WORKPLAN FOR OPERATIONS AND MONITORING OF SUMMER-FALL NORTH DELTA FOOD SUBSIDIES ACTION, 2023–2025

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California Department of Water Resources,

Ecosystem Monitoring, Research, and Reporting Branch,

Division of Integrated Science and Engineering

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Abbreviations

AF	Acre Feet
AG	Managed Agricultural Action
Ag #4	Agricultural Road Crossing #4
BiOp	Biological Opinion
BN	Below Normal water year type
BSA	BSA Environmental Services
C	Critically Dry water year type
CDFW	California Department of Fish and Wildlife
CFS	Cubic Feet per Second
Chl-a	Chlorophyll a
CNRA	California Natural Resources Agency
CPUE	Catch Per Unit Effort
CSC	Cache Slough Complex
D	Dry water year type
DCG	Delta Coordination Group
DIC	Dissolved Inorganic Carbon
DJFMP	Delta Juvenile Fish Monitoring Program
DO	Dissolved Oxygen
DSRS	Delta Smelt Resiliency Strategy

DWR	Department of Water Resources
EDI	Environmental Data Initiative (https://environmentaldatainitiative.org/)
EDSM	Enhanced Delta Smelt Monitoring Program
EMP	Environmental Monitoring Program
EOS	Estuarine and Ocean Science Center
EPA	United States Environmental Protection Agency
ESU	Evolutionarily Significant Unit
Fall X2	X2 is the location of 2 PSU salinity isohaline measured in kilometers from the Golden Gate Bridge, following the river channel. Fall X2 is an action designed to improve habitat conditions for Delta Smelt by maintaining X2 at 80 km in September and October.
FMWT	Fall Mid-Water Trawl
GCID	Glenn Colusa Irrigation District
IEP	Interagency Ecological Program
IR	Non-managed flows during infrastructure repairs
ITP	Incidental Take Permit
KLOG	Knights Landing Outfall Gates
MAST	Management Analysis Synthesis Team
NCRO	North Central Region Office
NDFS	North Delta Food Subsidies Study
NM	Non-managed Flows

QA/QC	Quality Assurance/Quality Control
RD 108	Reclamation District 108
RD 2035	Reclamation District 2035
SAC	Managed Sacramento Flow Action
SDM	Structured Decision-Making
SFE	San Francisco Estuary
SFHA	Summer-Fall Habitat Action
SFSU	San Francisco State University
STN	Summer Townet Survey
TAF	Thousand Acre Feet
USBR	United States Bureau of Reclamation
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
W	Wet water year
WY	Water Year
YBFMP	Yolo Bypass Fish Monitoring Program
YBWA	Yolo Bypass Wildlife Area

Updates for 2023

This workplan is similar to previous years; however, adaptive changes to operations, monitoring, and special studies have been made to reflect preparation for consultation of the proposed North Delta Food Subsidies (NDFS) Action and associated biological assessment. In addition, improvements that emphasize learning opportunities have been made following the Delta Coordination Group's iterative structured decision-making process (see 2023 SFHA Plan), and new results from a synthesis study evaluating flow pulses in the North Delta have been incorporated (Davis et al. 2022).

DWR will consider different action alternatives for augmenting flows in the Yolo Bypass in effort to enhance food availability. Alternatives include Sacramento River water pulses preferred over Agriculture drainage pulses, and a low intensity (~400cfs), long duration (4-6 weeks) pulse preferred over a high intensity (~800 cfs), short duration (2-4 weeks) period. Given previous year's results and structured decision-making outcomes, DWR will no longer consider implementation of fall agricultures pulses of high intensity.

Ecological monitoring will be similar to previous years, but the 3-4 month monitoring period will be shifted to begin earlier in summer to capture baseline conditions for future Sacramento River pulse actions. In addition, a year-round continuous, telemetered water quality sonde is being added to the Road 22 sampling site in the upstream region to better assess water quality (e.g., dissolved oxygen) in the project area in real-time prior to an action and to help evaluate potential impacts to salmonids.

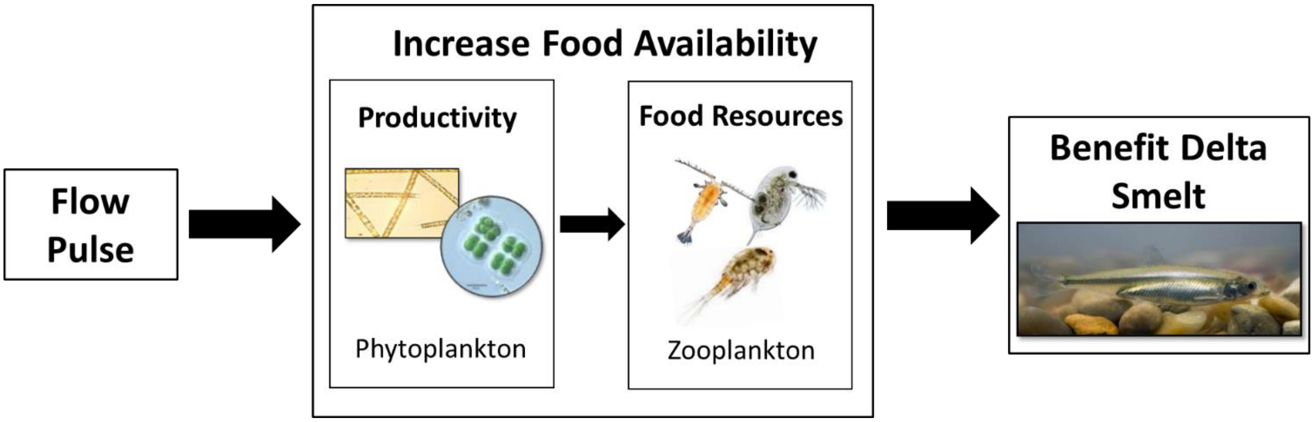
Special studies will continue to be explored in 2023. Field sampling for the stable isotope pilot study will be completed July and September to inform wet versus dry year effects on the isoscape. In this study, sulfur isotopes are being investigated as possible tracers to help determine feasibility of smelt enclosures. In the future, isotope analyses may help to address knowledge gaps related to food transport. Additionally, nutrient and phytoplankton uptake analysis will continue to characterize the upstream 'seed' in the Yolo Bypass to inform future efficacy of the action in different water year types.

