Great Basin Region

Photo Credit: USACE

U.S. Department of the Interior **December 2020**

Mission Statements

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

Delta Smelt Summer-Fall Habitat Seasonal Report for WY 2020

Central Valley Project, California
California-Great Basin Region

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Contents

Page

Table of Figures

Purpose

This 2020 Seasonal Report for Delta Smelt Summer-Fall Habitat describes the operations of the Central Valley Project (CVP) and State Water Project (SWP) and Delta Smelt habitat conditions in water year (WY) 2020. This report may support adjustments, if necessary, to the Delta Smelt Summer-Fall Habitat Action Guidance Document (Guidance Document) for WY 2021, and future operations, including Delta Smelt Summer-Fall Habitat Action Plans, by documenting conditions without an action. The structure of the Seasonal Report for Delta Smelt Summer- Fall Habitat will be modified for years when the action is implemented, and those modifications will be subject to coordinating agency review. This document also fulfills commitments under the Record of Decision (ROD) signed by the Bureau of Reclamation (Reclamation) for the Reinitiation of Consultation (ROC) on the Coordinated Long-Term Operations (LTO) of the CVP and SWP. Additionally, this Seasonal Report will be used to support the development of Reclamation's Annual Report. Finally, this document will inform the Four-Year Review Panels adopted under the ROD. Compliance with the Incidental Take Statements, including the Reasonable and Prudent Measures and associated Terms and Conditions in the 2019 Biological Opinions (BiOp) from the U.S. Fish and Wildlife Service (USFWS) and National Marine Fisheries Service adopted by the aforementioned ROD will be documented in the Annual Report and not in this document. This document strives to provide an integrated view of the factors affecting the low salinity zone habitat within the Sacramento- San Joaquin Delta. The results and discussion sections are focused on available Delta Smelt Summer-Fall habitat in WY 2020.

Preliminary Data

Real-time operations require compiling available data into seasonal reports to help inform the following year's management decisions on action implementation. The variables and data highlighted in this report were selected based on past Delta Smelt conceptual model work and the general understanding of Delta Smelt biology. However, given the expedited nature of this report to inform the potential following year's action implementation and the guidance document, some habitat information deemed important for Delta Smelt survival through the summer and fall (e.g., phytoplankton, benthic invertebrates, etc.) were not yet available upon the completion of this report. In addition, the majority of 2020 data that are included in this report have not undergone thorough quality assurance and quality control procedures. Information presented in this report should be interpreted with some caution, as many datasets remain preliminary and subject to correction, revision, and improvement. A more complete, final dataset from WY 2020 will be captured in the seasonal report for WY 2021.

Background

Most Delta Smelt complete their entire life cycle within or immediately upstream of the estuary's low salinity zone. Scientific research has generally shown that reducing salinity in Suisun Marsh and other areas within the Sacramento-San Joaquin Delta is beneficial for the Delta Smelt population due to increased distribution, foraging opportunities, and habitat complexity (Figure 1). The highest quality habitat in this large geographical region includes 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). Therefore, the ROD included a Delta Smelt Summer-Fall Habitat Action intended to improve Delta Smelt access to food supply and habitat, thereby contributing to the recruitment, growth, and survival of Delta Smelt (Pg. 33, ROD). The Delta Smelt Summer-Fall Habitat Action will investigate summer-fall habitat to better quantify and integrate information on how food, turbidity, salinity, velocity, and temperature interact with the species and contribute to the overall recruitment, growth, and survival of Delta Smelt (Pg. 1, Guidance Document). The ROD also provided a backstop commitment to maintain X2 no more eastward than 80 km in above normal and wet years during September and October (Pg. 33 and 34, ROD). Overall, the Delta Smelt Summer-Fall Habitat Action is intended to increase the spatial overlap of Delta Smelt habitat attributes with a focus on Suisun Marsh and experimental enhancements of prey supply from the Cache Slough Complex.

Figure 1 Map of the Sacramento- San Joaquin Delta (Credit: Google Earth)

As described in the 2019 USFWS BiOp for ROC for LTO of the CVP and SWP, Reclamation and the California Department of Water Resources (DWR) environmental and biological goals for summer and fall (June through October) of below normal, above normal and in wet years if preliminary analysis shows expected benefits, based on the Sacramento Valley Index, are:

(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).

The Suisun Marsh Salinity Control Gates (SMSCG) have the potential to provide an increase in low-salinity-zone habitat for endangered Delta Smelt, and to allow them to more frequently occupy Suisun Marsh, especially Montezuma Slough, one of their most important rearing habitats. To accomplish the goals listed above, Reclamation and DWR would implement SMSCG operations for up to 60 additional days (not necessarily consecutive) from June 1st through October 31st. Reclamation intends to meet Delta outflow augmentation in the fall primarily through export reductions as they are the operational control with the most flexibility in September and October (Pg. 4, Guidance Document). Storage releases from upstream reservoirs may be used to initiate the action by pushing the salinity out further in August and early September; however, the need for this initial action will depend on the hydrologic, tidal, storage, and demand conditions at the time (Pg. 4, Guidance Document). In addition, storage releases may be made in combination with export reductions during the fall period during high storage scenarios where near-term flood releases to meet flood-control limitations are expected (Pg. 4, Guidance Document).

The Delta Smelt Summer-Fall Habitat Action also includes food enhancement actions, e.g., those included in the Delta Smelt Resiliency Strategy to enhance food supply (CNRA 2016), including the Sacramento Deep Water Ship Channel Food Web Study, North Delta Food Subsidies-Colusa Basin Drain Study and the Suisun Marsh and Roaring River Distribution System Food Subsidies Study.

- The Sacramento Deep Water Ship Channel Food Web Study is a federal and local partnership between Reclamation and City of West Sacramento and West Sacramento Area Flood Control Agency to repair or replace the West Sacramento lock system to hydraulically reconnect the ship channel with the mainstem of the Sacramento River. Combined with an ongoing food web study, the reconnected ship channel has the potential to flush food production into the North Delta.
- The North Delta Food Subsidies – Colusa Basin Drain Study monitors and evaluates the effects of the North Delta Flow Action on the Delta food web. The North Delta Flow Action redirects agricultural drainage or Sacramento River water into Yolo Bypass for up to 2-4 weeks to generate a moderate flow pulse of 20-25 TAF (i.e. a managed 'flow action') to move food resources downstream, thereby enhancing the quantity and quality of food for Delta Smelt in the North Delta. The North Delta region is relatively rich in food resources compared to other parts of the Estuary but negative or low flows from water diversions during summer and fall limit the distribution of these resources to downstream areas to benefit Delta Smelt. The action takes an adaptive management approach planning and implementing annual augmented flow pulses (or not) in summer or fall based on a combination of factors including evaluation of past results, predicted WY type, water availability and collaboration with supporting stakeholders.
- The Suisun Marsh and Roaring River Distribution System Food Subsidies Study will coordinate managed wetland flood and drain operations and the operation Roaring River Distribution System, with the additional reoperation of the Suisun Marsh Salinity Control

Gates. The intent of this study is to flush food rich waters of the managed wetlands and Roaring River into Grizzly Bay.

When determining whether the measures above provide similar or better protection than the 80 km salinity management action, Reclamation and DWR will consider, at minimum, the following:

(1) habitat acreages in Suisun Marsh, Grizzly Bay, and other adjacent areas available to support Delta Smelt recruitment;
(2) recruitment projections based on lifecycle modeling and/or monitoring to evaluate the expected trend in Delta Smelt with and without the 80 km salinity management action; and
(3) the presence (or absence) of Delta Smelt in both the target areas (main Delta channels and Suisun Marsh) and other areas (such as Montezuma Slough and Cache Slough), including information from monitoring, presence/absence modeling, or similar tools (Pg. 4-73, BA and Pg. 3-4, Guidance Document).

One or more habitat suitability indices that include calanoid copepod biomass density are being developed, which could be used to evaluate the success of food enhancement actions. Recruitment projections using an individual-based model (e.g., Rose et al. 2013 a,b; Kimmerer and Rose 2018) could also be calculated under different food enhancement actions. Results of caged Delta Smelt studies could be used as a measure the success of food enhancement actions. However, future cage studies would need to compare prey availability inside and outside of cages and whether these metrics change with food enhancement actions.

The Guidance Document (Pg. 4 and 5) identified a Collaborative Planning Process to implement the Delta Smelt Summer-Fall Habitat Action. In June 2020, Reclamation and DWR formed the Delta Coordination Group (DCG) to coordinate planning of the Delta Smelt Summer-Fall Habitat Action with USFWS, National Marine Fisheries Service, California Department of Fish and Wildlife (CDFW), and representatives from federal and state water contractors. Agencies and stakeholders participating in the DCG identified the ProACT decision support tool as the structured decision-making process to use in informing the Delta Smelt Summer-Fall Habitat Action in 2021.

The Delta Smelt Summer-Fall Habitat Action is informed by several conceptual models such as the Delta Smelt Management, Analysis, and Synthesis Team (MAST), Fall Low Salinity Habitat (FLaSH), Flow Alteration (FLOAT) model (FLOAT 2019). For example, the FLaSH conceptual model suggested that Delta Smelt habitat should include salinity conditions ranging from fresh to low salinity (0-6 ppt), minimum turbidity of approximately 12 Nephelometric Turbidity Units (NTU) for adults, temperatures below 23°C, food availability, and bathymetric complexity (Brown et al. 2014, pp. 15-23; Komoroske et al. 2015).

Reclamation is developing a numerical model to evaluate the anticipated impacts to Delta Smelt habitat suitability that would result from implementation of different action alternatives (e.g., no action; each action alone; different combinations of actions) under different WY types (e.g., below normal, above normal, etc.). The model will use the habitat suitability index (HSI) developed by Bever et al. (2016) as a base model. The base model uses turbidity, salinity, and current speeds. Current refinements to the HSI under development include adding temperature as a binary filter and including copepod biomass using field data for the type of WY being simulated. Model simulations will be completed by January, 2021, and a web-based data visualization and access tool will be available for DCG members to view different action-water year simulations interactively and download certain data sets.

DWR is developing a parallel modeling effort to assess 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 model would produce two metrics of Delta Smelt habitat area. First, the spatial area of habitat below 6 PSU. Second, the area below 6 PSU that also has a Secchi disk depth of 0.5m or less (higher turbidity) and water temperature of 25 °C or lower. Temperature and turbidity may be interpolated from discrete water quality monitoring stations and/or data collected from continuous sondes. In light of improvements in the continuous turbidity monitoring network close to Suisun Bay and Marsh, modelers will, explore whether it is possible to translate the current index from Secchi depth to turbidity in order to take advantage of better temporal resolution in continuous turbidity sensor data.

However due to time restraints, neither model (from Reclamation or DWR) will be available by the time this report is completed to assess habitat conditions for 2020. Habitat conditions will be measured using only existing monitoring programs supplemented by targeted studies and expansions of existing monitoring programs.

In January of 2024 and 2028, Reclamation and DWR will charter an independent panel to review the Delta Smelt Summer-Fall Habitat Action, among other actions. The purpose of the independent review will be to evaluate the efficacy of the Delta Smelt Summer-Fall Habitat Action and its adaptive management program, and understand potential resulting beneficial effects on listed species, focusing on the Delta Smelt.

In all years during the summer and fall, Reclamation and DWR will also be complying with the State Water Resources Control Board's Decision 1641 (D-1641). This water rights decision prescribes minimum salinity and outflow requirements for the San Francisco Bay/Sacramento-San Joaquin Delta Estuary. While the original purpose of the marsh salinity objectives was to protect habitat for waterfowl in managed wetlands, these salinity objectives provide multi-species habitat benefits (D-1641, pg. 49, SMPA, pg. 18).

Operations

The 2020 WY was classified as "dry", as defined by the Sacramento Valley 40-30-30 index water year hydrologic classification (SWRCB D-1641). Since, it was a "dry" WY, Reclamation and DWR did not implement Delta Smelt Summer-Fall Habitat Action as described within the 2019 USFWS BiOp, see Figure 2 below. SMSCG operations began September 8th, 2020 in compliance with salinity thresholds for the western marsh outlined in the Suisun Marsh Preservation Agreement (SMPA 2015).

The 2020 CDFW Incidental Take Permit (ITP) for the SWP includes an additional provision for a Summer-Fall Habitat Action in some dry years. DWR conducted a modeling exercise using the Delta Simulation Model 2 to investigate the potential for an action. The results of many of the modeling scenarios indicated that minimum export requirements to maintain health and safety standards precluded gate operations. Therefore, DWR did not implement additional SMSCG operations.

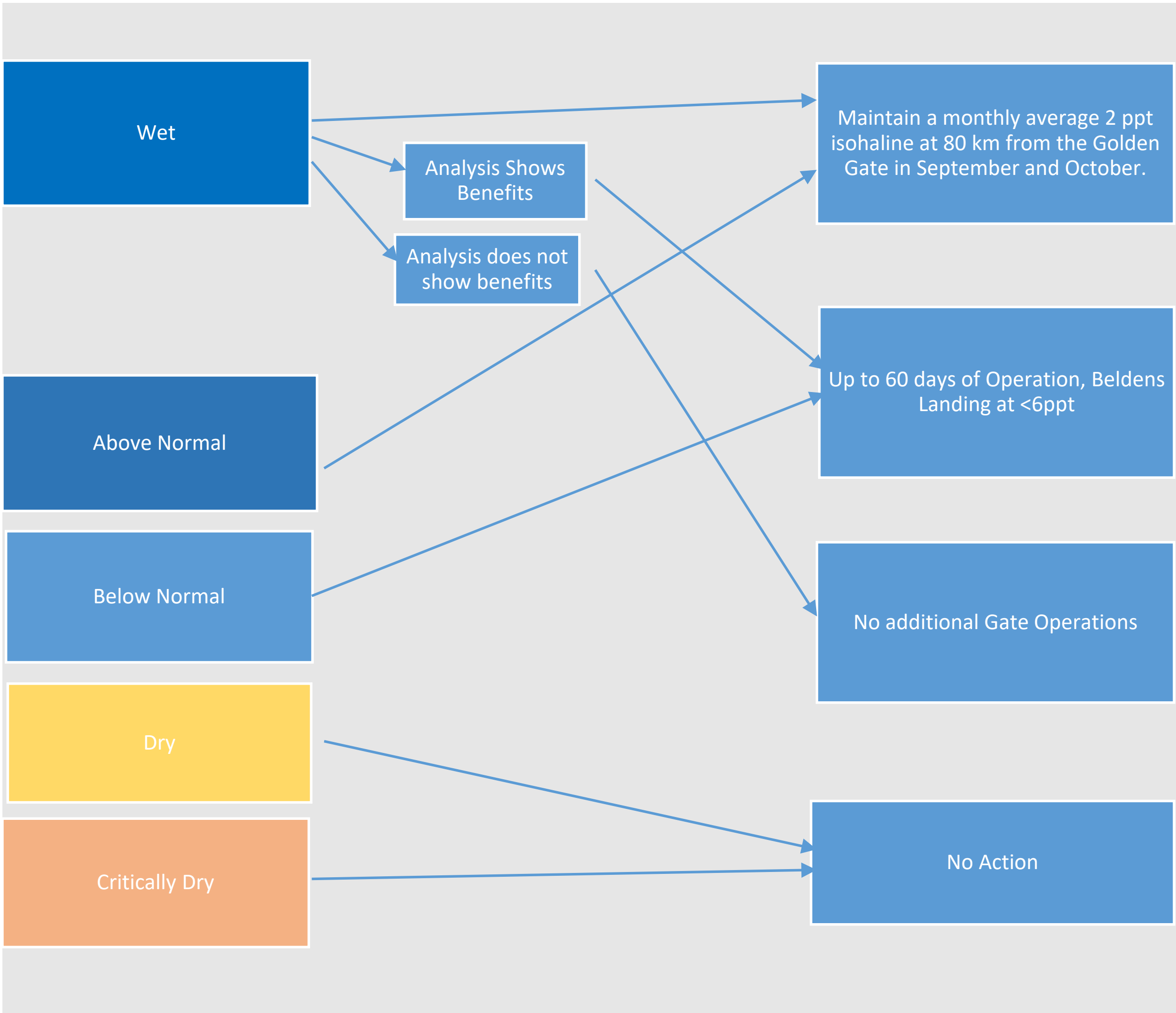


Figure 2 Flow Chart for additional Suisun Marsh Salinity Control Operations and X2 location as part of the Delta Smelt Summer Fall Habitat Action

Salinity Control Gates Operations

The SMSCG were open the majority of time from June through October of 2020. Tidal operations of the gates occurred in September and for the entire month of October, see Table 1 below.

Table 1 2020 SMSCG Operations. Gate status indicates if the gates are open or in tidal operation. 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
June 1-30	Gates Open	Removed	Closed
July 1-31	Gates Open	Removed	Closed
August 1-31	Gates Open	Removed	Closed
September 1-8	Gates Open	Removed	Closed
September 8-24	Tidal Operations	Installed	Operational
September 24-30	Gate Open	Installed	Operational
October 1-31	Tidal Operations	Installed	Operational

The SMSCG tidal operations are reflected in the salinity measurements at Belden's Landing. There was a noticeable decrease in salinity during mid-September following implementations of operations, see Figure 3 below.

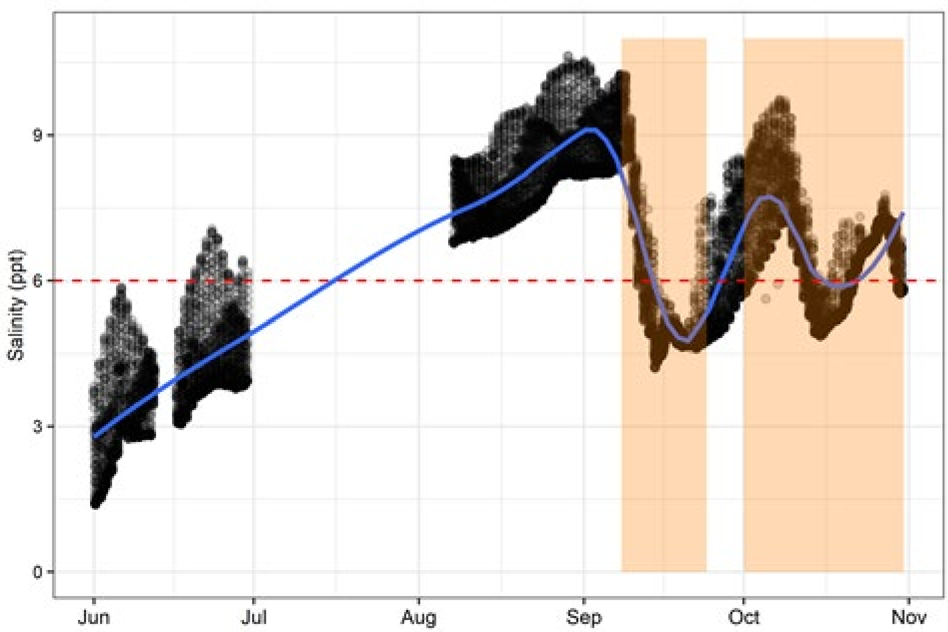


Figure 3 Salinity at Belden's Landing from June through October (Station BDL at CDEC). Orange shading indicate dates when SMSCG tidal operations occurred. Data was missing for July and part of August due to an electrical issue with instrument.

Delta Outflow

Delta operations during the summer and early fall of 2020 were controlled by a combination of D-1641 Delta water quality and Delta outflow requirements. As seen in the Figure 5, generally Delta outflow was near the monthly target other than early June, early September and late October when management of salinity in the Delta required additional outflow. During the summer and fall the CVP maintained steady exports below 5000 cubic feet per second (CFS) while the SWP exports during this period were more variable (Figure 4).

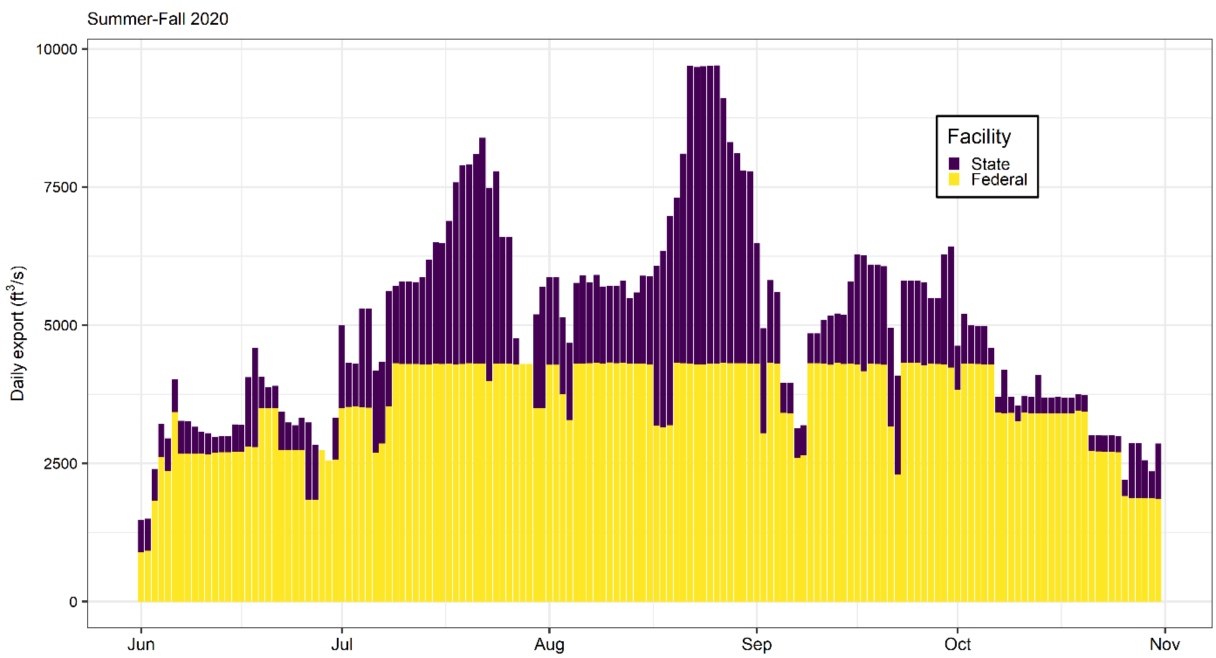


Figure 4 Delta Exports at SWP and CVP pumping facilities

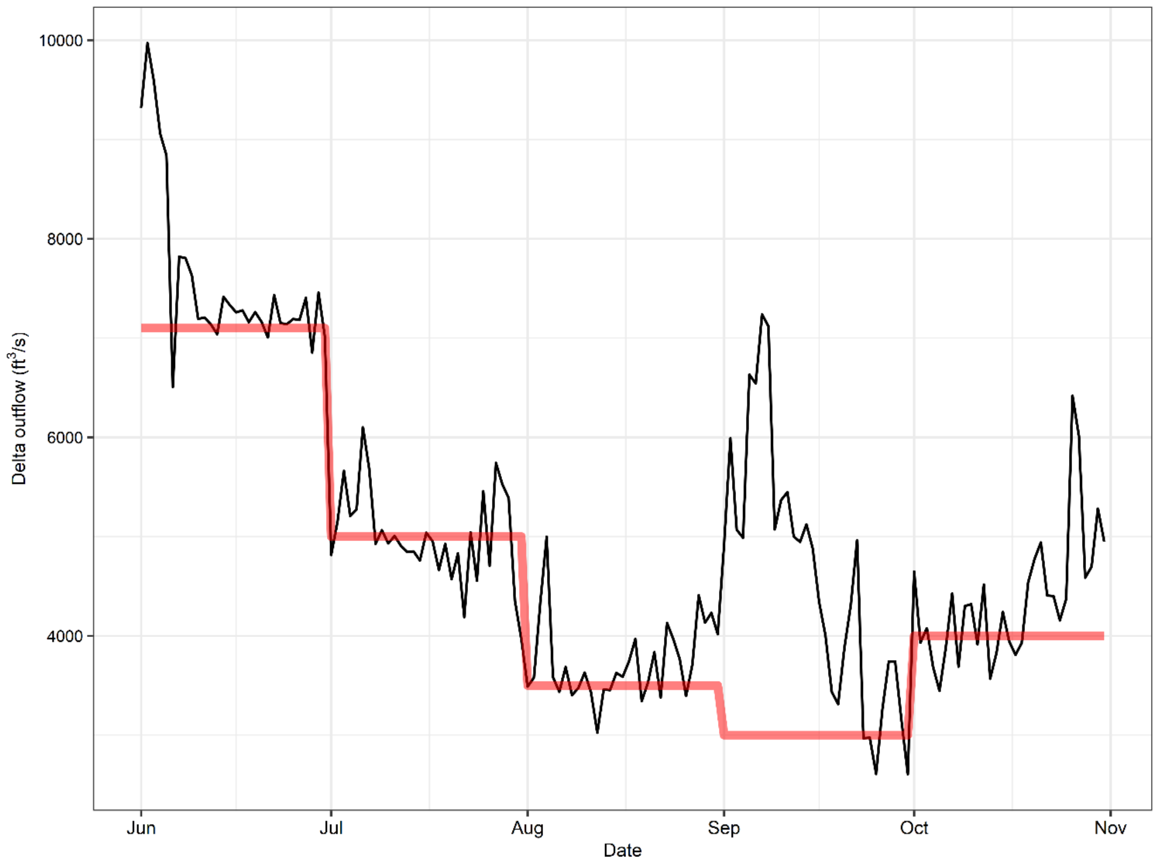


Figure 5 Delta Outflow during 2020 (Black line) and SWRCB's D-1641 Outflow Standards for a dry year (Red Line) from June through October.

The summer and fall periods of 2020 saw the lowest Delta outflow and highest X2 (distance from Golden Gate Bridge at which water salinity measures at roughly 2 parts per thousand) estimates since the end of the 2012-2015 California drought (Figure 6). Outflow and X2 in June and early July of 2020 was comparable to the "below normal" years 2016 and 2018; however, conditions became more similar to the "critically dry" year of 2015 towards the months of September and October, which necessitated the outflow pulse to lower salinity in the Delta. Although 2020 WY was the driest in the past five years, the overall hydrograph was well within the range of other "dry" years that California has experienced since 1997 (Figure 7). Outflow in summer and fall of 2020 was higher than the "dry" WY of 2001 and lower than the "dry" WY of 2013.

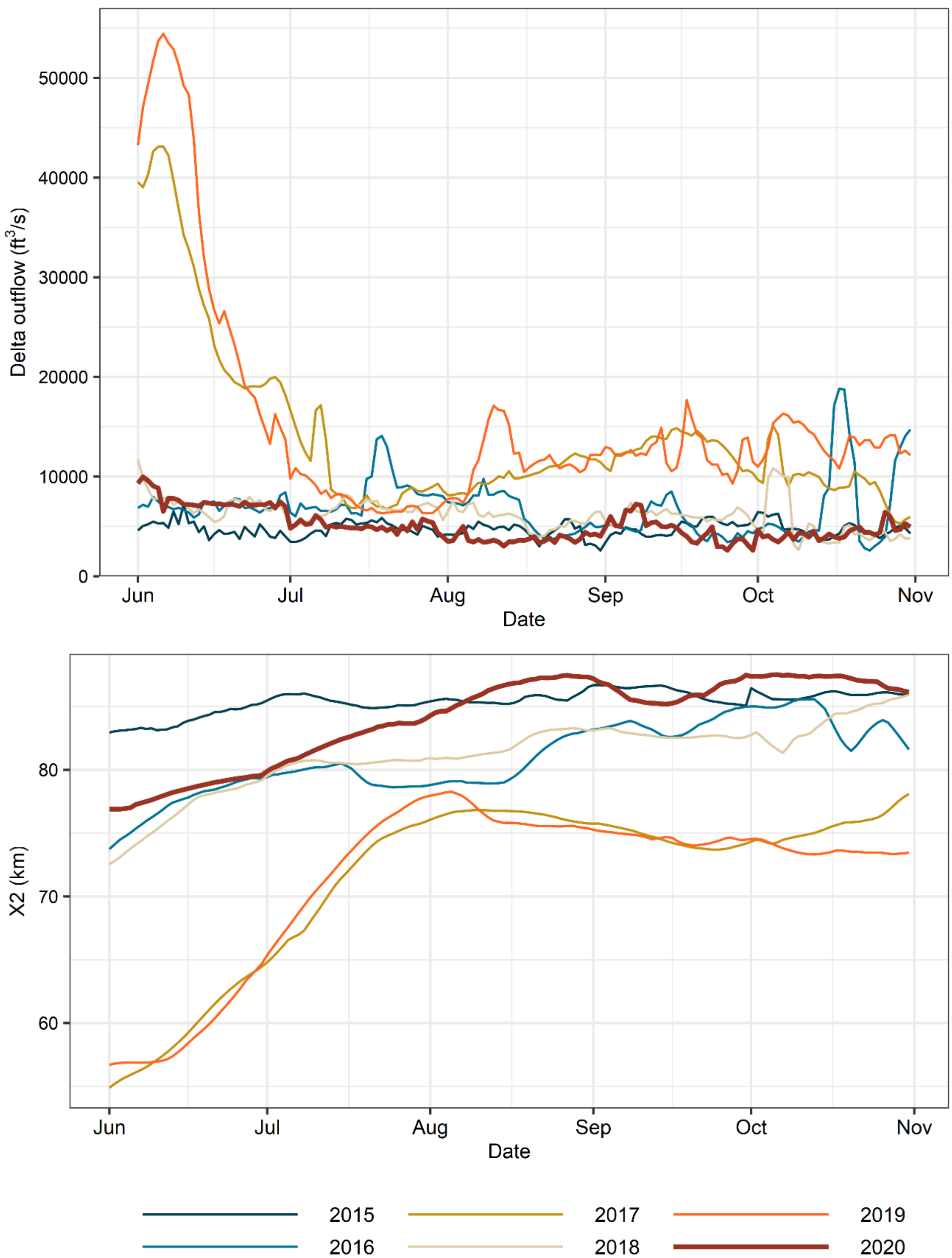


Figure 6 Top: Modeled daily Delta outflow from DWR Dayflow model from 2015 to 2019 and Bottom: Modeled daily X2 from DWR Dayflow model (with the exception of 2020) Modeled daily Delta outflow from DWR Dayflow model from 2015 to 2019, plotted alongside 2020 estimated Delta outflow data from California Data Exchange Center (CDEC) Delta Outflow (DTO) station. Bottom: Modeled daily X2 from DWR Dayflow model (with the exception of 2020), plotted alongside calculated X2 for 2020 using X2 equation used in Dayflow and CDEC DTO data (bottom). Red dotted dash line indicates the year 2020.

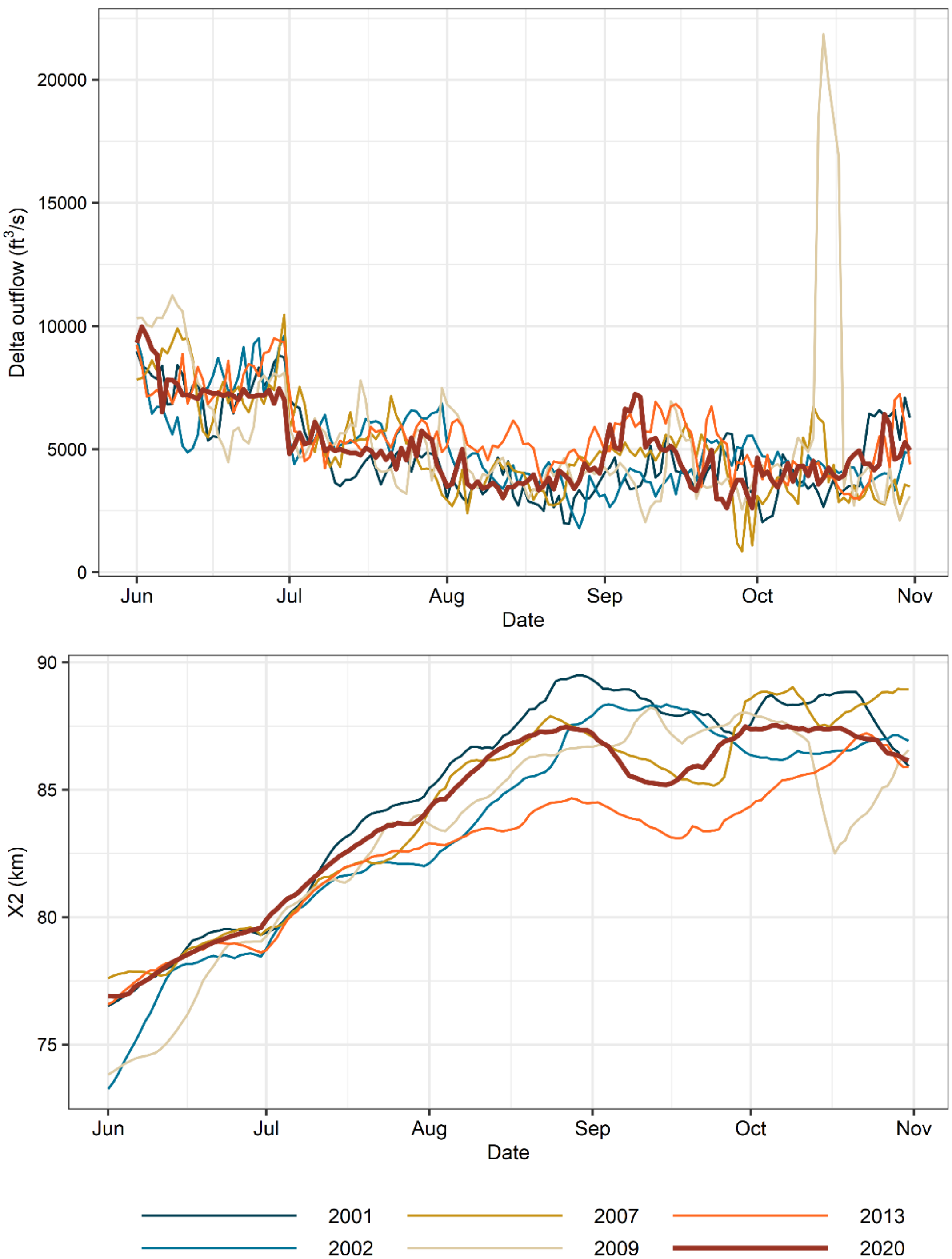


Figure 7 Top: Modeled daily Delta outflow from DWR Dayflow model for all dry years since 1997 (with the exception of 2020), plotted alongside 2020 estimated Delta outflow data from CDEC DTO station

Bottom: Modeled daily X2 Top: Modeled daily Delta outflow from DWR Dayflow model for all dry years since 1997 (with the exception of 2020), plotted alongside 2020 estimated Delta outflow data from CDEC DTO station. Bottom: Modeled daily X2 from DWR Dayflow model (with the exception of 2020), plotted alongside calculated X2 for 2020 using X2 equation used in Dayflow and CDEC DTO data (bottom). Red dotted dash line indicates the year 2020.