1. Project Description

Summary

The North Delta region of the San Francisco Estuary (SFE) is relatively rich in aquatic food resources compared to other regions, but low or negative flows from water diversions during summer and fall limit the distribution of these resources to downstream areas. With interagency support, the California Department of Water Resources (DWR) has developed the North Delta Food Subsidies-Colusa Basin Drain Study (NDFS), one of several adaptive management strategies of the Delta Smelt Summer-Fall Habitat Action (SFHA). The goal of the NDFS is to increase flows and increase food availability downstream using managed flow pulses (i.e., above-average flows or "flow actions" measured at Lisbon Weir in the Yolo Bypass Toe Drain), thereby restoring net positive flow, and enhancing the quantity and quality of food for Delta Smelt (*Hypomesus transpacificus*) and other species in the North Delta (Figure 1-1). The NDFS action may redirect agricultural drainage or Sacramento River water into the Yolo Bypass region for up to 2-6 weeks during summer or fall to generate a flow pulse of 15-35 TAF (18-37 mil m^3; dependent on the operation scenario) and monitors and evaluates the effects of these flow actions on water quality and the Delta food web. Flow actions, science monitoring, and assessments will occur annually in summer and/or fall depending on hydrology. This work plan summarizes background information about the project and the decision framework for how DWR and interagency collaborators will recommend whether to implement a NDFS flow action, dependent on hydrologic conditions. We also provide a detailed overview of flow action operations, study questions, predictions, and science monitoring. In addition, we review the proposed budget, deliverables, and coordination.

Figure 1-1 Conceptual diagram of the objectives of the North Delta Food Subsidies Study. A managed flow pulse is redirected through the Yolo Bypass that is hypothesized to transport phytoplankton into downstream Delta Smelt habitats of the Cache Slough Complex. Phytoplankton provide food for zooplankton (Delta Smelt prey) to benefit Delta Smelt.



Introduction

This operations and monitoring plan supports the North Delta Food Subsidies – Colusa Basin Drain Study (NDFS) intended to improve the food web for Delta Smelt, a high-profile endangered species in the SFE. The food subsidies study monitors and assesses the effects of flow actions (managed, above-average flow events) on the food web in the Yolo Bypass, Cache Slough Complex (CSC) and the Lower Sacramento River. The NDFS action is normally conducted during summer or fall, when flows are low and downstream transport of plankton in this region is low. Flow from Colusa Basin agricultural drainage or Sacramento River diversions is redirected through the Yolo Bypass Toe Drain as a flow action with the intention of increasing net positive flow, food web productivity, and transport of food to downstream regions including the CSC and lower Sacramento River (Figure 1-2 and Figure 1-3.

In coordination with US Bureau of Reclamation (USBR), Glenn Colusa Irrigation District (GCID), and Reclamation Districts 108 (RD 108) and 2035 (RD 2035), DWR has led three flow actions in recent years (2016, 2018, and 2019) in efforts to benefit juvenile and sub-adult Delta Smelt. Three different types of flow pulses (above-average flow events as measured at

Lisbon Weir in the Yolo Bypass Toe Drain, Figure 3-1) have been associated with increased productivity in the Yolo Bypass, the CSC, and the Sacramento River at Rio Vista (Figure 1-3): 1) a non-managed flow pulse due to agricultural activities (NM in 2011) or infrastructure repairs (NM-IR in 2012) that result in water redirected down the bypass, 2) a managed flow pulse using diversions of Sacramento River water (SAC in 2016) or 3) a managed flow pulses using combined agricultural drainage water (AG in 2018 and 2019). The 2018 and 2019 AG actions resulted in local productivity in the Yolo Bypass but not downstream in the CSC or Sacramento River, possibly due to the type of flow pulse (Table 1-1), annual variability in abiotic and biotic influences such as hydrology, nutrients, or other factors. Flow pulses from previous years (2011-2022) are summarized below in Table 1-1 and Figure 1-3.

Due to variability in food web responses following managed NDFS flow actions, an adaptive management approach is warranted with additional flow actions and monitoring to investigate how abiotic and biotic factors influence the efficacy of flow actions for increasing food availability. In future years, alternative NDFS action scenarios may be implemented that differ from previously implemented actions. These alternative scenarios include long duration, low intensity AG or SAC actions (400 cfs of flow over one month, for example, from Jul - Aug for SAC), short duration, high intensity AG or SAC actions (800 cfs of flow over two weeks, similar to the SAC action implemented in 2016), and combined SAC/AG action (400 cfs of flow for two months not necessarily continuous from Jul 1 – Sept 30) (2022 SFHA Plan).

Figure 1-2 **Map of the San Francisco Estuary (SFE). General SFE regions, rivers, and bays are shown. The area outlined in gray is the Yolo Bypass floodplain and tidal slough, which is used as a corridor during flow actions to transport food to downstream regions of the Cache Slough Complex and the lower Sacramento River at Rio Vista (outlined in green).**