Food Enhancement Actions

The Delta Smelt Summer Fall Habitat Action included three food and habitat enhancement studies. These projects are the North Delta Food Subsidies/Colusa Basin Drain Study, Sacramento River Deepwater Ship Channel Food Study, and Suisun Marsh and Roaring River Distribution System Food Subsidies Study. Food and Habitat Enhancement studies are addressed within the USFWS 2019 BiOp programmatically and are subject to future consultation and collaborative planning. Future consultations may require additional reporting specific to each action below.

North Delta Food Subsidies/Colusa Basin Drain Study

The North Delta Food Subsidies/Colusa Basin Drain Study redirects agricultural drainage or Sacramento River water into the Yolo Bypass Toe Drain in order to enhance the quantity and quality of food for Delta Smelt in the North Delta including Cache Slough Complex and lower Sacramento River. This is accomplished by generating a moderate flow pulse of 20-25 thousand acre feet (TAF) in the Yolo Bypass Toe Drain during the summer or fall period for up to 2-4 weeks, which has been shown to be successful in transporting lower trophic plankton and/or triggering phytoplankton blooms downstream in some years (Frantzich et al. 2018, Twardochleb et al. 2020).

There was no coordinated action for the North Delta Food Subsidies/Colusa Basin Drain Study in 2020; however, an unmanaged flow pulse from agricultural return water typically occurs within the Yolo Bypass Toe Drain (Twardochleb et al. 2020). In summer and fall of 2020, flow at Lisbon Weir within the Yolo Bypass Toe Drain was low overall and largely influenced by tides, with net negative flow between June and August (Figure 8). A small flow pulse was observed in September resulting in net positive outflow for a couple weeks in the upper Yolo Bypass; however, the effects of this flow pulse on the aquatic food web is expected to be minimal and/or localized (Twardochleb et al. 2020).

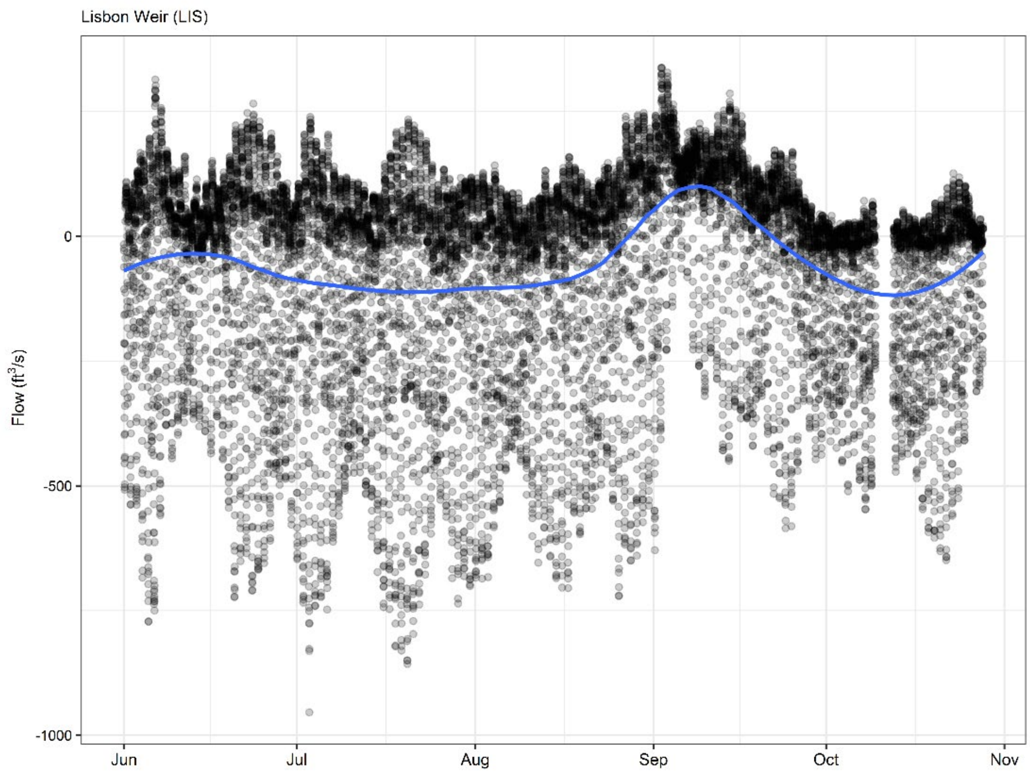


Figure 8 CDEC flow data from Lisbon Weir at the Yolo Bypass Toe Drain (station LIS) from June through October of 2020, taken at 15-minute intervals. Blue line indicates LOESS smoothing line. Note that data did not undergo quality control/check.

Sacramento Deep Water Ship Channel Food Web study

The Sacramento Deep Water Ship Channel Food Web Study is investigating the feasibility of exporting phytoplankton, zooplankton and other food web resources from the upper relatively productive reaches of the ship channel to the lower reaches of the ship channel and Cache Slough. Export production would be managed adaptively in part by controlling inflow from the Sacramento River at West Sacramento. Presently, inflow is limited to the small amount of flow (~3 cfs) that leaks through the lock structure gates which are inoperable and locked in their closed position. As part of its 200-year flood protection planning process, the City of West Sacramento has evaluated several infrastructure alternatives for restoring the hydraulic connection between the ship channel and the Sacramento River (City of West Sacramento 2020). The alterative selected for further consideration includes a wall with four culverts with flap-gates that would be operated during April 15th through October 31st to enhance local water quality and manage aquatic food web production and downstream redistribution. The ultimate goal is to supply the lower Sacramento River mainstem with a 'seed source' capable of taking advantage of the relatively abundant nutrient supply derived from the Regional San wastewater treatment effluent discharge downstream of Freeport thereby boosting the trophic level of the confluence area and the export of food resources to Suisun Bay. However, in the future, nitrogen loading from the wastewater treatment plant is anticipated to be cut in half.

Since 2012, Reclamation and its University of California Davis (UCD) partners have conducted monthly fixed-station sampling of nutrients, suspended solids, chlorophyll concentration, phytoplankton and zooplankton density and other constituents to document baseline trophic conditions in the ship channel and how they vary longitudinally and seasonally (Figure 9). Reclamation is also funding the US Geological Survey (USGS) to operate four continuous monitoring stations that record variation in tidal stage and velocity as well as EC, temperature, dissolved oxygen, turbidity and chlorophyll fluorescence. At one location in the upper ship channel (in the reach where nitrogen addition experiments were conducted by Reclamation, UCD and USGS in 2018 and 2019) (Reclamation 2019), nitrate concentration is also being monitored continuously. These data provide the basis for determining how temperature stratification, nitrogen concentration, chlorophyll concentration and other parameters vary at the tidal and finer temporal scales required to model hydrodynamics and food web dynamics.

The monthly discrete sampling effort was suspended in March 2020 due to the COVID-19 epidemic. Continuous monitoring, however, has continued at all four stations (Figure 10). These data are available at: https://waterdata.usgs.gov/nwis/uv?site_no=11455095,%2011455136,%2011455142,%2011455335.

Table 2 Links to USGS continuous monitoring station data.

ID	USGS #	Link
CM72	11455095	https://waterdata.usgs.gov/nwis/uv/?site_no=11455095
CM66	11455136	https://waterdata.usgs.gov/nwis/uv/?site_no=11455136
CM62	11455142	https://waterdata.usgs.gov/nwis/uv/?site_no=11455142
CM54 (DWS)	11455335	https://waterdata.usgs.gov/nwis/uv/?site_no=11455335

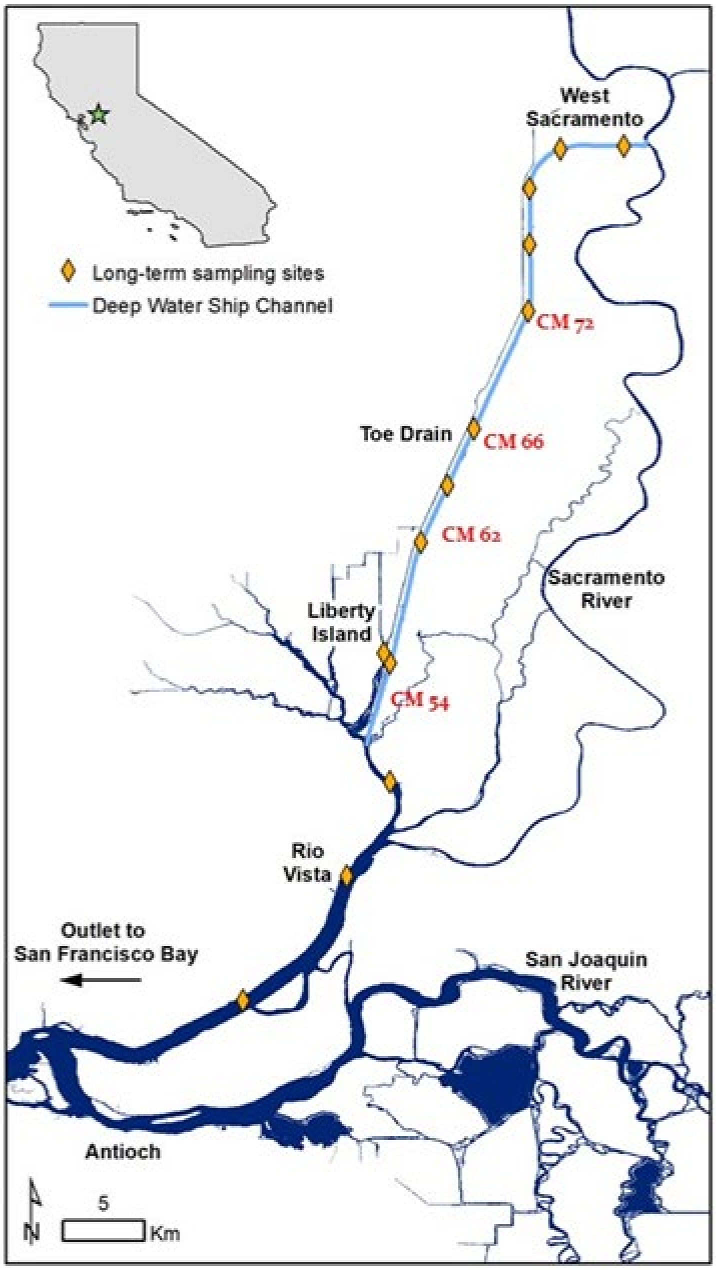


Figure 9 Location of monthly discrete sampling stations (gold) and four USGS continuous monitoring stations (red) in the Sacramento Deepwater Ship Channel.

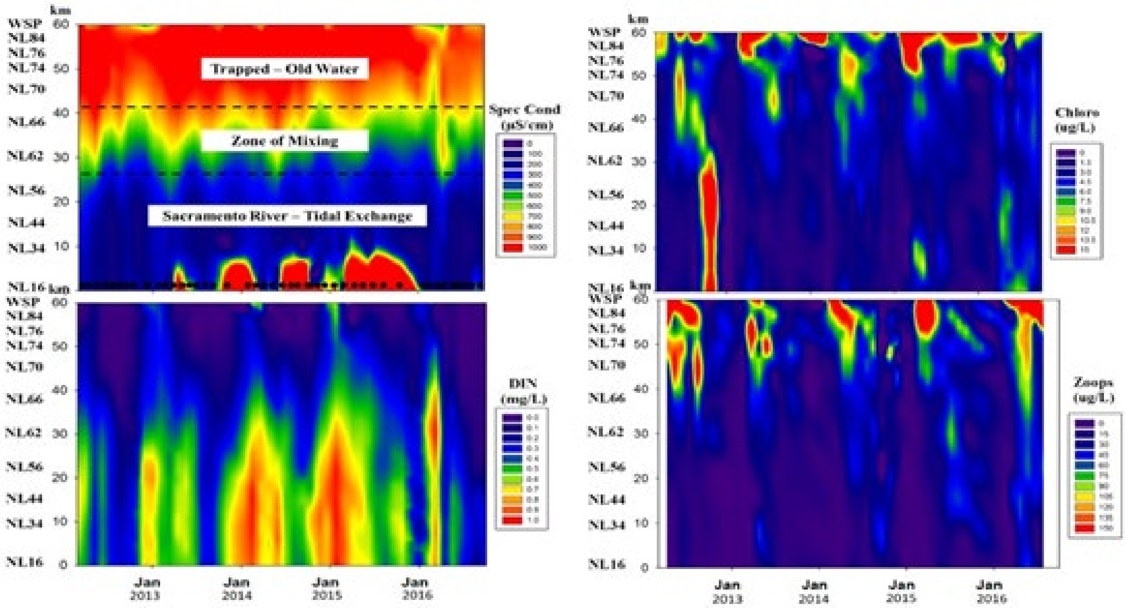


Figure 10 Longitudinal and temporal variation in specific conductance, dissolved inorganic nitrogen, chlorophyll concentration and zooplankton biomass recorded by monthly fixed-station discrete sampling during January 2013, 2014, 2015, and 2016

Experimentally manipulating flow into the ship channel cannot occur until the required infrastructure is constructed and permitted for operation. Once net flow is restored to the ship channel, it will be important to determine how much chlorophyll it exports to the lower Sacramento River and how this export compares to chlorophyll fluxes at stations up- and downstream. For this purpose, Reclamation funds USGS to maintain continuous monitoring stations in the Sacramento River at Walnut Grove and Decker Island, in Cache Slough and in the San Joaquin River at Jersey Point (Figure 11).

Figure 11 Map showing selected USGS-operated stations Upper Sacramento River above Delta Cross Channel (WGA), Cache Slough above Ryer Island ferry (CCH), Lower Sacramento River at Decker Island (DEC), and Lower San Joaquin River at Jersey Point (JPT). Stage and velocity data to calculate discharge for DEC is collected upstream at the Sacramento River at Rio Vista bridge (station not shown).

The stations at Decker Island (DEC) and Jersey Point (JPT) represent the flux from the northern and southern Delta into the low salinity zone, respectively. The station at Walnut Grove (WGA) represents flux from upper Sacramento River and the station at Cache Slough (CCH) represents the flux from the Cache Slough complex making it possible to separate their relative contribution to the flux into Suisun Bay via DEC.

Suisun Marsh and Roaring River Distribution System Food Subsidies Study

The Roaring River Distribution System Food Subsidies Study would use the existing infrastructure to drain food-rich water from the canal into Grizzly Bay to augment Delta Smelt food supplies in that area. This management action may attract Delta Smelt into the high quality Suisun Marsh habitat in greater numbers, reducing use of the less food-rich Suisun Bay habitat (California Natural Resources Agency 2016). Modified operations for the study will require extensive coordination with private landowners as the majority of managed wetlands are private property. Infrastructure repairs may also be needed. This study is still in the planning and development phase and was not implemented in 2020. Thus, it will not be addressed further in this report.

Habitat Restoration

This section is intended to inform on the incremental progress of habitat restoration projects. These projects are being implemented by DWR and others to enhance the food web that supports Delta Smelt. The majority of monitoring, including fish food production, is being conducted by CDFW. Unlike the summer-fall actions, habitat restoration may provide food web benefits year-around and in all water year types. Assessment of habitat restoration progress can provide better context for Delta Smelt status for the year and is important to review as it can affect the efficacy of the Delta Smelt Summer-Fall Habitat Action. The following is a list of tidal marsh restoration sites within Cache Slough Region, Sacramento River Region and Suisun Marsh Regions and their current implementation (Sacramento Valley Salmon Resiliency Strategy 2020).

Cache Slough Region

- **Dutch Slough Tidal Habitat Restoration Project-** Construction of internal channels and habitat features were launched in 2018 to prepare for breaching. Revegetation is underway in 2020 and the levee breach is planned for 2021.
- **Lookout Slough Tidal Habitat Restoration and Flood Improvement Project-** This restoration project is currently in the planning process and construction is planned for April 2021.
- **Lindsey Slough-** The restoration project completed construction in 2014. This project restored habitat function and connectivity to 159 acres of freshwater emergent wetlands and 69 acres of alkali wetlands, and recreated and reconnected a one-mile tidal channel.
- **Lower Yolo Ranch –** Project completed construction in 2020.
- **Yolo Flyway Farms –** Project construction was completed in September 2018. Approximately 300 acres of tidal freshwater wetlands, and an additional 30 acres of seasonal wetlands, at the southern end of the Yolo Bypass were created. The restoration site is currently adaptively managed by DWR.

- **Prospect Island Tidal Habitat Restoration-** This restoration project is currently in the planning process.

Lower Sacramento/ Confluence Region

- **Decker Island-** Tidal interaction was restored to the 140 acre site in October 2018, which converted an existing wetland into tidal habitat. The project consisted of 3 main elements: (1) lowering a 300 foot section of levee at the northern end of the Island to internal elevation to create a flow through system that would increase access for fish and inhibit the establishment of invasive vegetation, (2) reconfiguring the internal berms to assist in moving water on and off site and would provide upland habitat for wildlife within the existing tidal wetland and (3) widening the existing breach at the southern end of the Island that would provide full tidal access to the site.
- **McCormack-Williamson Tract Tidal Habitat and Floodplain Restoration Project-** Construction related to the restoration project to protect the transmission tower, pre-existing infrastructure was completed in 2019. Habitat restoration efforts are in the planning and permitting stage.
- **Winter Island Tidal Habitat Restoration Project –** Tidal interaction was restored in 2019 to roughly 586 acres of muted brackish wetlands with muted tidal connectivity to fully tidal habitat.