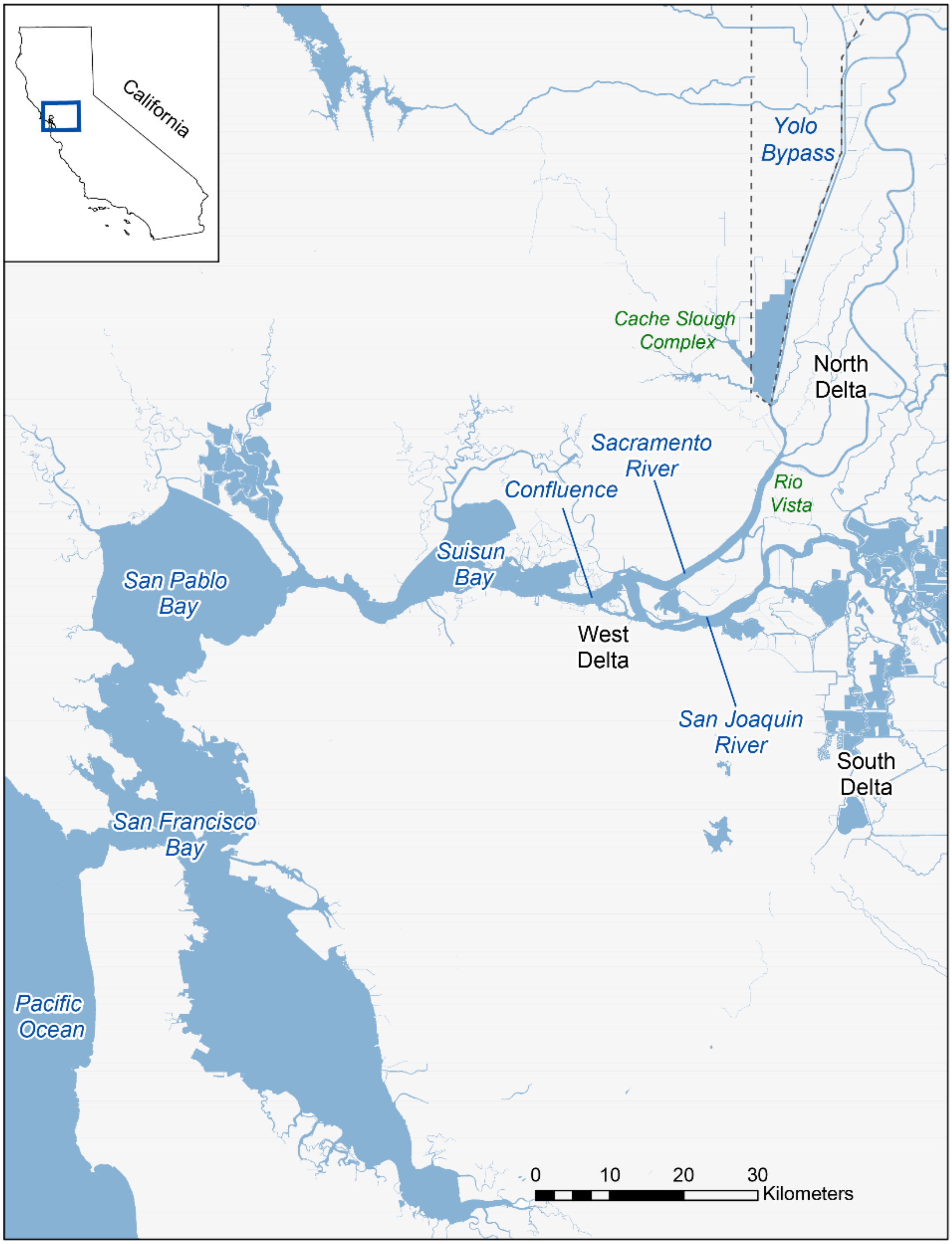
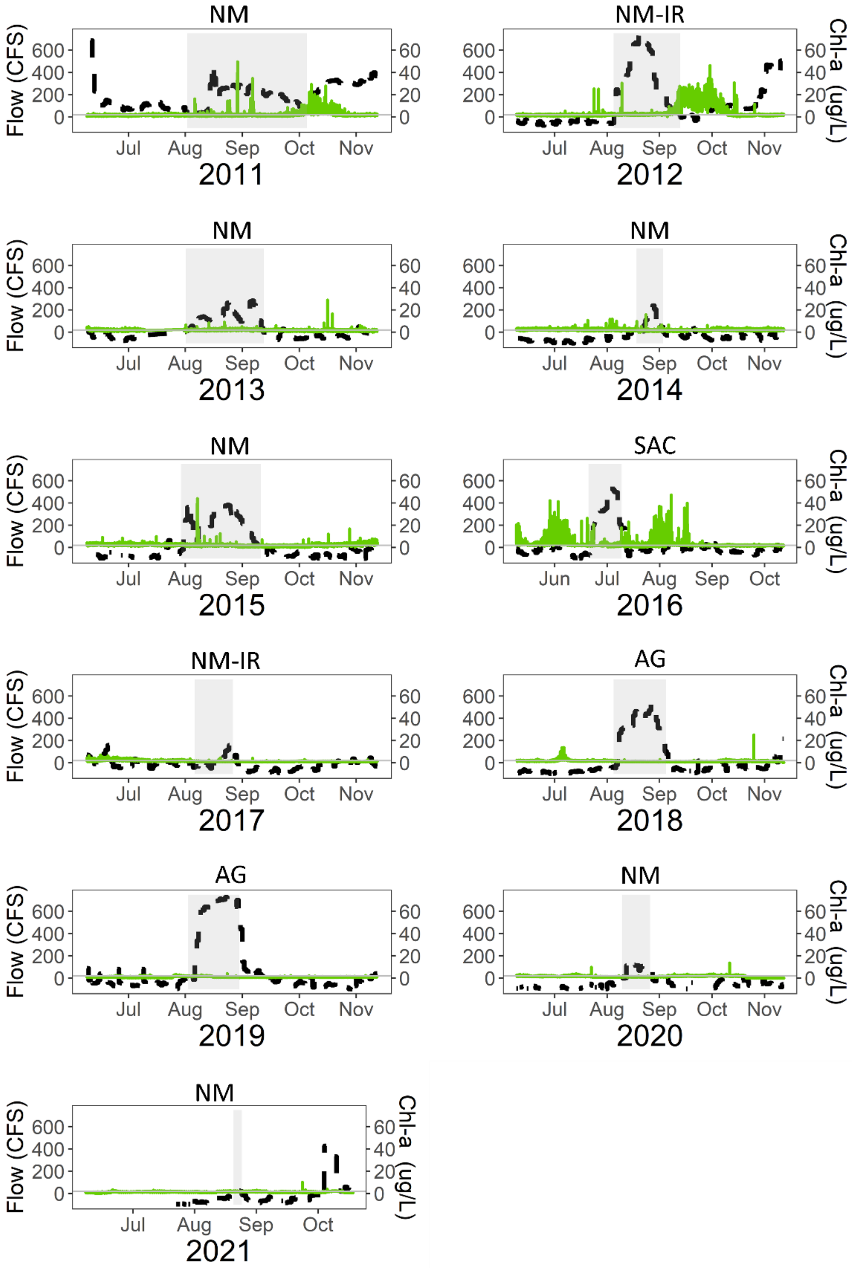


Table 1-1 Summer-fall flow pulses in the Yolo Bypass from 2011-2022. Net positive flow pulse magnitude (Max Daily Ave Net Flow and Total Average Net Volume) and duration (Total Days Net Positive Flow and Date Range) were measured at Lisbon Weir in the Yolo Bypass. WY indicates water year type including wet (W), below normal (BN), dry (D), and critical (C). Flow pulse types include managed flow pulses using diversions of Sacramento River water (SAC) or agricultural return flows (AG), non-managed flow pulses during construction and infrastructure repairs (NM-IR), or non-managed flow pulses (NM) from agricultural activities. Flow pulse magnitude is measured in cubic feet per second (cfs) and acre feet (AF). In the absence of flow pulses, net flow is negative (upstream) through the Yolo Bypass during this time.

Year	WY Type	Flow pulse type	Max Daily Ave Net Flow (cfs)	Total Average Net Volume (AF)	Total Days Net Positive Flow	Date Range (start/end of flow pulse)
2011	W	NM	412	22,356	63	Aug 23 - Oct 24
2012	BN	NM-IR	723	27,224	38	Aug 26 - Oct 2
2013	D	NM	283	11,437	42	Aug 22 - Oct 2
2014	C	NM	239	2,503	15	Sep 9 - Sep 23
2015	C	NM	383	17,909	42	Aug 21 - Oct 1
2016	BN	SAC	546	12,752	19	Jul 14 - Aug 1
2017	W	NM-IR	125	1,022	12	Aug 29 - Sep 18
2018	BN	AG	548	19,821	30	Aug 28 - Sep 26
2019	W	AG	750	31,600	26	Aug 26 - Sep 21
2020	D	NM	159	3,081	17	Sep 1 - Sep 16
2021	C	NM	31	183	4	Sep 11 - Sep 14
2022	C	NM	31	113	2	Sep 21 – Sep 22

Figure 1-3 Continuous daily average water flow (cfs) at Lisbon Weir and chlorophyll (µg/L in 15-minute intervals) at Sacramento River at Rio Vista Bridge. Flow is depicted with black, dashed line. Chlorophyll is solid green line. Flow pulses (managed and non-managed) are depicted with dark gray boxes. Flow pulse types include flow actions using diversions of Sacramento River water (SAC) or agricultural return flows (AG), or non-managed flow pulses from agriculture activities (NM) or infrastructure repairs (NM-IR). Note that tick marks on the x-axis mark the middle of the month.



Regulatory Background

The NDFS is a management action originally outlined in the 2016 Delta Smelt Resiliency Strategy (DSRS; CNRA 2016). The DSRS is a science-based document that identifies a suite of applied and adaptive science strategies that should be implemented to benefit Delta Smelt by promoting resiliency to altered habitat and drought. The proposed actions of the DSRS are based on recommendations outlined in the Interagency Ecological Program (IEP) Management Analysis and Synthesis Team (MAST) report and conceptual models on Delta Smelt population dynamics (Figure 1-4); IEP-MAST 2015). Specifically, this study includes scientific activities that evaluate the influence of Environmental Drivers on food production (Tier 2), Habitat Attributes such as food availability (Tier 3), and Delta Smelt responses (Tier 4) of the conceptual model (IEP-MAST 2015).

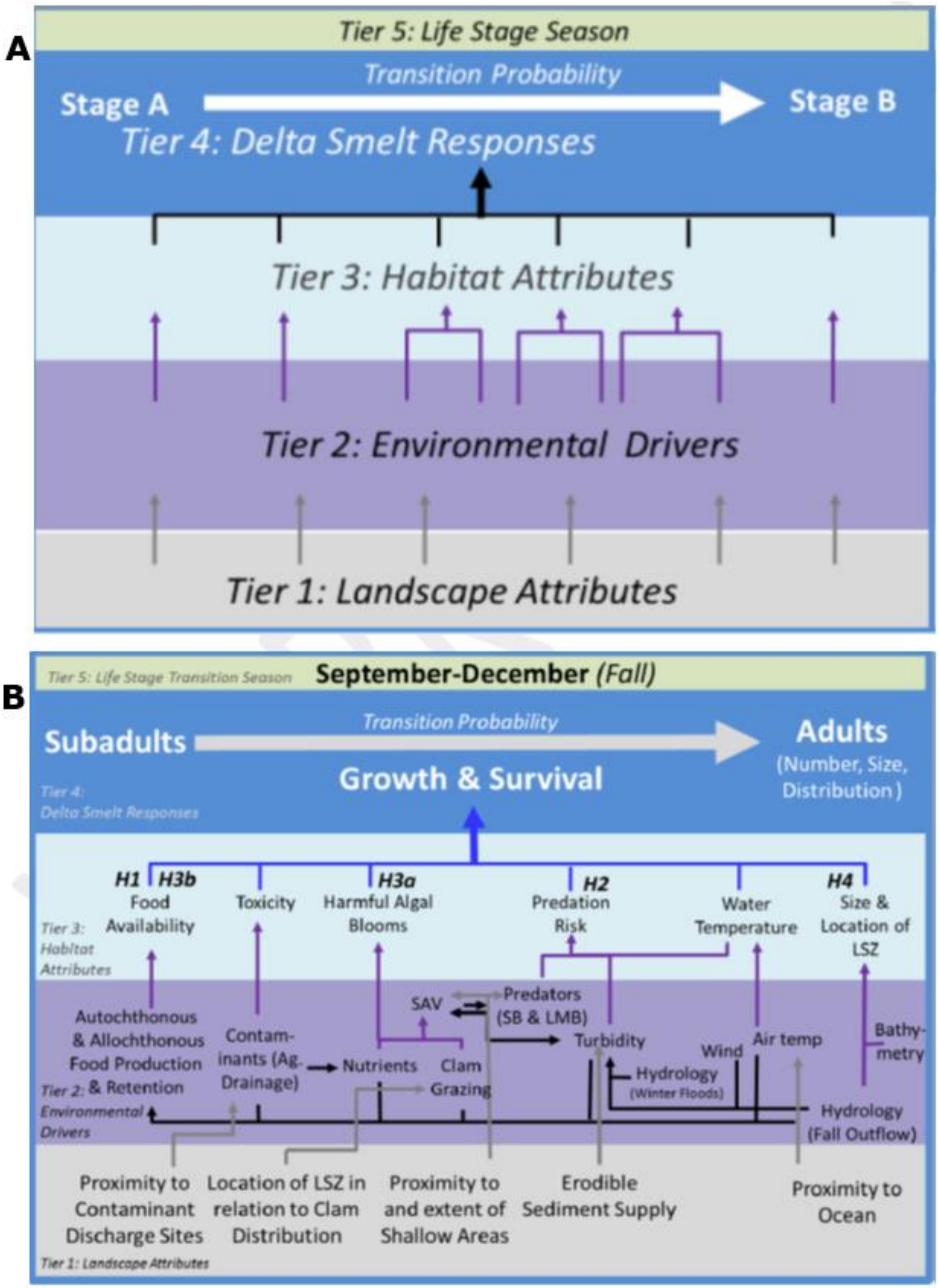
Following several initial years of experimental studies, the NDFS was included as a food enhancement action of the Delta Smelt Summer-Fall Habitat Action (SFHA) in Reclamation and DWR’s Proposed Action for the coordinated long-term operation (LTO) of the Central Valley Project and State Water Project, corresponding USFWS and NMFS Biological Opinions (BiOps; USFWS 2019; NMFS 2019) and the CDFW Incidental Take Permit (CDFW 2020 ITP). The NDFS will be considered annually for implementation by the inter-agency Delta Coordination Group (DCG) with input from the Hydrology and Operations and Science Working Groups. The DCG and affiliated technical working groups consist of Federal and State agency representatives and Water Contractors, and other technical experts, who will consider alternative action scenarios and recommended implementation of the SFHA during the Spring of each year. Implementation of the NDFS and other habitat and food actions of the SFHA relies on structured decision making (SDM) to decide the scope and timing of actions and adaptive management using results from annual monitoring to improve action implementation. The NDFS operations and monitoring plan described in this document will contribute to the “Actions Work Plans” requirement of the SFHA Monitoring and Science Plan developed in coordination with the DCG in the spring of every year, and the annual SFHA Action Plan developed in the Spring of action years (Delta Smelt Summer-Fall Habitat Action Monitoring and Science Plan 2020; SFHA Action Plan 2022, 2023).

The NDFS will be considered annually for implementation (contingent on ESA coverage) and science monitoring will continue through at least 2025, where feasible, and if supported by DCG agencies. After 2025, DWR will evaluate continued experimentation and investment in the action. In general, the NDFS may be implemented in the following California hydrologic years: Above Normal (AN), Below Normal (BN), and Dry (D), with some exceptions. For example, if Spring conditions in a Wet year bring increased plankton, an action may be implemented during that summer-fall. Alternatively, if dry year conditions adversely affect water quality, then an action may not be implemented. DWR will coordinate the implementation of flow actions with input from the DCG using a SDM process informed by hydrologic, operations, and water quality forecasts produced from modeling by DWR and Central Valley Operators.