Suisun Marsh Region

- **Arnold Slough-** This restoration project is currently in the planning process and construction is slated for 2021.
- **Blacklock Restoration Site-** Tidal interaction was restored to 140 acres of tidal wetland habitat in 2006.
- **Bradmoor Island-** This restoration project is currently in the planning process and construction is slated for 2021.
- **Chipps Island-** This restoration project is currently in the planning process and construction is slated for 2023.
- **Hill Slough**- The restoration project began construction in 2019 but has yet to breach exterior levees and return tidal habitat.
- **Meins Landing**- This restoration project is currently on hold.
- **Tule Red-** Tidal interaction was restored in October of 2019. This project included 400 acres of restored tidal habitat and 200 acres of tidal habitat enhancement.
- **Wings Landing-** This restoration project completed construction in October of 2020.

Monitoring

To assess Delta Smelt habitat conditions in 2020, a no-action year, this report evaluates regional and historical comparisons. Regional comparisons examine differences between different geographic areas within the estuary to determine areas of quality Delta Smelt habitat. Since the estuary has been relatively well-monitored for many years, comparisons to historical years examine conditions in relation to other past drier years. This work serves to establish a baseline of conditions in the absence of the Delta Smelt Summer-Fall Habitat Action, as described in the Background section.

Fish Monitoring

Fish monitoring efforts that are utilized in this seasonal report include existing surveys conducted by IEP, specifically the CDFW's Summer Townet Survey (STN) (operates every other week from June through August), Fall Midwater Trawl Survey (FMWT) (operates first two weeks of the month from September through December), as well as the UC Davis Suisun Marsh Survey and USFWS Enhanced Delta Smelt Monitoring Program (EDSM) (year-round). Because monitoring relies entirely on existing monitoring programs, each of which has limited sampling, statistical analysis of community composition may not be possible until multiple action years are combined. Each survey is described fully in the Appendix D- Monitoring.

Water Quality Monitoring

The water quality in the LSZ, Suisun Marsh, and lower Sacramento River region are relatively well-monitored by routine and long-standing IEP surveys such as the Environmental Monitoring Program (http://www.water.ca.gov/iep/activities/emp.cfm) (operates second week of the month all year long), which collects water quality, phytoplankton, zooplankton and benthic invertebrate samples on a monthly basis. DWR maintains a number of water quality stations in the LSZ and Suisun region. Several continuous water quality stations that cover the downstream range of Delta Smelt were selected in order to provide a general overview of the abiotic habitat conditions in the summer and fall of 2020 (Figure 12). Stations at Grizzly Bay (GZL), Hunter's Cut (HUN), Belden's Landing (BDL), and National Steel (NSL) were used to describe conditions within Suisun Marsh. To evaluate conditions along the Sacramento River, data from stations at Mallard Island (MAL), Decker Island (SDI), and Rio Vista (RVB) were used.

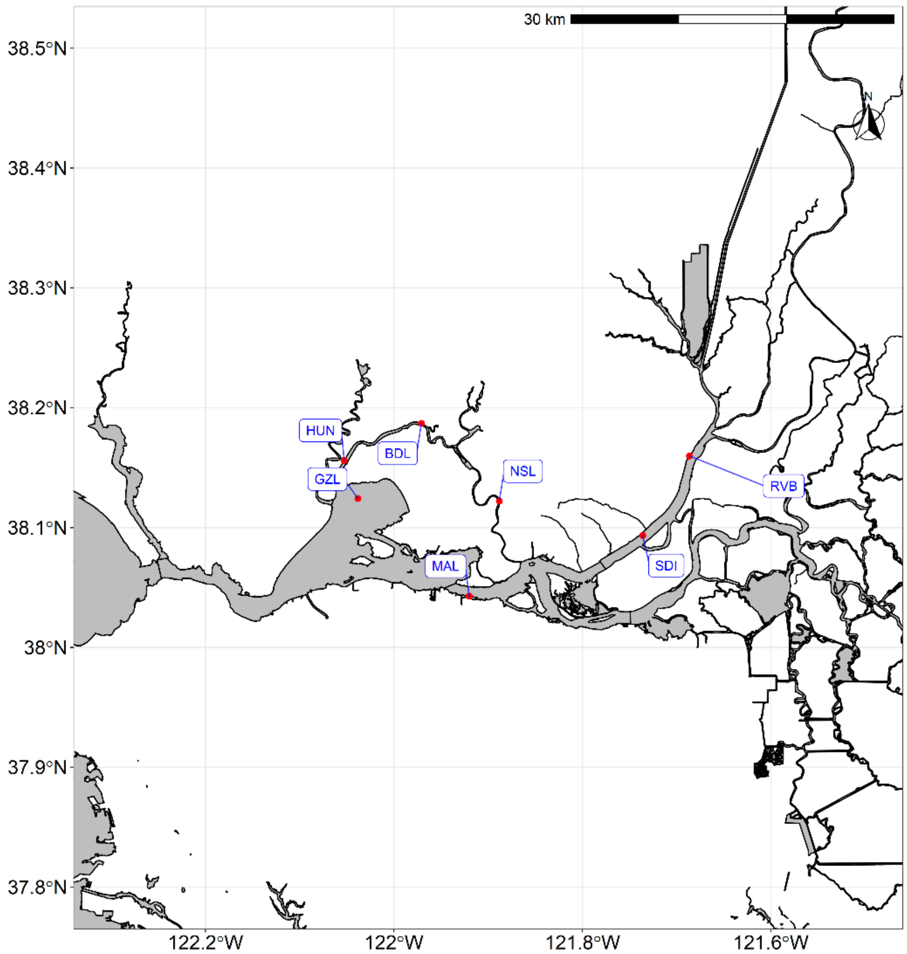


Figure 12 Map of the general low salinity zone within the San Francisco Bay-Delta and the CDEC stations used to create figures in this document. HUN = Hunter's Cut, BDL = Belden's Landing, NSL = National Steel, GZL = Grizzly Island, MAL = Sacramento River at Mallard Island, SDI = Sacramento River at Decker Island, RIV = Sacramento River at Rio Vista.

Phytoplankton and Zooplankton

Zooplankton monitoring utilized in this report is produced from the DOP. The DOP (https://www.usbr.gov/mp/bdo/directed-outflow.html), established in 2016, collects data on water quality, phytoplankton, zooplankton, and fish (Schultz 2019). Like EDSM, DOP conducts stratified random sampling instead of sampling at fixed station. The DOP uses a generalized random-tessellation stratified sampling design (Stevens and Olsen 2004; Starcevich et al. 2016; also used by the current Enhanced Delta Smelt Monitoring [EDSM] program) to select 3 sampling sites within each regional sampling strata within the full study area per weekly sampling period. DOP habitat monitoring occurs during the majority of the Delta Smelt rearing-stage period (April – November; start date coincides with start of EDSM 20-mm sampling). The DOP study area (Figure 13) includes the North Delta Arc (Moyle et al. 2016) an area consistently occupied by a large portion of the Delta Smelt population. Phytoplankton and Zooplankton monitoring is further detailed in Appendix D.

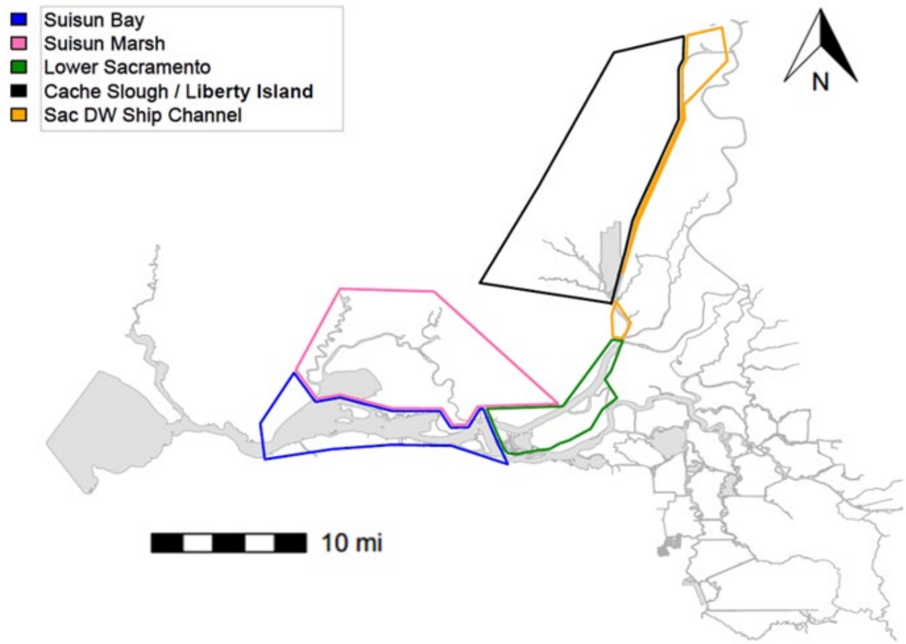


Figure 13 Map of the Directed Outflow Project Study Area depicting sampling strata

Clam Density and Biomass

The presence of *P. amurensis*, along with the more freshwater-adapted *Corbicula fluminea* (a clam species introduced to the system in the 1940s) (Brown et al. 2016), have been presumed to impact Delta Smelt by reducing food availability (Mac Nally et al. 2010). The density and biomass of these two clam species are important parameters to monitor for the management of Delta Smelt. Benthic invertebrate data is routinely collected by EMP and was supplemented by a special investigation of clams in Suisun Marsh to further investigate the habitat value of this area. However, benthic invertebrate data collected by the EMP is not yet available at the publication of this report.

DWR staff conducted bivalve surveys in July and September of 2019 and 2020, matching the survey months of earlier years. Samples from the regular EMP surveys and the supplemental surveys will be available in February of 2021, and so are not yet available for this report.

Clam Density and Biomass monitoring is further detailed in Appendix D.

Results

Abiotic Habitat Attributes

The current prevailing hypothesis is that 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. 2013). Three commonly measured water quality parameters form the underlying basis for this hypothesis: salinity, water temperature, and turbidity; as demonstrated by past studies on Delta Smelt (Nobriga et al. 2008; Mac Nally et al. 2010, Feyrer et al. 2011, Bever et al. 2016).

Abiotic habitat attributes within suitable ranges for Delta Smelt are defined in this report as low salinity conditions of 6 ppt or less, turbidity higher than 12 NTU, and water temperatures below 75°F (~23.9°C) based on Brown et al. (2014). To illustrate conditions for Delta Smelt at the various stations, proportion of time in each day deemed suitable for Delta Smelt based on each water quality parameter threshold was calculated and plotted in a summary heat map (Figure 14). Based on the general understanding of Delta Smelt biology, unsuitable condition based on just a single parameter (e.g., salinity), may preclude most Delta Smelt from the area. More detailed discussion on each water quality parameter can be found below.

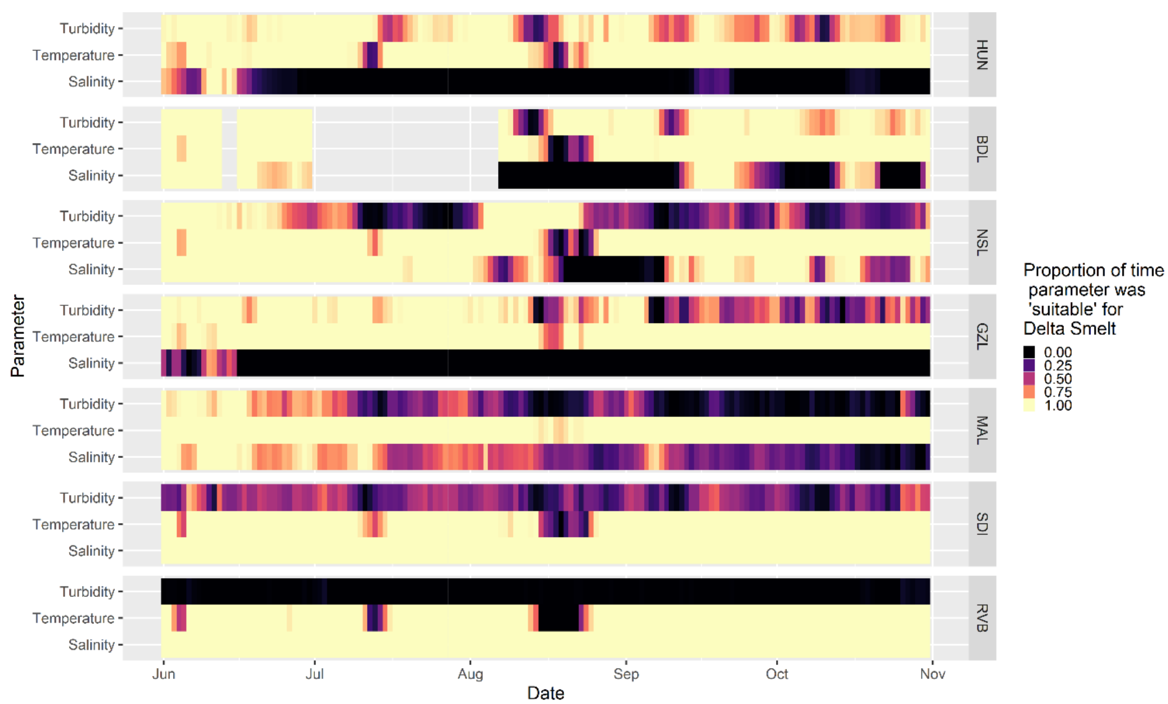


Figure 14 Heat map demonstrating proportion of time in each day that each water quality parameter was suitable for Delta Smelt at the stations shown in Figure 12 (i.e., salinity ≤ 6 ppt, turbidity ≥ 12 NTU, temperature ≤ 23.9° C). Note that data has not undergone quality control/check and that stations may actually record formazin nephelometric units (FNU) instead; however, the general turbidity patterns observed should remain valid.

Salinity

Delta Smelt has been described as a semi-anadromous species. The species spawns in freshwater habitat and most migrate to brackish low-salinity habitat where they spend large parts of their life cycle. Although some Delta Smelt reside in freshwater year-round, they are uncommon in higher salinity waters. Delta Smelt physiological stress response to high salinity (Komoroske et al. 2016), and studies that demonstrated the species' higher occurrence in low salinity habitat based on field data (Feyrer et al. 2007, Nobriga et al. 2008) are the reasons why size and location of the low-salinity zone have been described as key factors for Delta Smelt habitat.

In 2020, salinity within Suisun Marsh was generally highest downstream at Hunter's Cut and lowest at National Steel site upstream (Figure 14 and Appendix-A Figure 1). All sites within Suisun Marsh exhibited the same general pattern of increasing salinity between June and September, followed by a short reduction in salinity during mid-September and a return to moderate-high salinity levels in October. It is likely that salinity was a limiting factor in Suisun Marsh for Delta Smelt for the majority of the 2020 Summer-Fall period (>6 ppt). As expected based on X2 estimates (Figure 6, Operations Section), the MAL station showed a pattern of increasing salinity over time from June to October of 2020. Delta Smelt were not likely to be present around the vicinity of MAL station starting around August; however, salinity upstream of the confluence between Sacramento and San Joaquin Rivers remained suitable for Delta Smelt based on the stations SDI and RVB.

Salinity at Belden's Landing (BDL), a monitoring station central to the additional operation of the SMSCG, was below 6 ppt from June to about mid-July based on extrapolation of existing data (Figure 3). After mid-July, salinity at BDL stayed above 6 ppt, except for a brief period in mid-September when salinity occasionally decreased to below 6 ppt. This is similar to salinity patterns for other recent dry summers (Sommer et al. 2020). Several days of high water temperature (>23.9° C) and low turbidity (<12 NTU) deemed unsuitable for Delta Smelt were observed at BDL in Summer-Fall of 2020 (Figure 14).

In 2020, mean salinity in the Suisun regions among randomly selected DOP sampling sites was often near or above 6 psu during the summer period and well above this during the fall period (Appendix-A Figure 2). As expected, upstream regions were mostly within freshwater parameters with the Lower Sacramento region having some increase in salinity during the fall.

Turbidity

Turbidity has been demonstrated 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, Mahardja et al. 2017a, Polansky et al. 2018). Under culture conditions, Tigan et al. 2020 found that both turbidity and light intensity, as well as the interaction between these factors, play an important role in the feeding activity, growth, and survival of larval Delta Smelt.

In summer and fall of 2020, Suisun Marsh sites and MAL station saw higher turbidity relative to the lower Sacramento River sites upstream of the confluence (SDI and RVB) (Figure 14 and Appendix A Figure 5). The observed low turbidity (<12 NTU) in the Lower Sacramento River may have been a limiting factor for Delta Smelt in this region during summer and fall of 2020. It should be noted that reported readings in this document are in NTU, but collected data from continuous water quality stations may be in formazin nephelometric units (FNU) instead (DWR Memorandum). Nevertheless, the relative turbidity patterns observed should remain valid as both units (FNU and NTU) are very similar (DWR Memorandum) and referred to by some as "essentially equivalent" (Morgan-King and Schoellhamer 2013).

In both the summer and fall of 2020, turbidity averaged and maximum ranged was higher in the Suisun regions sampled by DOP than other regions (Appendix-A Figure 6). Turbidity was greater in the Sacramento Deep Water Ship Channel than other monitored freshwater locations in both the summer and fall.

Temperature

Evidence of Delta Smelt's sensitivity to high water temperatures has come from both laboratory and field studies. Critical thermal maxima of juvenile Delta Smelt range between 25 to 29°C in a controlled laboratory setting (Swanson et al. 2000, Komoroske et al. 2014), a temperature range that is observed in the field at times. High summer temperature was also found to have a negative impact on juvenile Delta Smelt survival from summer to fall based on a multivariate autoregressive model work and the life cycle model (Mac Nally et al. 2010, Polansky et al. 2020). Moreover, Delta Smelt occurrence seems to be less common at higher water temperature (Nobriga et al. 2008, Sommer and Mejia 2013).