Scientific Background

The SFE (Figure 1-2) has low primary productivity and plankton biomass (Cloern and Jassby 2008) that have been declining since the mid-1970s (Jassby 2008, Cloern 2019). The decrease in primary productivity has affected other trophic levels in the SFE and is hypothesized to be a significant factor among others (e.g., water exports, invasive clams) contributing to the decline in zooplankton (i.e., fish prey) and pelagic fishes including Delta Smelt, Threadfin Shad, Longfin Smelt, and Age-0 Striped Bass since the early 2000s (Mac Nally et al. 2010, Hammock et al. 2019). The decline of pelagic fishes in the SFE is referred to as the Pelagic Organism Decline (Sommer et al. 2007, Baxter et al. 2008, 2010). Since the Yolo Bypass (Figure 1-2) generates high levels of food resources, increased flow through the region may help increase lower trophic food web productivity in the downstream habitats of the SFE to benefit pelagic fishes such as Delta Smelt.

Figure 1-4 Framework for the Delta Smelt life stage conceptual models (A) and the Fall Conceptual model for subadult to adult Delta Smelt (B). Figures from the IEP-MAST (2015).



While overall productivity in the SFE is low, plankton production is relatively high in the Yolo Bypass (Figure 1-2); the region provides a significant source of phytoplankton biomass to the Delta during winter and spring when the floodplain is inundated (Lehman et al. 2008, Sommer et al. 2004). However, high diversion rates during summer and fall result in low or net negative flows measured at Lisbon Weir in the Yolo Bypass (i.e., net flow is upstream after accounting for tidal effects), that likely inhibit transport of lower trophic level biomass to downstream areas of the estuary (Frantzich et al. 2018). Managed flow pulses during summer or fall through the Yolo Bypass can increase flow from the Yolo Bypass into the Cache Slough region, thereby transporting and increasing availability of plankton in the downstream regions of the estuary (Frantzich et al. 2018, 2019).

Historical monitoring and special studies in the North Delta provide insight into how managed flow pulses may influence lower trophic levels. In 2011, Fall Low Salinity Habitat studies observed a phytoplankton bloom in the lower Sacramento River shortly after a prolonged seasonal agricultural flow pulse passed through the Yolo Bypass (Brown et al. 2014). An agricultural flow pulse occurred again in 2012, followed by a downstream Delta phytoplankton bloom (Frantzich et al. 2018). These were the first fall blooms in over 20 years (ASC 2012). Moreover, isotopic studies indicated that the bloom came largely from the Cache Slough corridor, of which Yolo Bypass is a part (C. Kendall, USGS, 2012 Interagency Ecological Program [IEP] Workshop oral presentation). Delta phytoplankton blooms such as those resulting from the 2011 and 2012 flow pulses can indirectly benefit declining pelagic fish species by providing a food source for zooplankton (fish prey) (Sommer et al. 2007, Hammock et al. 2019). Monitoring by DWR has shown that the phytoplankton species composition during these fall flow pulses is dominated by diatoms (Frantzich et al. 2018), which are a primary food for copepods (Brown 2009, Lehman 1992, Orsi 1995). Copepods are an important component of the diet for many Delta larval and juvenile fishes, including Delta Smelt (IEP-MAST 2015). In 2013 and 2014, a collaborative study investigated nutrient concentrations, water quality, flow, and phytoplankton dynamics within the Yolo Bypass and south through the CSC (Frantzich et al. 2018). Results of these studies provided evidence of fall phytoplankton blooms and subsequent increased zooplankton abundance in the Yolo Bypass and CSC but found no evidence of increased phytoplankton biomass within the Lower Sacramento River (Figure 1-3).

Previous Experimental Actions

2016 SAC Action

Because of the potential benefits to the food web of the SFE using summer-fall flow pulses through the Yolo Bypass, the Delta Smelt Resiliency Strategy included managed flow pulses as a core strategy to benefit Delta Smelt (CNRA 2016). As a result, DWR together with interagency, landowner, and local irrigation district coordination, executed the first experimental NDFS managed flow pulse during the summer of 2016 using diversions of Sacramento River water through the Yolo Bypass (Table 1-1). The 2016 flow action resulted in increased net flow through the Yolo Bypass that was followed by a significant increase in phytoplankton biomass downstream in the CSC and Lower Sacramento River at Rio Vista (Figure 1-3) (Frantzich et al. 2018, 2019, 2021). This downstream bloom was dominated by diatoms and cryptophytes that provide improved food quality for zooplankton (Frantzich et al. 2021). Specific taxa of zooplankton densities increased demonstrating potential transport (Davis et al. 2022), and DWR found positive correlations between zooplankton growth and reproductive rates and phytoplankton biomass, demonstrating overall improved food web production and food quality (Frantzich et al. 2019, Owens et al. 2019). This successfully managed flow pulse provided evidence that the NDFS may provide intended ecological benefits; however, a recent synthesis study also described ecological changes were likely from antecedent Delta conditions, such that the action likely transported an upstream plankton bloom downstream to CSC making it more accessible, but the study did not promote in-situ production of plankton downstream (Davis et al. 2022).

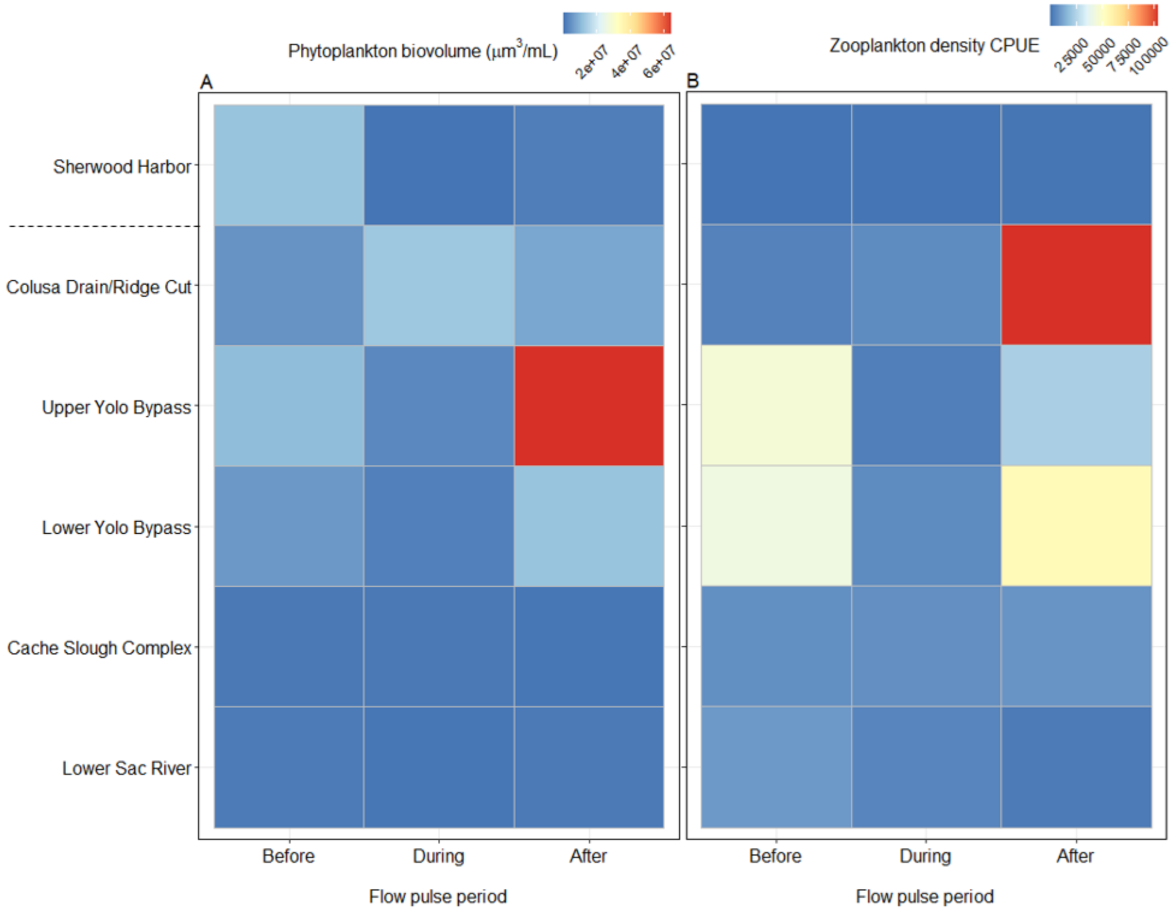
2018 AG Action

DWR and collaborators repeated the NDFS managed flow pulse in 2018 but instead of using Sacramento River water, redirected agricultural return flows from rice field drainage through the Yolo Bypass. The 2018 managed flow pulse relied entirely on agricultural return flows primarily from rice field drainage in Colusa Basin Drain. Unlike 2012 and 2016, phytoplankton biomass did not increase downstream in the CSC and Lower Sacramento River (Figure 1-3) (Frantzich et al. 2019). Results showed that phytoplankton composition contained fewer diatoms, specifically the centric diatom *Aulacoseira* sp., which was observed in past blooms (2012 and 2016). While the flow pulse did not increase phytoplankton production downstream as in 2011, 2012, and 2016, higher densities of zooplankton after the flow pulse were evident suggesting potential advection of zooplankton to downstream habitats of the CSC and Lower Sacramento River. The difference in source water used to generate flow pulses in 2018 (agricultural drainage) and 2016 (Sacramento River water) may have influenced water quality and phytoplankton composition and biomass. For example, pesticides and contaminants in agricultural drainage water are of concern throughout the SFE as contributors to fish and food web declines (IEP-MAST 2015). Thus, contaminant concentrations and their food web consequences are being evaluated in subsequent years of the NDFS. In addition, differences in timing (AG actions occur Aug-Sept and the SAC action in 2016 occurred in July), and preceding hydrologic conditions (2018 followed a wet year, whereas 2016 was at the end of a drought), could have influenced the efficacy of the 2018 AG action on food web productivity.

2019 AG Action

As in 2018, the 2019 NDFS redirected agricultural return water into the Yolo Bypass during fall to generate a managed flow pulse. The 2019 NDFS action increased the quantity of plankton in the Yolo Bypass, but not downstream in the CSC and Lower Sacramento River (Figure 1-5) (Twardochleb et al. 2021). In addition, more nutritious diatoms grew in the Yolo Bypass after the flow pulse than before, providing food for zooplankton (Twardochleb et al. 2021). Collaborator studies provided demonstrated that the 2019 NDFS action did not significantly negatively affect survival of Chinook Salmon (CDFW 2019, Davis et al. 2022). Despite these benefits to the food web, increased contaminant concentrations and low nutrient availability in the flow pulse water could have affected the magnitude of food web responses. Moreover, the 2019 NDFS action did not increase food availability downstream by as the 2016 NDFS action using diversions of Sacramento River water (Figure 1-3). Future actions, including a repeat of the SAC action, will help us assess the effects of source water (agricultural return flows vs. Sacramento River), and other mediating factors such as timing and hydrology, to adaptively manage the flow action to maximize food availability downstream.

Figure 1-5 Plankton responses to the 2019 managed flow pulse. (A) Phytoplankton biovolume (µm³/mL) and (B) Zooplankton densities (CPUE, catch per unit effort) collected before, during, and after the 2019 managed flow pulse. Phytoplankton and zooplankton are shown for Sherwood Harbor (a control site) and five regions of the study area, from north to south: Colusa Basin Drain/Ridge Cut Slough to Lower Sacramento River. Figure from Twardochleb et al. (2021).



Adaptive Management Approach

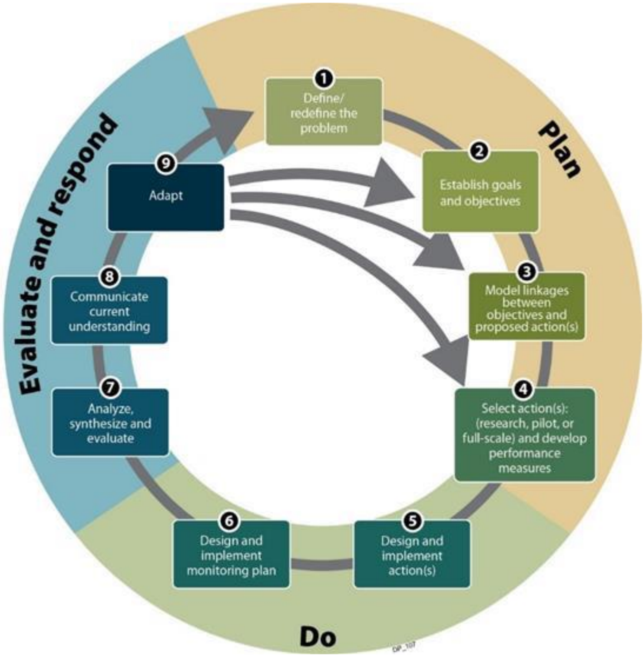
As prescribed by the 2020 ITP and in coordination with the DCG, DWR takes an adaptive management approach to plan, implement, evaluate, and modify the NDFS action, following a commonly used adaptive management life cycle (Delta Stewardship Council 2013). The adaptive management life cycle includes three phases: 1) Planning Phase; define problem; establish goals and objectives; develop conceptual models and performance measures; 2) Do Phase; design and implement actions and monitoring plans; 3) Evaluate and Respond Phase; analyze, synthesize, and evaluate;

communicate current understanding; adapt (Figure 1-6). Phase 1 occurred during the initial years of monitoring (2011-2015), but goals and objectives, conceptual models, and performance measures are continuously refined as part of the SDM process of evaluating the SFHA by the DCG.