In both the summer and fall of 2020, mean water temperature measured by DOP generally increased toward more landward freshwater areas and was lower than 23.9°C (Appendix-A Figure 7). Several sampling events for the freshwater regions of Lower Sacramento, Cache Slough, and Sacramento Ship Channel had readings that approached or exceeded 23.9°C. While mean temperatures in the fall were lower than the summer, early periods of the fall in the Sacramento Shipping Channel had water temperatures occasionally exceeding 23.9°C.

Water temperatures did not vary substantially between fixed stations (relative to turbidity and salinity) and generally stayed under 23.9°C for most of the summer and fall period. Nonetheless, there was a notable heatwave in mid- to late-August that likely impacted the Delta Smelt population to a considerable extent. Days of high-water temperature (>23.9°C) and low turbidity (<12 NTU) deemed unsuitable for Delta Smelt were observed at BDL in Summer-Fall of 2020 (Figure 14), lasting for as much as a week. Although mean water temperatures as measured by DOP were below 23.9°C for all regions during both seasons, the DOP noted a pattern of warmer temperatures further inland and multiple sampling events when water temperature was near or above 23.9°C. Based on the upper thermal limit for Delta Smelt suitable habitat used in this document (23.9°C, 75°F), water temperature may have occasionally limited Delta Smelt survival or distributions in freshwater regions of the northern Delta during summer of 2020 (Figure 14 and Appendix-A Figure 7).

Extent of Contiguous Low Salinity Habitat

In years of high net Delta outflow, habitat suitable for Delta Smelt may extend contiguously from the freshwater habitat of Cache Slough Complex in the North Delta to much of Suisun Bay and Suisun Marsh. However, based on the 2020 X2 location estimates and data from continuous water quality stations, Delta Smelt may have been excluded from large parts of Suisun Bay and Suisun Marsh regions by the fall of this year (Figure 15 and 16). X2 was estimated above 80 km starting in July of 2020 (Figures 6, 7), while MAL and BDL stations showed salinity levels generally considered too high for persistent Delta Smelt use around August and September (Figure 14 and Appendix A Figure 1).

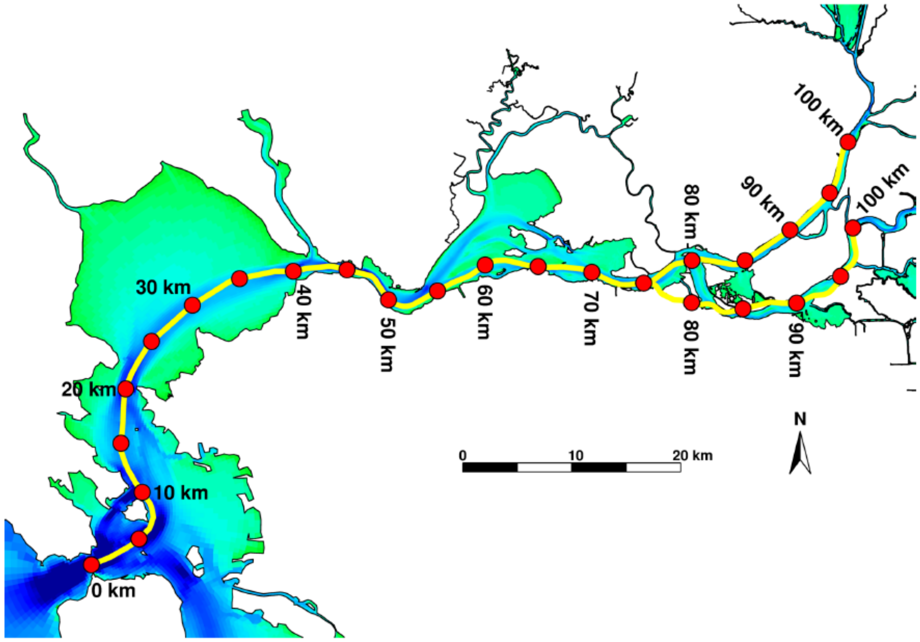


Figure 15 Map of the San Francisco Bay-Delta depicting location of X2 based on distance from the Golden Gate Bridge according to UnTRIM Bay-Delta model taken from MacWilliams et al. (2015).

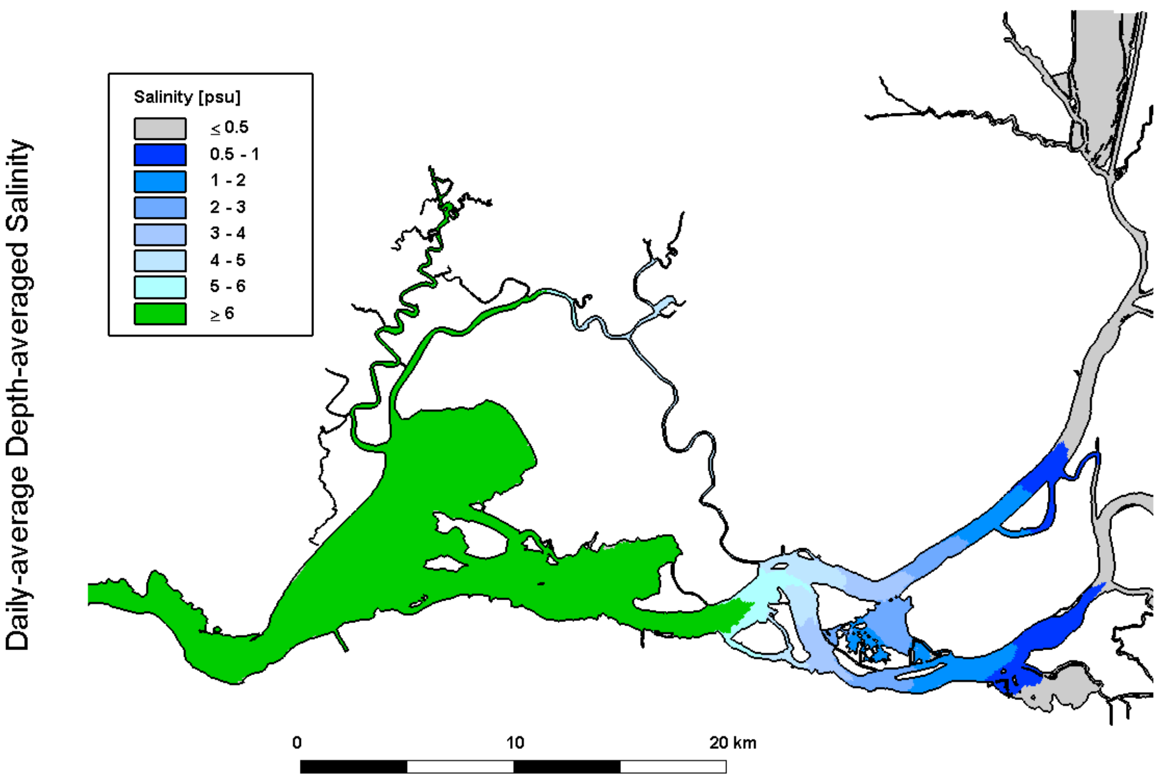


Figure 16 Daily- Average Depth-averaged Salinity when X2 is located at 88km (Delta Modeling Associates 2014), the maximum X2 value between June and October 2020 based on the X2 calculation with CDEC DTO station data.

Contiguous fresh water to low saline water conditions extended between Cache Slough and Suisun Bay during early summer. As outflow declined, salinity increased in Suisun Bay, which likely isolated low salinity habitat in Eastern Grizzly Bay and portions of western Suisun Marsh and caused contiguous low salinity habitat to contract eastward. As the summer progressed into fall, habitat within Grizzly Bay, Honker Bay and the western part of Suisun Marsh became unsuitable for Delta Smelt. As shown in the figure 16 above, low salinity habitat (<6 ppt) was generally located in the lower Sacramento and San Joaquin Rivers and their confluence.

Abiotic Limiting Factors

Based on abiotic habitat attributes alone, Delta Smelt distribution in Suisun Marsh was likely limited in Summer-Fall of 2020 due to encroachment of high salinity (0.5 to 6 ppt) water over time, while Delta Smelt's presence within the lower Sacramento River, Cache Slough and Sacramento Shipping Channel, may have been limited by low turbidity and a brief period of potentially acute high water temperature extending up the river into Cache Slough (Figure 14).

Biotic Habitat

Food availability is an essential component of Delta Smelt habitat, but how much is needed is difficult to evaluate in the field because prey densities can vary as a function of water temperature and this may affect the amount of time Delta Smelt can safely forage without excessive risk of predation (Kimmerer 2004, Davis et al. 2019). Food availability can also be impacted by harmful algae blooms and by competition between Delta Smelt and other fishes. The following section describes the factors that influenced biotic habitat for Delta Smelt in WY 2020.

Chlorophyll

Continuous water quality stations (Figure 12) varied in Chlorophyll fluorescence but had generally higher readings of chlorophyll during the summer period than fall (Figure 17). Chlorophyll fluorescence was highest at the BDL station and was generally greater for Suisun area stations than other regions. Chlorophyll fluorescence was lowest at the MAL, SDI (Decker) and RVB stations, with the latter never ranging above 3 fluorescence units. Chlorophyll fluorescence was highest in Suisun Marsh and Grizzly Bay, similar to patterns in previous years (Sommer et al. 2020).

In both the summer and fall of 2020, the average and upper range of Chlorophyll a (mg/l) measured by DOP was greatest in Suisun Marsh, followed by Suisun Bay, when compared to other regions (Figure 18), agreeing with data collected by the fixed stations. The trend in Chlorophyll a (mg/l) among regions was similar between the seasons, where Chlorophyll a decreased moving upstream from Suisun Marsh to the lower Sacramento River.

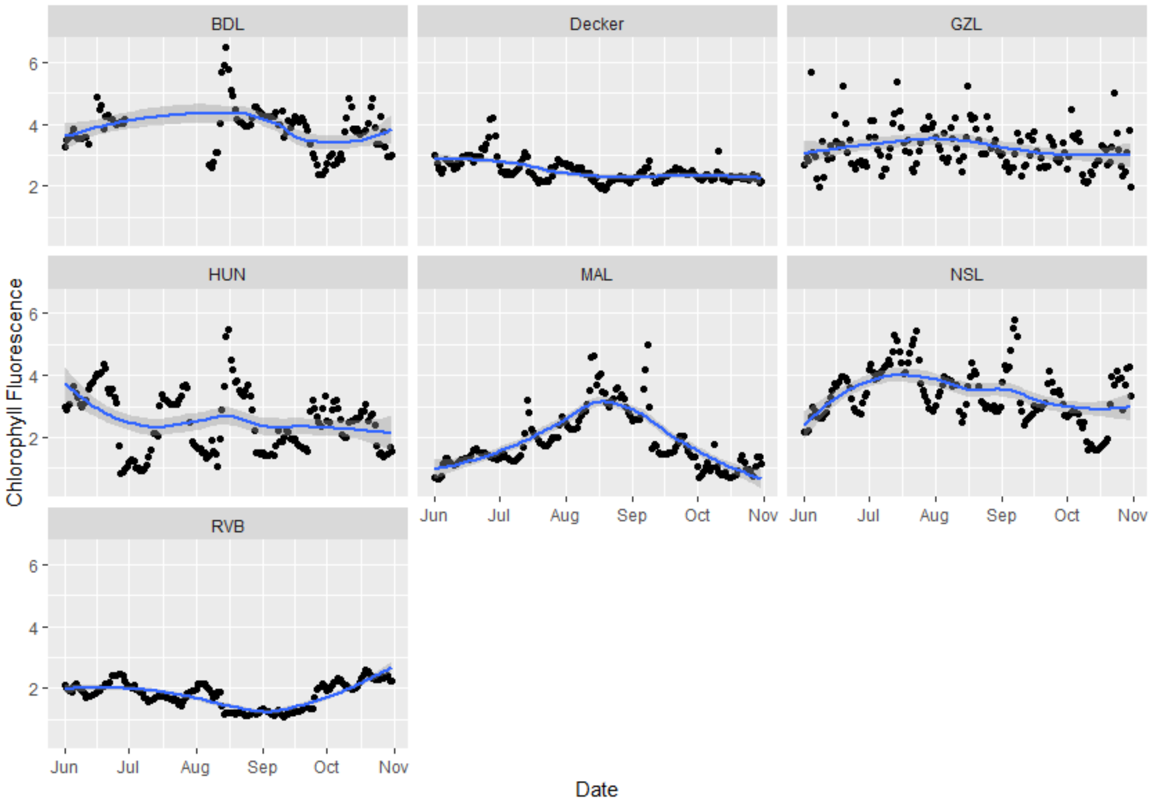


Figure 17. Daily average Chlorophyll fluorescence (in relative fluorescence units) from continuous sondes.

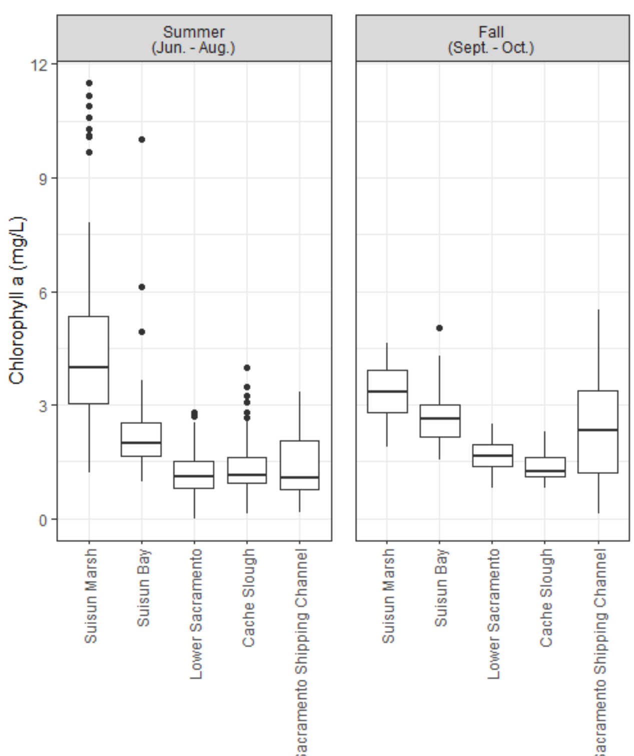


Figure 18 Variation in Chlorophyll a (mg/l) across regional strata as measured during 2020 DOP sampling

Phytoplankton

To assess habitat conditions, a total of 66 samples were collected by CDFW and DWR for monitoring of the phytoplankton community during July to October 2020. These samples were distributed across the three focal regions of the study, including the Lower Sacramento River/Confluence (n = 23), Eastern Suisun Marsh (n = 23), and Western Suisun Marsh (n = 20). However, the data were not available in time for this 2020 seasonal report.

Zooplankton

To assess localized habitat conditions, a total of 107 samples were collected by CDFW for monitoring of the zooplankton community during July to October 2020. These samples were distributed across four regions, including the Lower Sacramento River/Confluence (n = 45), Eastern Suisun Marsh (n = 26), Western Suisun Marsh (n = 19), and Suisun Bay (n = 17). Currently, about one-third of these samples have been processed. However, the data were not available in time for this 2020 seasonal report.

To assess regional habitat conditions, preliminary data from a sub-set of meso-zooplankton tows conducted by the DOP in the summer (n = 189; June-August) and early fall (n = 121; September-October) of 2020 is presented in figures 19 and 20 and summarized below. Data were chosen from weeks 1 and 3 from the months of June through October, except for of September, which used weeks 2 and 3 due to inconsistent sampling in week 1 resulting from poor air quality caused by regional wildfires. This dataset only used the channel surface and channel deep tows. Channel deep tows were not done when sampling sites were less than 20 feet in water depth. No shoal samples were processed for this dataset. The remaining 2020 meso- and macro-zooplankton data from the DOP will not be available in time for this 2020 seasonal report.

For the DOP, in both the summer and early fall of 2020, total meso-zooplankton biomass and abundance was greatest in the Sacramento Deepwater Ship Channel region, followed by Cache Slough, when compared to other regions (Figure 19 and 20). Meso-zooplankton was lowest in Suisun Marsh during the summer and the Lower Sacramento during the early fall. This is consistent with previous studies showing lower zooplankton biomass in brackish water, and Suisun Marsh in particular (Hammock et al. 2017; Sommer et al. 2020).

Patterns in zooplankton composition were roughly similar between biomass and abundance among and within regions for both seasons. The calanoid copepod *Pseudodiaptomus forbesi* was a major species component in the relative abundance and biomass of the three freshwater regions sampled (Sacramento Deepwater Ship Channel, Cache Slough, and Lower Sacramento). In addition, *cladocerans*, from the families *Daphnidae* and *Sididae*, contributed greatly to the zooplankton biomass and abundance in the freshwater regions sampled, especially in the Sacramento Deepwater Ship Channel and Cache Slough. The calanoid copepod *Acartiella sinenesis* was the major species component in the low-salinity regions of Suisun Marsh and Suisun Bay followed by the calanoid copepod genus *Tortanus*.