Phases 2 and 3 of the adaptive management life cycle occur annually. Each year, we evaluate and communicate the efficacy of the previous seasons' managed flow action by testing our hypotheses (Ch. 3) with science monitoring and reporting. The results of our evaluations are then used to modify and plan the next seasons' NDFS action and monitoring (see Ch. 3, Learning from Monitoring). In addition, we use synthesis analyses of our monitoring data to compare the efficacy of flow pulses (managed and non-managed) across years to examine how food web responses to the action are mediated by flow pulse type, magnitude, timing, and hydrologic conditions (Davis et al. 2022). These assessments are then used to inform the SDM process by the DCG and have already resulted in modifications to NDFS operations, including altering flow targets. In addition, we have added special studies to NDFS monitoring, including phytoplankton growth experiments (initiated in 2019), a study of contaminant concentrations in zooplankton (begun in 2021), to assess potential consequences of flow actions on the food web, a stable isotope pilot study to determine if we can trace biota transported to downstream habitat (begun in 2022) and an annual-telemetered water quality station to help decision-making surrounding potential negative effects to salmonids.

We will continue using this adaptive management approach to explore implementation alternatives potentially modifying the timing, magnitude, and type of action to maximize efficacy. For example, using information from our monitoring assessments, the DCG considered the following alternative action scenarios for future implementation: long duration, low intensity AG or SAC actions, short duration, high intensity AG or SAC actions, and combined SAC/Ag actions (2022 SFHA Plan). In 2023, however, following the NDFS synthesis report (Davis et al. 2022) and another iteration of SDM, the DCG no longer would include an AG action alternative with short duration high intensity, with keeping the AG long/low alternative for learning purposes (2023 SFHA Plan). The DCG is currently prioritizing planning and implementation of a long duration, low intensity SAC action when hydrologic conditions permit (see Ch. 3), however, we may implement any other alternative actions in the future for learning objectives and then compare their efficacy using science monitoring. The DCG may then adjust priorities using information from science monitoring during the next round of SDM.

Figure 1-6 Adaptive Management Life Cycle as outlined in The Delta Plan



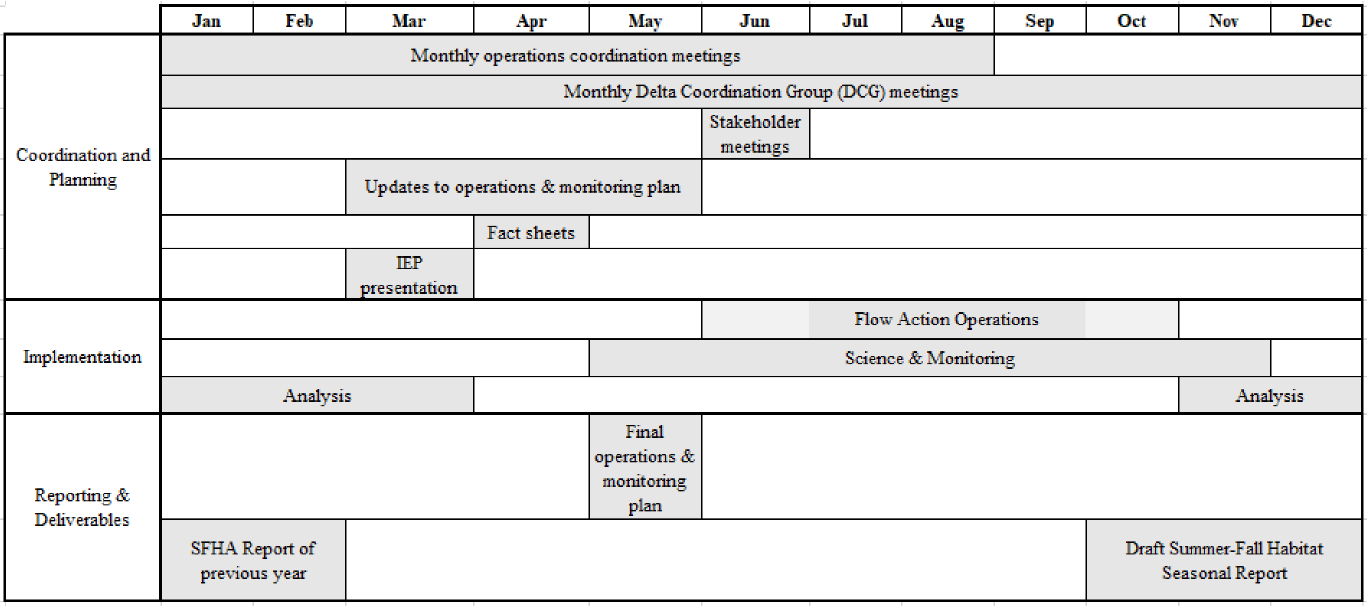
Proposed Activities for 2023-2025

NDFS flow actions, science monitoring, and assessments will occur annually in summer and/or fall depending on hydrology. In the following two chapters, we present an operations plan for conducting flow actions (Ch. 2) and a science monitoring plan for evaluating their effects on the Delta food web (Ch. 3) for 2023-2025. The previous three-year plan (2021 to 2023) aligns with the 4-year review cycle of the SFHA (Delta Smelt Summer-Fall Habitat Action Monitoring and Science Plan 2020); however, no flow action was conducted in 2020, 2021, and 2022 due to drought. Monitoring plans and the structured decision-making process will be reviewed for NDFS in January of 2024 as part of the large Summer-Fall Habitat Action (see ITP COA 3.13.8). In coming years, we will conduct a flow action when hydrologic conditions permit (see *Chapter 2. Operations Plan* for details of the annual decision-making process). We plan to carry out science monitoring annually during summer and fall, regardless of whether a flow action is planned, but monitoring will depend on safety conditions for field sampling, coordination with other projects and construction, and resources. For example, 2020 was an NDFS non-managed flow year with planned baseline monitoring that was limited in duration and scope due to the COVID-19 emergency and poor air quality from wildfire smoke, and construction is planned for a key NDFS operation structure in 2024. Continuing the NDFS science monitoring during non-managed flow years will provide an assessment of baseline conditions to compare food web productivity and composition resulting from managed and non-managed flow pulses and underlying seasonal changes.

Timeline of Activities and Deliverables

Due to the inclusion of the NDFS as a possible SFHA to benefit Delta Smelt, the timeline for NDFS operations and monitoring plans and reporting follows a similar timeline for SFHA deliverables (Figure 1-7), where possible (Delta Smelt Summer-Fall Habitat Action Monitoring and Science Plan 2020).

Figure 1-7 Timeline of annual activities and deliverables for the North Delta Food Subsidies Study-Colusa Basin Drain Study for 2023-2025. Note that operations and monitoring plans are updated annually, as needed.