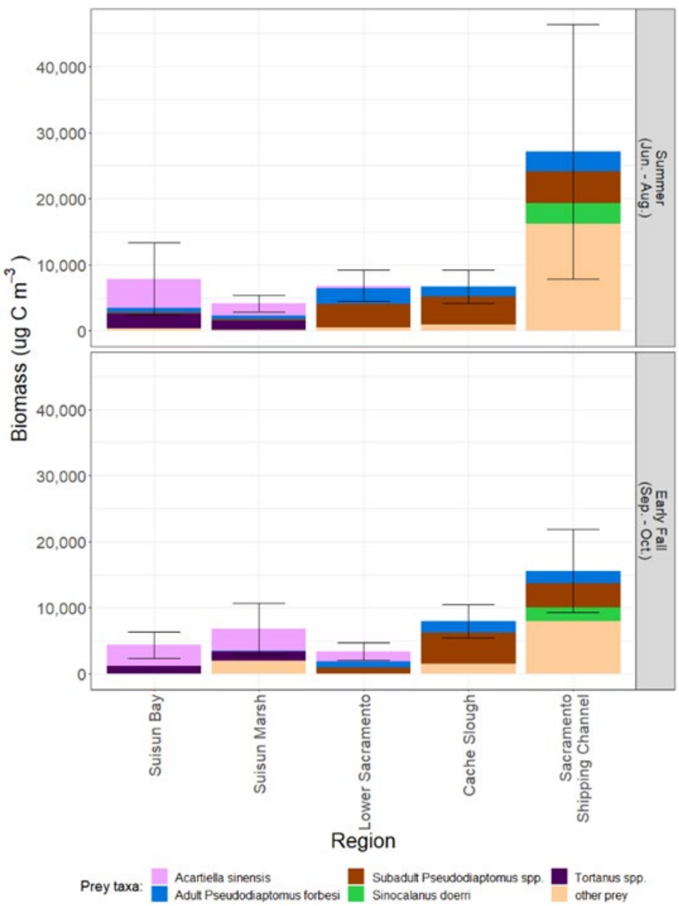


Figure 19 Variation in zooplankton biomass (µg C/m3) across regional strata as measured during 2020 DOP sampling.

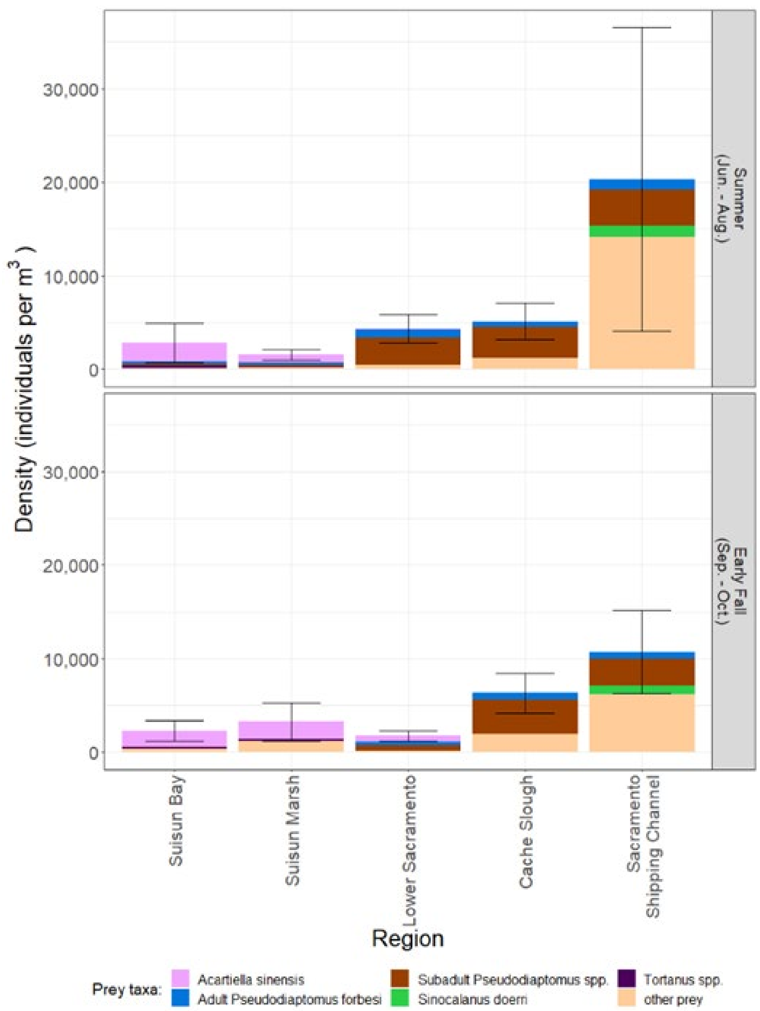


Figure 20 Variation in zooplankton abundance (individuals/m3) across regional strata as measured during 2020 DOP sampling.

Microcystis

Microcystis is a genus of cyanobacteria often associated with harmful algal blooms in the San Francisco Bay-Delta. *Microcystis* is generally considered one of the most toxic cyanobacteria due to their capability of producing the toxin microcystin, which has been demonstrated to have detrimental effects to the health of humans, fish, and wildlife. *Microcystis* blooms have occurred annually during the summer and fall since 1999, particularly between July and September, and they often increase in magnitude with high water temperature, low streamflow and brackish water conditions associated with drought (Lehman et al. 2008, 2017, 2018, Kurobe et al. 2018). Visual assessments of *Microcystis* levels from the EMP (IEP et al. 2020a) indicate that 2020 had slightly higher occurrence of *Microcystis* throughout the system than the five preceding years, with a peak in July and August (Figure 21).

Variation in harmful algal constituents (HAC) among regional strata as measured during 2020 DOP sampling largely followed a similar trend between seasons (Figure 22). HAC presence and overall intensity was lowest in the Cache Slough and Sacramento Deep Water Ship channel regions, and highest the Suisun Bay and Lower Sacramento regions.

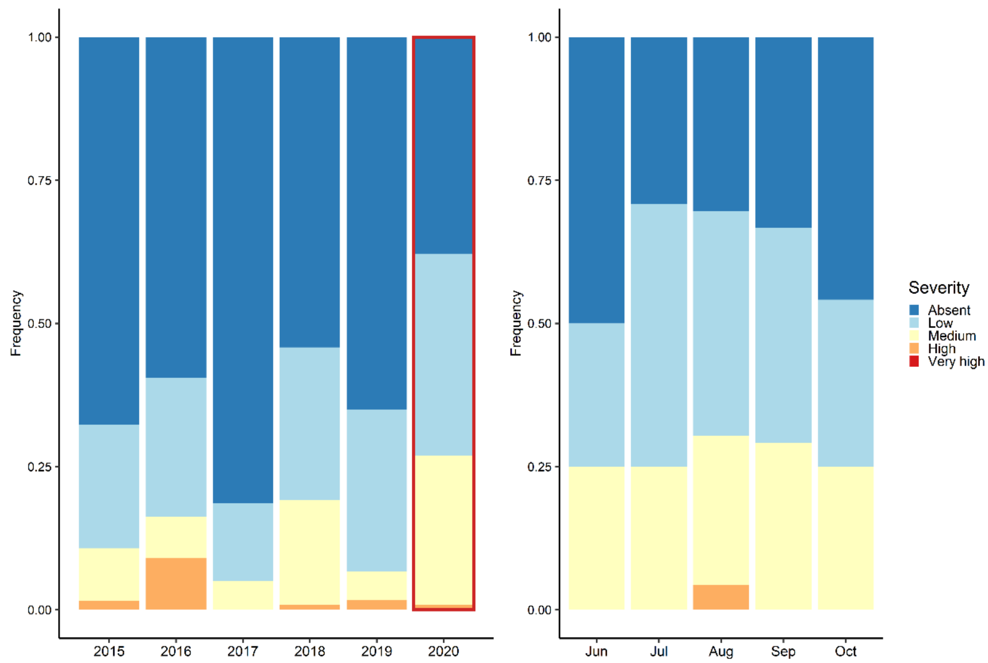


Figure 21 Summer-Fall Microcystis bloom intensity based on visual ranking data from EMP comparing previous years to 2020 (left) and the summer-fall months of 2020 (right). Means were calculated by pooling discrete measurements from all fixed stations for each month (and then by year for annual data). Microcystis bloom presence and intensity are measured on a qualitative scale with 5 categories: absent, low (widely scattered colonies), medium (adjacent colonies), high (contiguous colonies), and very high (concentration of contiguous colonies forming mats/scum).

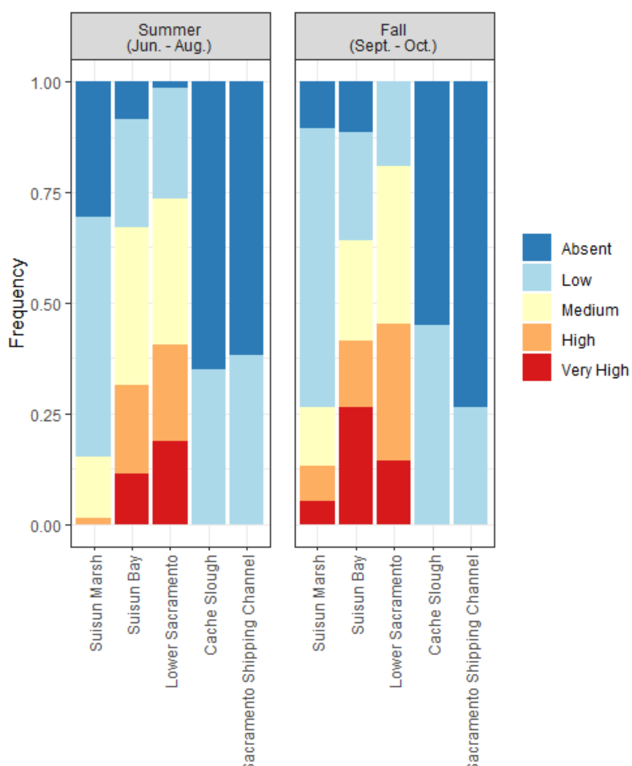


Figure 22 Variation in harmful algal constituents (HAC) among regional strata as measured during 2020 DOP sampling. HAC presence and intensity were measured on a qualitative scale with 5 categories: absent, low (widely scattered colonies), medium (adjacent colonies), high (contiguous colonies), and very high (concentration of contiguous colonies forming mats/scum).

Clam Density and Biomass

Samples from 2020 are still being processed and the data from 2018-2020 are currently being analyzed; full analysis of invasive bivalve density and biomass are expected for the 2021 Seasonal report. Next year's report could include experiments performed by Dr. Grosholz (University of California Davis) through fall 2020, examining the potential for differential clam growth and mortality of the two species, *Potamocorbula amurensis* and *Corbicula fluminea*, in different Suisun Marsh habitats, which are also still in the process of data collection and analysis. Historically, clam densities increase in low flow years (Peterson and Vayssieres 2010).

Biotic Limiting Factors

Previous studies have shown the factors that lead to decline of Delta Smelt are multifaceted and often operate simultaneously. As such, it is difficult to determine the limiting biotic factors that drive Delta Smelt abundance and distribution in 2020, especially given that the majority of biotic data remain unavailable at the time of this report's publication. Based on the available data so far, there seem to be no strong indications of a system-wide collapse of plankton productivity or of a widespread harmful algal bloom in 2020. However, the effects of long-term biotic changes to the system that are detrimental to Delta Smelt (e.g., reduction of food due to invasive clams, shifts in the zooplankton community) have continued to persist.

Food Enhancement Actions

North Delta Food Subsidies/Colusa Basin Drain Study

A majority of baseline information collected by the North Delta Food Subsidies/Colusa Basin Drain Study in 2020 (e.g., nutrients, contaminants, phytoplankton, zooplankton, etc.) are not yet available for this 2020 seasonal report. Additionally, the discrete sampling portion of the study meant to monitor conditions in 2020 was cancelled partway through the summer and fall due to the excessive number of missing samples caused by wildfire smoke. Nonetheless, chlorophyll-a fluorescence data from continuous water quality stations (figure 23) indicate that the small non-managed flow pulse in the Yolo Bypass Toe Drain during September 2020 was indeed followed by an increase in chlorophyll levels (Figure 24). As predicted for a baseline year with no managed flow pulse, this increased chlorophyll event seems to be localized and did not quite extend to the Cache Slough Complex (as represented by the Liberty Island station) or reach the Lower Sacramento River.

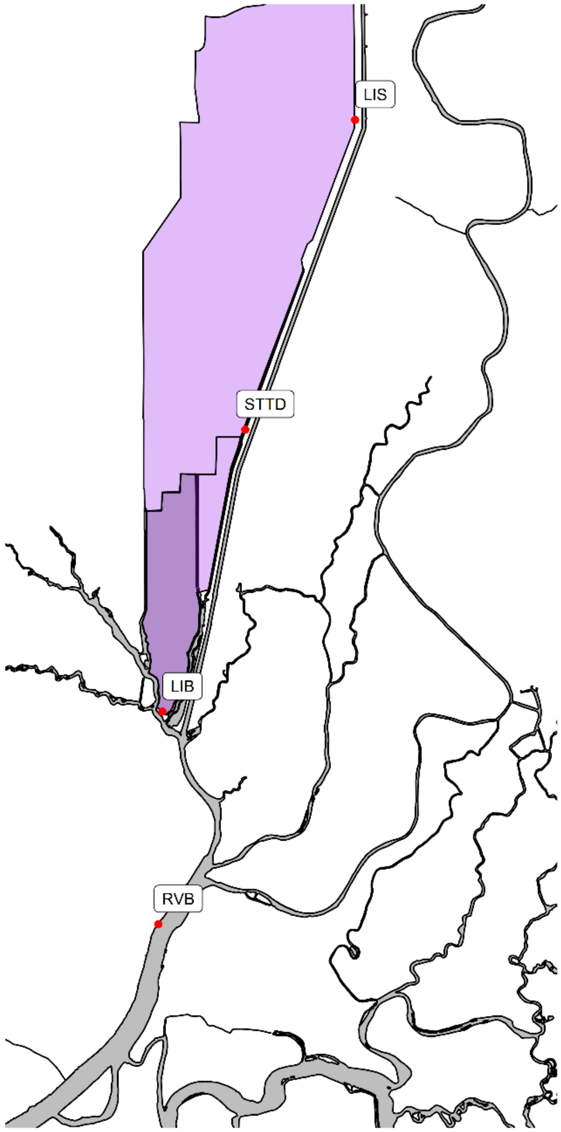
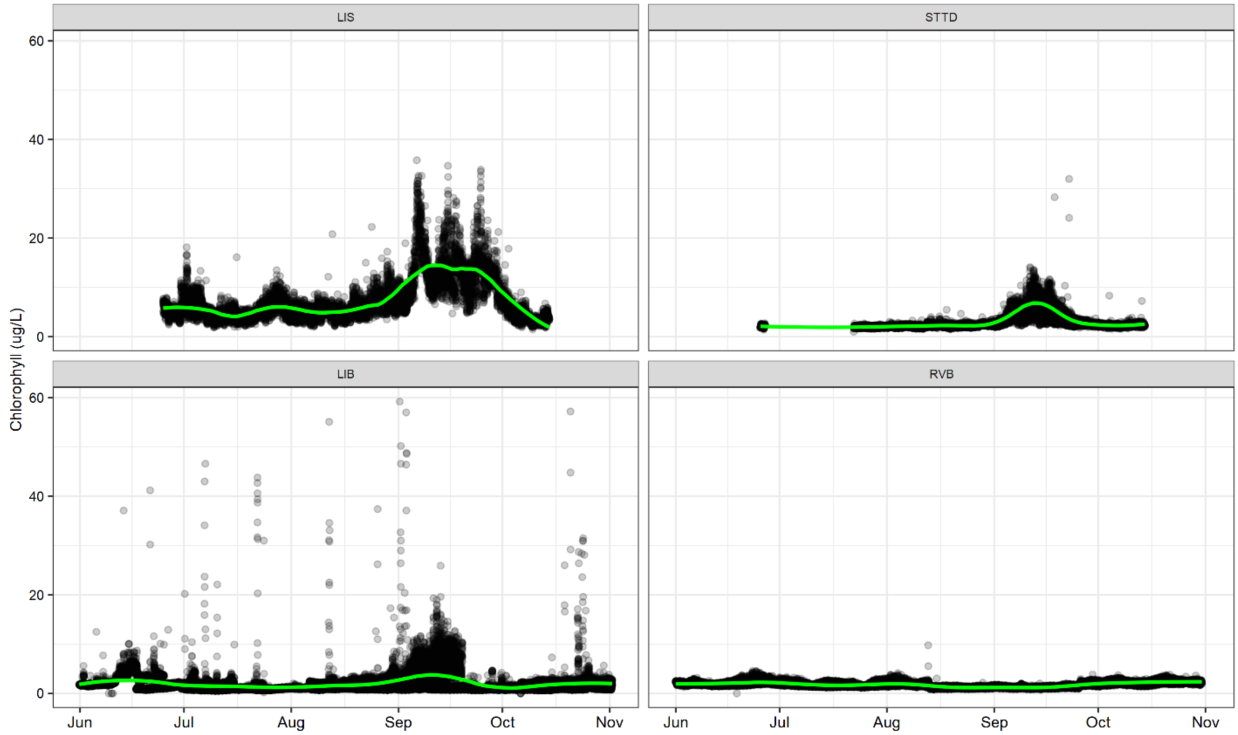


Figure 23 Map of the North Delta and Cache Slough Complex, denoting the locations of Lisbon Weir (LIS), Yolo Bypass Toe Drain (STTD), Liberty Island (LIB) and Sacramento River at Rio Vista (RVB) continuous water quality stations used to evaluate the North Delta Food Subsidies/Colusa Basin Drain Study Area shaded in purple indicate the Yolo Bypass area.

Figure 24 Chlorophyll data from continuous water quality stations in order from most upstream site to downstream: Lisbon Weir (LIS), Yolo Bypass Toe Drain (STTD), Liberty Island (LIB), and Sacramento River at Rio Vista (RVB) between June and November of 2020. Greenline indicates

LOESS smoothing line. Note that LIB and RVB data have not undergone quality control/check



Sacramento Deep Water Ship Channel Food study

Baseline water quality conditions in the ship channel during 2020 resembled conditions documented in previous years. Specific conductance increased with distance upstream with a median value of ~200 uS/cm at CM54 and ~800 uS/cm at CM72 (Figure 25). Similarly, as in previous years, summer water temperature generally increased with distance upstream peaking in July-August.

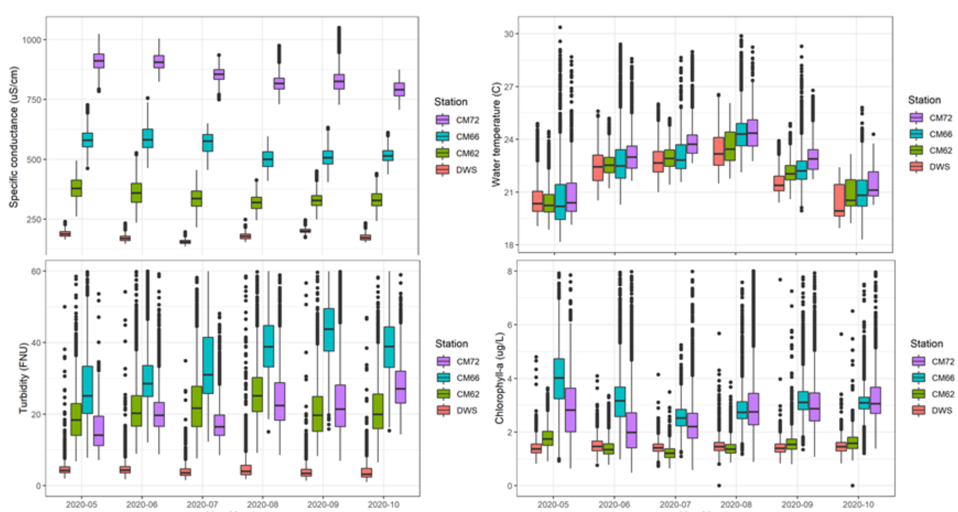


Figure 25 Box and whisker plots (median, 25-75%) showing longitudinal variation in specific conductance, water temperature, turbidity and chlorophyll concentration in the Sacramento Deepwater Ship Channel during May-October 2020. DWS = CM54. Turbidity spikes are due to ship traffic.

As in previous years, turbidity in 2020 was highest at CM66 in the ship channel's turbidity maximum zone, which extends downstream to CM62. It is in this reach that Delta smelt are most frequently observed. Similarly, chlorophyll concentration increased with distance upstream. Concentrations at the two upstream stations were roughly double the values observed at the two downstream stations (Figure 25).

Compared to the previous four years, cumulative June- October chlorophyll flux to Suisun Bay during 2020 was the lowest in the record totaling to a negative value, i.e., net flux was upstream (Figure 27). In all years, flux out of the Delta was dominated by the lower Sacramento River (DEC), with negative contributions from the southern Delta (JPT). In this context, a negative contribution means a net draw of phytoplankton into the south Delta. In all years, the upper Sacramento River (WGA) exported chlorophyll with cumulative fluxes averaging some 5000 kg whereas fluxes in Cache Slough were typically negative. Chlorophyll fluxes to the estuary at DEC in 2016 and 2018 were substantially higher than fluxes past WGA and CCH, indicating that substantial productivity occurred in the lower river.

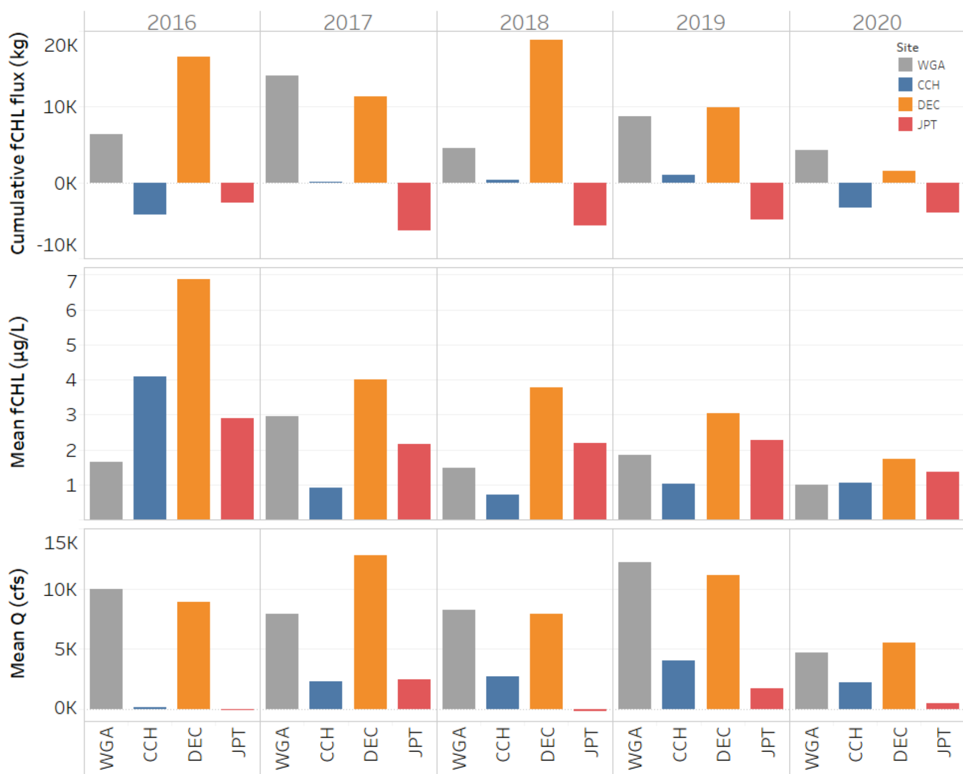


Figure 26 Cumulative total chlorophyll flux (top panel), mean chlorophyll concentration (middle panel), and mean discharge at Walnut Grove (WGA), Cache Slough (CCH), Decker Island (DEC), and Jersey Point (JPT) for the period between June 1 and October 30 for each calendar year shown. The DEC station represents chlorophyll contribution from the lower Sacramento River to Suisun and the JPT station represents chlorophyll contribution from the southern Delta. Data are provisional. [fCHL, chlorophyll fluorescence; kg, kilograms; µg/L, micrograms per liter; Q, discharge; cfs, cubic feet per second]

Chlorophyll flux is a product of chlorophyll concentration and the net direction of river discharge. Persistently elevated average discharge at WGA in all years drove the contribution of the upper Sacramento River despite modest variation in concentration (Figure 27). In contrast, the comparatively large variation in average summertime concentration at DEC was responsible for most of the variation in flux observed there given the much stronger bidirectionality of tidal flows. Decomposing the time series data into the river-like 'advective' flux and the tidally-driven mixing – the 'dispersive' flux – for the months of summer 2020 provides insights into the role hydrodynamics plays in the total observed fluxes (Figure 28). The average magnitude of the advective and dispersive fluxes are often similar, though they can differ in sign. Average advective fluxes were positive for all stations in all months, except JPT in July. At DEC, the average advective flux was positive in all months, but the average dispersive flux was negative, lowering the average total observed flux, and suggesting that concentrations in the estuary were greater than those in the lower Sacramento River. At JPT, the average dispersive flux was large and negative, accounting for the large negative flux observed in the total value, even as the average advective fluxes were modestly positive, with a concentration difference similar to that at DEC. Taken together, these data suggest that the low advective flows observed in summer 2020 were primarily responsible for the low export of chlorophyll biomass to the estuary during this period.

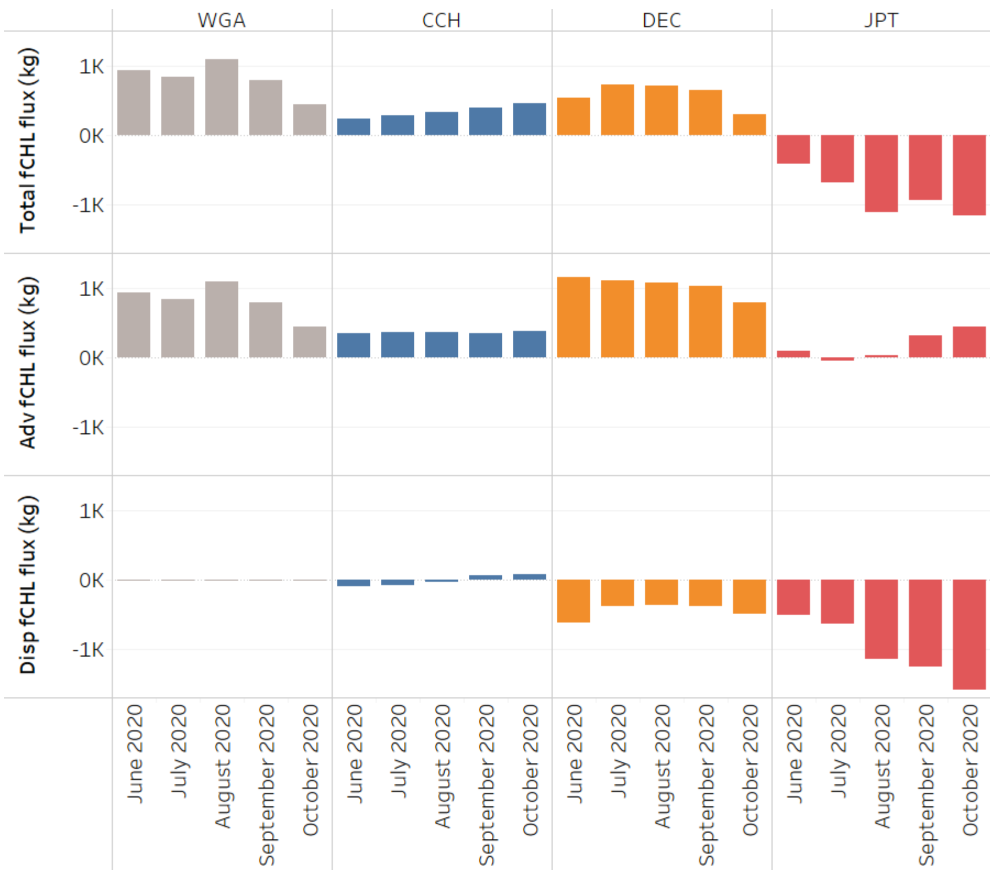


Figure 27 Sum of instantaneous chlorophyll flux, advective chlorophyll flux, and dispersive chlorophyll flux observed by month (June – October 2020) and by station for Walnut Grove (WGA), Cache Slough (CCH), Decker Island (DEC), and Jersey Point (JPT). Data are provisional. [CHL, chlorophyll fluorescence; kg, kilograms]

Habitat Restoration

Site specific tidal restoration data for 2020 is still being processed and was not available in time for this seasonal report.

Fisheries Status

Delta Smelt Status

Abundance

CDFW Summer Townet Survey and Fall Midwater Trawl Survey 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. The Summer Townet Survey Delta Smelt abundance index for 2020 was zero, marking the fifth year since 2014 that the survey has recorded zero catch for the species at their index stations. Although the 2020 Fall Midwater Trawl Survey is ongoing at the time of writing of this report, the survey has not captured any Delta Smelt at their fixed index stations thus far this season, nor has it in the two preceding years. Survey efforts were not reduced due to COVID or wildfire smoke.

In late 2016, the USFWS implemented the Enhanced Delta Smelt Monitoring Program (EDSM), a year-round, spatiotemporally intensive sampling effort to provide near real-time data for all life stages of Delta Smelt (USFWS et al. 2020). EDSM sampling effort was reduced at times during the summer and fall of 2020 due to the widespread wildfires in California that led to hazardous air quality for field crews. However, EDSM's modeled abundance estimates of Delta Smelt from weeks in which full sampling occurred indicate that the 2020 cohort of Delta Smelt may be less abundant than previous cohorts (Figure 29).

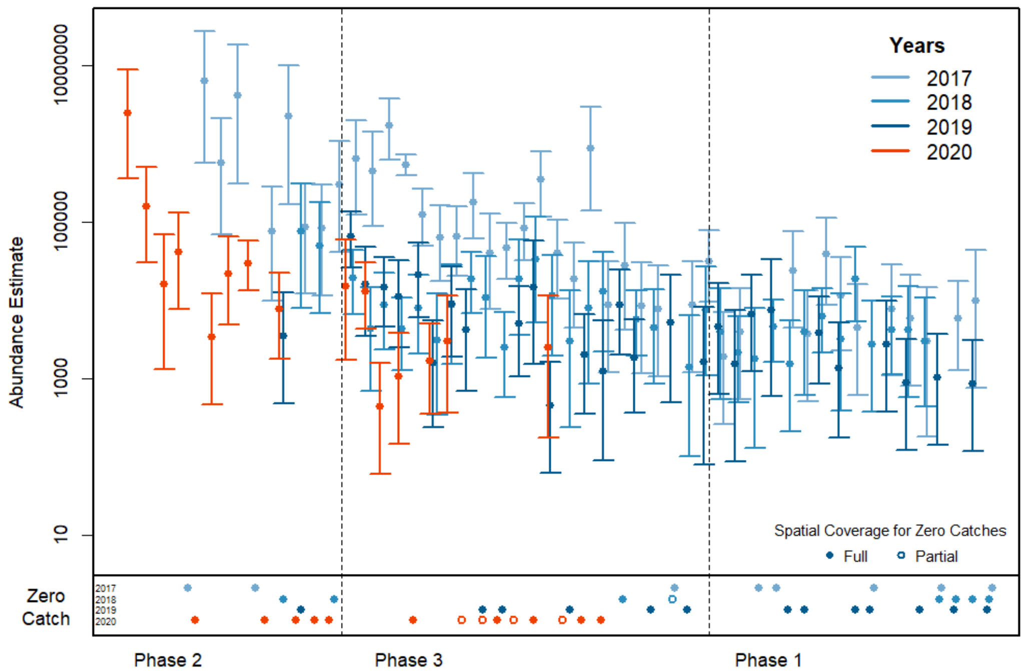


Figure 28 EDSM-ANNUAL. Weekly Delta Smelt abundance estimates from EDSM survey. Years indicates the years in which each Delta Smelt cohort was born. Phase 1 of EDSM runs from December through March and focuses on adult Delta Smelt. Phase 2 sampling takes place from April through June and targets post-larval and juvenile Delta Smelt. Phase 3 runs from July through November and targets juvenile and sub-adult Delta Smelt. Closed circles indicate normal sampling effort for the week and open circles indicate a reduced sampling effort. Summer and Fall of 2020 (Phase 2) had multiple weeks with incomplete spatial coverage due to wildfire smoke/hazardous air quality. Figure was provided by Vanessa Tobias and Lara Mitchell (USFWS).

Distribution

Between the start of phase 3 sampling and the end of October 2020, EDSM has caught Delta Smelt on 15 different sampling events. All observations of Delta Smelt between July and October of 2020 fall under one of the four following regions: Sacramento Deep Water Shipping Channel, Lower Sacramento River, Suisun Bay, and Suisun Marsh (Figure 30). Delta Smelt has not been observed by EDSM in Suisun Bay since July 1st 2020, and while Delta Smelt were observed in Suisun Marsh in July, August, and September of 2020, each observation consisted of a single Delta Smelt and salinity level >6 ppt (Appendix B). No Delta Smelt were caught by EDSM in the month of October.

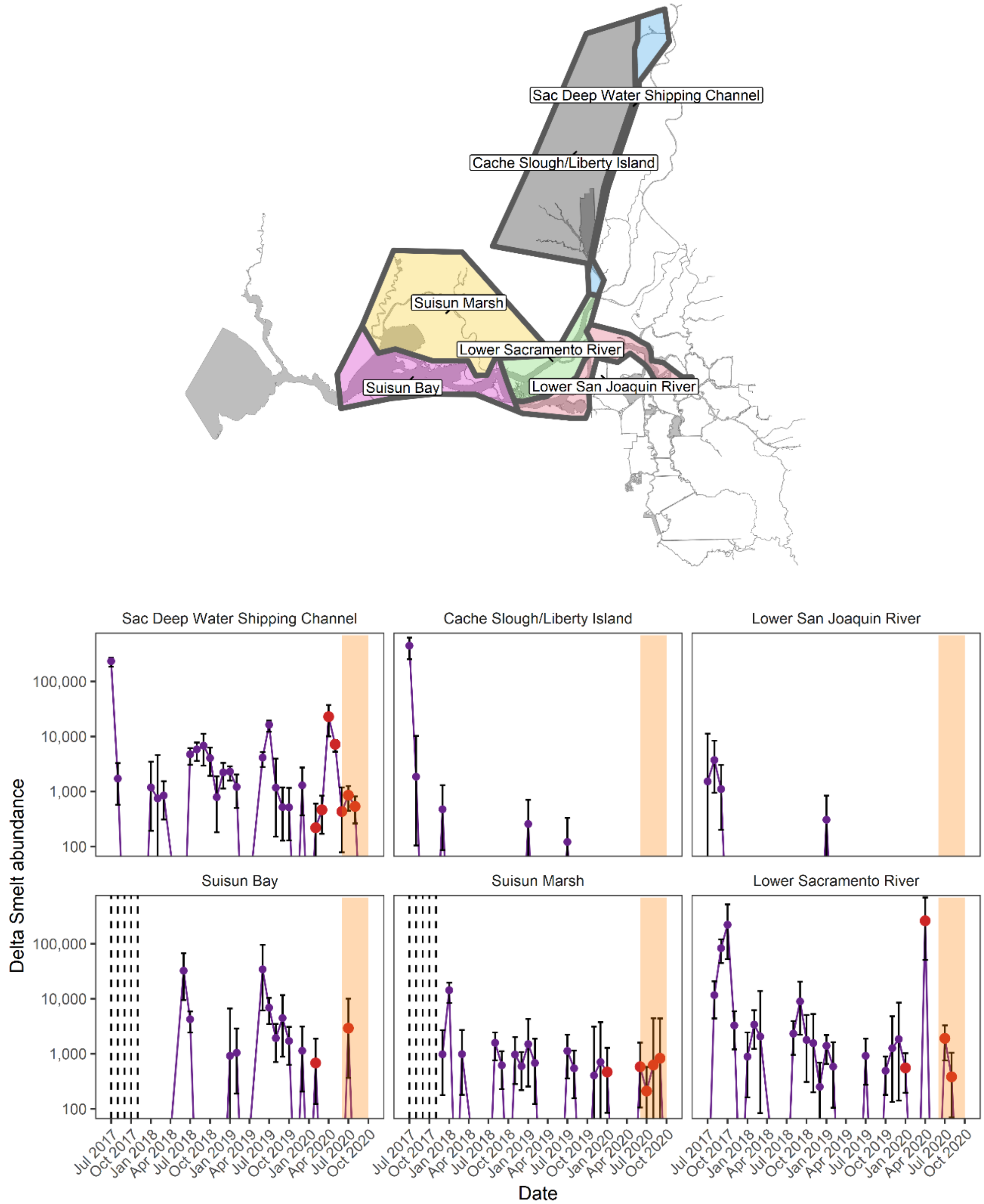


Figure 29 Map of a subset of EDSM strata (top), and Delta Smelt abundance estimates from EDSM survey summarized by month and split by these strata (bottom). Error bars indicate 95% confidence intervals. Red dots indicate data from the calendar year of 2020. Orange highlight indicate the summer-fall period of 2020 (June to October of 2020).

Fish Assemblage

Native vs Non-Native Fish Species

The Delta Plan listed percentage of native fish biomass or relative abundance as a performance measure in the Delta. This metric is based on the Delta Juvenile Fish Monitoring Program beach seine survey data that has demonstrated an increase in non-native fish numbers over the past two decades (Mahardja et al. 2017b, IEP et al. 2020b). One of the goals of this report is to evaluate this metric for WY2020; however, COVID-19 pandemic and wildfire smoke resulted in cancellation of beach seine sampling for large parts of 2020 and therefore, we were unable to include this information.

Abundance of POD Species

The steep decline of Delta Smelt that occurred in the early 2000s was a part of the Pelagic Organism Decline (POD) event, in which four pelagic fish species experienced simultaneous, abrupt decline in abundance likely caused by common factors (Thomson et al. 2010). The 2020 status of two introduced species listed in the POD, Striped Bass (*Morone saxatilis*) and Threadfin Shad (*Dorosoma petenense*), are reviewed in this report to compare and contrast their responses to Delta Smelt under this dry year condition. Age-0 Striped Bass numbers in the summer and fall based on long-term surveys appear to be somewhat correlated with water years (Figure 31), with 2020 catch being lower than recent wet years (e.g., 2011, 2017, 2019). Unlike Delta Smelt and Striped Bass, Threadfin Shad numbers in 2020 were comparable and possibly higher relative to the past few years (Figure 32), lending support to the idea that physical conditions in the upper San Francisco Estuary are generally more suitable for Threadfin Shad relative to some other pelagic fish species (Feyrer et al. 2009).

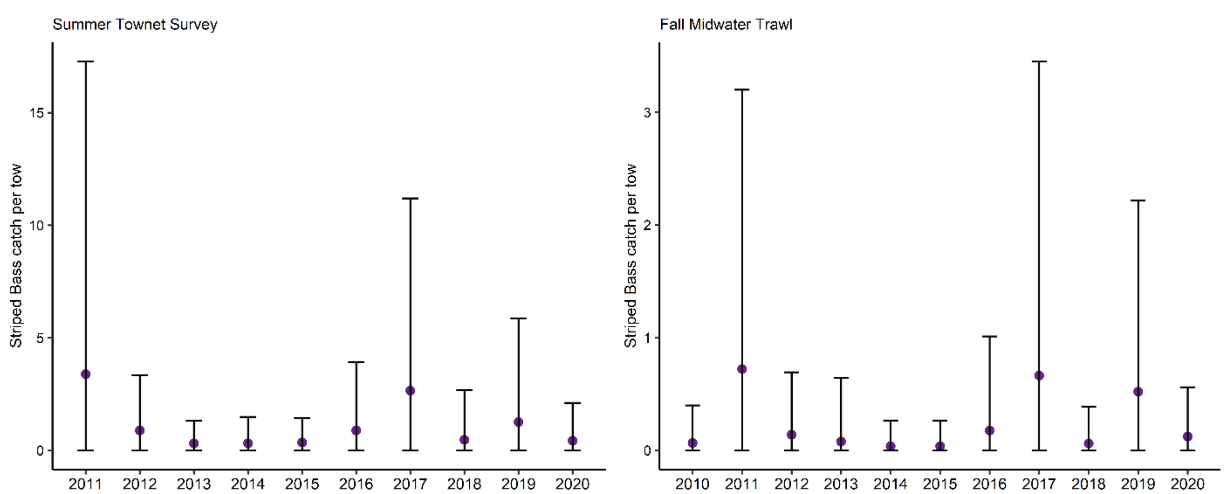


Figure 30 Mean Striped Bass catch per tow and standard deviation (error bars) from the CDFW Summer Townet Survey from all stations for each year since 2011 (left) and mean Striped Bass catch per two and standard deviation (error bars) from the CDFW Fall Midwater Trawl Survey from all stations for each year since 2010 (right). Only data from September and October surveys were used for Fall Midwater Trawl Survey to ensure consistency with 2020 data.

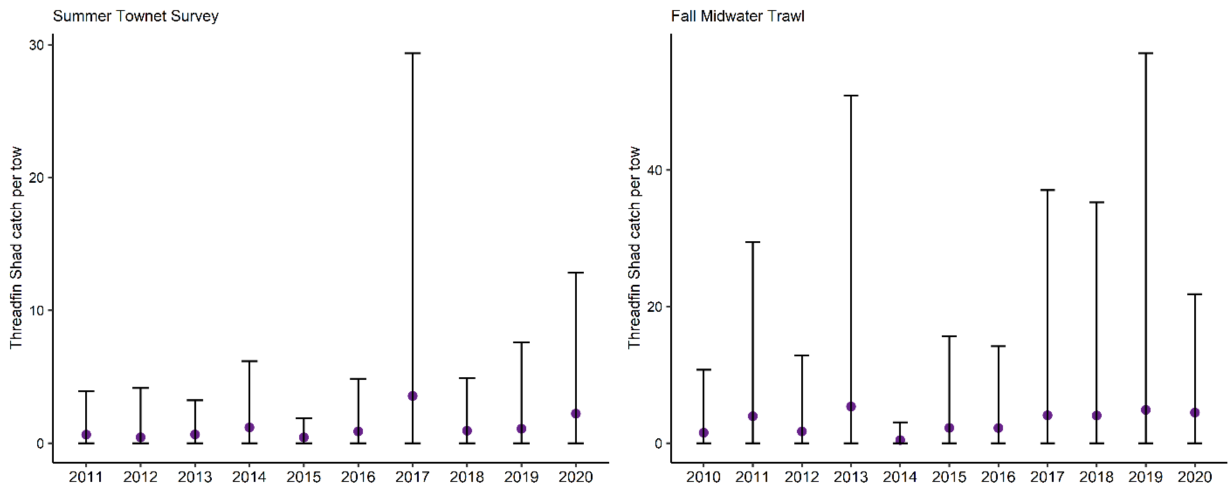


Figure 31 Mean Threadfin Shad catch per tow and standard deviation (error bars) from the CDFW Summer Townet Survey from all stations for each year since 2011 (left) and mean Threadfin Shad catch per two and standard deviation (error bars) from the CDFW Fall Midwater Trawl Survey from all stations for each year since 2010 (right). Only data from September and October surveys were used for Fall Midwater Trawl Survey to ensure consistency with 2020 data.

Discussion

Abiotic Habitat Attributes

The overall abiotic habitat conditions in summer and fall of 2020 for Delta Smelt were well within expectations based on a dry, non-action year, i.e., stressful at times throughout much of the species' typical range. Outflow and X2 in summer and fall of 2020 fell within the range of other dry years from the past two decades (Figure 6). Based on outflow and X2 calculations for summer and fall of 2020, salinity levels within the Suisun Marsh and Suisun Bay are similar to previous dry years (Figure 7). Salinity at Belden's Landing and within the western portion of Montezuma slough was likely to contribute to constraining the western distribution of Delta Smelt for large parts of the season. Salinity at the BDL station largely stayed above 6 ppt starting mid-July. Brief periods of low turbidity and high temperature were also observed at the BDL station (Figure 14); this combination of factors likely imposed additional stress for any Delta Smelt in this area.

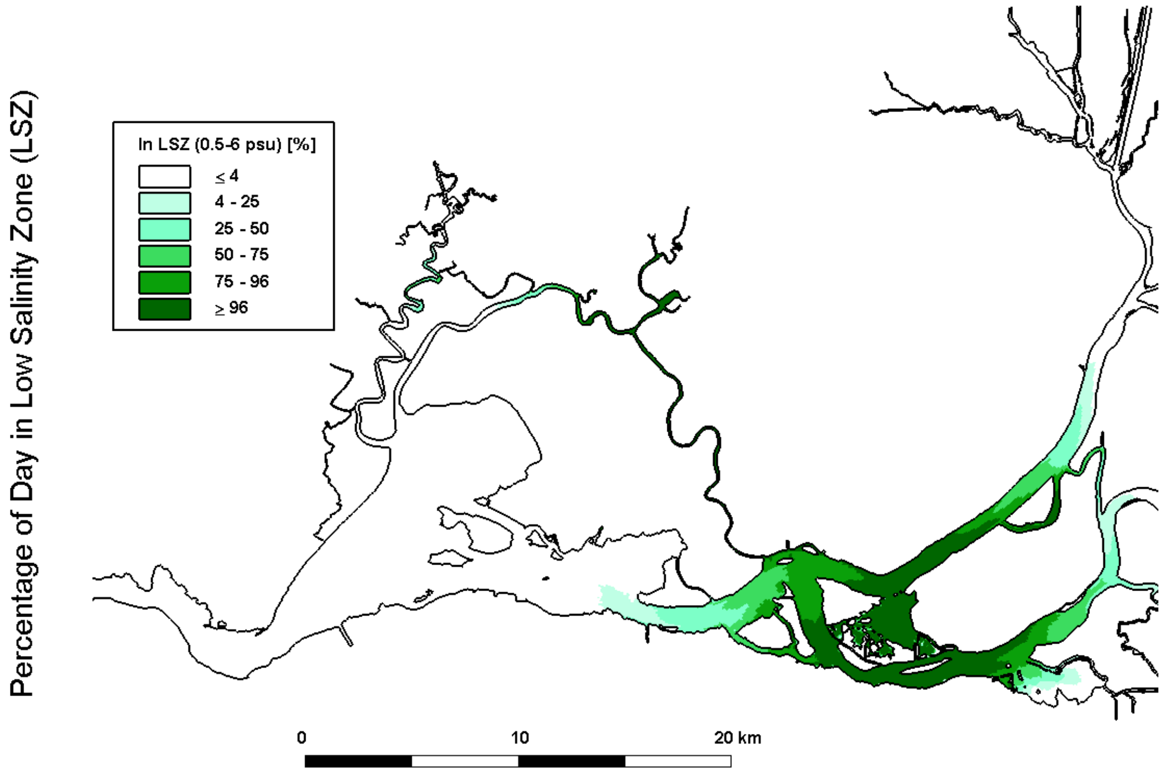


Figure 32 Percentage of Day in the Low Salinity Zone (LSZ) when X2 is located at 88km (Delta Modeling Associates 2014)

Delta Smelt low salinity habitat in late summer and fall 2020 was most likely similar to Figure 33 above, which represents low salinity zone spatially distributed at a steady-state when X2 is at 88 km.

The San Francisco Bay-Delta system has seen a long-term reduction in turbidity over the past several decades (Schoellhamer et al. 2011, Hestir et al. 2013, Bever et al. 2018); however, some regional differences persist. Within the range of Delta Smelt, the Suisun region and the North Delta have generally seen the highest turbidity, along with the general area of low salinity zone where X2 is located. Turbidity in 2020 appeared to be fairly typical, where the Lower Sacramento River remained less turbid than shallower downstream areas. Summer and fall water temperature in 2020 was generally under the 23.9 C threshold, but a heatwave that occurred in mid- to late-August was likely detrimental to Delta Smelt population.

Extent of Contiguous Low Salinity Habitat

One of the goals of the Delta Smelt Summer-Fall Habitat Action is to establish contiguous low salinity habitat from Cache Slough Complex to the Suisun Marsh. However, dry conditions in the non-action year of 2020 may have isolated low salinity habitat in Grizzly Bay from that which extended from Honker Bay east, during summer. During fall, dry conditions likely limited low salinity habitat to the eastern section of Honker Bay and east of Brown Island. This would isolate any fish that remained in Suisun Bay or Marsh from the lower Sacramento River through the North Delta/Cache Slough Complex. Because the location of X2 in WY 2020 was similar to previous dry years, it can be assumed that the temporal and spatial extent of contiguous low salinity habitat between regions was also similar to previous dry years.

Biotic Habitat

It is unclear how Delta Smelt abundance and distribution was driven by biotic habitat factors in WY2020, as the majority of biotic data remain unavailable at the time of this report's publication. To date, there have been no indications of a system-wide collapse in plankton productivity or of a widespread harmful algal bloom. However, based on the available data, the Cache Slough Complex and the Sacramento Deep Water Ship Channel may have provided better food and lower levels of harmful algal constituents for Delta Smelt in 2020 relative to Suisun Bay and Suisun Marsh.

North Delta Food Subsidies/Colusa Basin Drain Study

North Delta Food Subsidies/Colusa Basin Drain Study results from previous years indicate that phytoplankton blooms downstream require certain amounts of water volume and maximum daily net flow through the Yolo Bypass. Seasonal agriculture return flow from Colusa Basin appeared to have occurred in September of 2020 (Figure 6) and was followed by an increase of chlorophyll fluorescence at Lisbon Weir (Figure 24). However, this September, flow pulse at Yolo Bypass Toe Drain did not seem to trigger a phytoplankton bloom downstream in Sacramento River based on the limited available information to date. Monitoring for this study was heavily impacted by the California wildfires in 2020, and most of the data from 2020 were yet available at the completion of this report. Of particular interest will be the potential effects of heavy smoke cover on light availability, which may have negatively affected phytoplankton production. Reclamation intend to re-evaluate the remaining 2020 data when they become available as part of the adaptive management strategy adopted in the ROD and the 2019 USFWS BiOp.

Sacramento Deep Water Shipping Channel Food study

Full implementation of the food study will require construction of infrastructure capable of diverting flow from the Sacramento River. The existing infrastructure consists of a lock structure with two gate systems that are currently inoperable. The City of West Sacramento owns this infrastructure and the adjacent property. The City has selected an alternative (wall with culverts) for further analysis. This analysis will be informed by the results of pre-implementation monitoring and special studies slated to begin in the spring of 2021 and continue through 2023. This work will include biweekly day-night and near-shore-open water fish and zooplankton monitoring as well as daily ecosystem metabolism measurements (using continuous monitoring dissolved oxygen data and O-18 isotope measurements) and quantification of nutrient fluxes from bottom sediments. Experiments to estimate zooplankton grazing rates will also be conducted. These data will be used to populate models for use in comparing the performance of multiple flow-nutrient management scenarios as they affect environmental conditions, food supply and Delta Smelt.

Fisheries Status

Delta Smelt Status

Delta Smelt catch was infrequent throughout the San Francisco-Bay Delta in 2020, reflecting the very low adult spawning stock and the stress of dry year conditions including those reviewed here. This low catch issue was further complicated by the incomplete coverage in sampling by fish surveys due to a combination of hazardous air quality from wildfire smoke and the COVID-19 pandemic. Evaluating the impacts of the 2020 non-action year on Delta Smelt is difficult because the species' numbers appear to be at yet another record low given that only 21 Delta Smelt were caught throughout the system between June and October by all the fish monitoring programs.

Based on the existing literature and monitoring information for Delta Smelt, we expect 2020 conditions to be mostly detrimental (high salinity in the Suisun region, low turbidity due to long-term changes in the system, etc.). However, a few Delta Smelt were observed at relatively high salinity in Suisun Marsh between July and September (Table EDSM), and this was the only location that Delta Smelt were found in September and November of 2020. Though the evidence is clearly limited, the presence of Delta Smelt at elevated salinity in Suisun Marsh demonstrates the multivariate nature of fish habitat, and leaves open the possibility that the Suisun Marsh Salinity Control Gate operation can be a strong option for future Summer-Fall habitat improvements, to be considered in combination with other actions such as downstream locations of X2.

Management Summary

The average outflow and the location of X2 during WY 2020 was similar to other dry years as defined by D-1641. Delta smelt abundance was similar to or likely lower the last few years. It is likely that salinity was a limiting factor in Suisun Marsh for Delta Smelt for the majority of the 2020 Summer-Fall period (>6 ppt), though it did not fully preclude the species from being there. This seasonal report does not suggest changes or clarification to the Delta Smelt Summer Fall Habitat Action guidance document.

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Attachments

Appendix A- Abiotic Habitat Figures

Appendix B- Fisheries Status Figures and Tables

Appendix C- DWR Summary of Water Cost

Appendix D- Monitoring