<table>
<tr><th></th><th>Jan</th><th>Feb</th><th>Mar</th><th>Apr</th><th>May</th><th>Jun</th><th>Jul</th><th>Aug</th><th>Sep</th><th>Oct</th><th>Nov</th><th>Dec</th></tr>
<tr><td rowspan="6">Coordination and Planning</td><td colspan="8">Monthly operations coordination meetings</td><td colspan="4"></td></tr>
<tr><td colspan="12">Monthly Delta Coordination Group (DCG) meetings</td></tr>
<tr><td colspan="5"></td><td>Stakeholder meetings</td><td colspan="6"></td></tr>
<tr><td colspan="2"></td><td colspan="3">Updates to operations & monitoring plan</td><td colspan="7"></td></tr>
<tr><td colspan="3"></td><td>Fact sheets</td><td colspan="8"></td></tr>
<tr><td colspan="2"></td><td>IEP presentation</td><td colspan="9"></td></tr>
<tr><td rowspan="3">Implementation</td><td colspan="5"></td><td colspan="5">Flow Action Operations</td><td colspan="2"></td></tr>
<tr><td colspan="4"></td><td colspan="7">Science & Monitoring</td><td></td></tr>
<tr><td colspan="3">Analysis</td><td colspan="7"></td><td colspan="2">Analysis</td></tr>
<tr><td rowspan="2">Reporting & Deliverables</td><td colspan="4"></td><td>Final operations & monitoring plan</td><td colspan="7"></td></tr>
<tr><td colspan="2">SFHA Report of previous year</td><td colspan="7"></td><td colspan="3">Draft Summer-Fall Habitat Seasonal Report</td></tr>
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2 Operations Plan

Summary

During flow actions, DWR alters the operation of the Knights Landing Outfall Gates (KLOG) and Wallace Weir (near Knights Landing, CA) to increase fall agricultural return flows (AG) or redirect Sacramento River water (SAC) into the Yolo Bypass Toe Drain to create a managed flow pulse of sustained positive, daily average net flow measured at Lisbon Weir (2016, 2018, 2019, Figure 2-1).

Action operations would begin in July for SAC actions and are coordinated among DWR, USBR, and local irrigation and reclamation districts and require increased pumping of Sacramento River water into Colusa Basin Drain and Knights Landing Ridge Cut (Ridge Cut) (Figure 2-2). This diversion requires that flow on the Sacramento River at Wilkins Slough be at about 5,000 cfs. Only a small percentage of the flow pulse is “consumed” by the flow action (e.g., evaporation, local diversions) as the water is directed down a different path to the Delta. For example, in 2016, the estimated water cost was less than 15 percent of the additional Sacramento diversions.

AG actions begin in mid-to late-August, depending on suitable water allocations and water quality within the Colusa Basin Drain, Ridge Cut, and Yolo Bypass as determined by DWR and monitoring by reclamation districts. This type of action relies on coordinated releases of rice field drainage into

Colusa Basin Drain (Figure 2-3). Overall, the SAC action requires coordination among a larger number of entities and facilities, while the AG action represents a modest change to normal operations of the facilities in the region. Table 2-1 and Figure 1-1 and Figure 2-3 below provide an overview of the flow targets and operations for the two action types. In either case, the action is designed to maximize the environmental benefits of water.

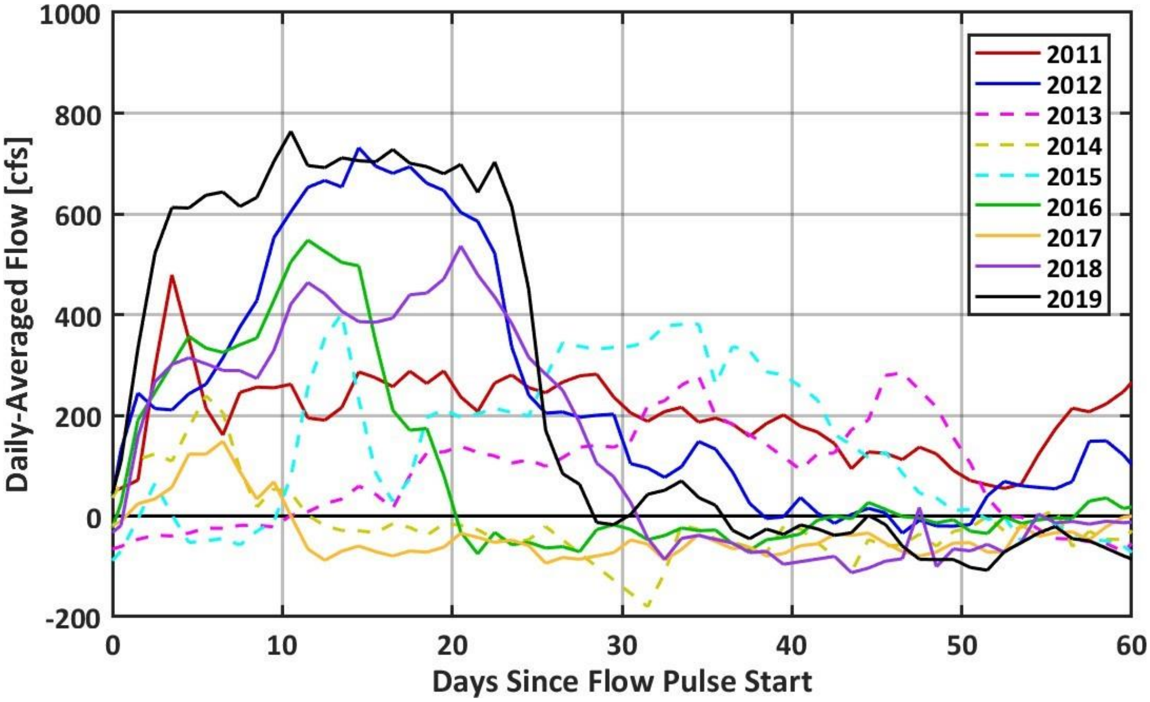
In addition to AG and SAC actions, the DCG is considering combined SAC/AG actions for future implementation as part of the SDM process for the SFHA. A combined SAC/AG action has not yet been implemented, and DWR and USBR are working with project coordinators, including GCID, RD108, water operators, and the DCG technical working groups, to assess feasibility and develop an operations plan for this action scenario. This action alternative (AG/SAC) has the potential to provide sustained net positive flow in the bypass for up to 4-8 weeks which could improve nutrient transport, dilution of contaminants, increase residency time for primary production, and enhance zooplankton availability. This operations plan will be updated in the future with information about conducting this type of action.

Flow Targets

SAC Flow Action

For the SAC action, DWR would target two to six consecutive weeks of positive net flow, a maximum daily average flow of 400-800 cfs measured at Lisbon Weir on the Yolo Bypass Toe Drain, and a total flow pulse volume exceeding 30,000 AF. These targets are based on historical flow data measured at Lisbon Weir from 2011 and 2012, years in which we observed evidence of downstream plankton blooms in the Lower Sacramento River at Rio Vista after a flow pulse (Figure 1-3; Frantzich et al. 2018). One previous experimental redirection of Sacramento River water resulted in a substantial flow pulse with daily average flows of 300-550 cfs for over two weeks (Jul 14 – Aug 1) and net positive flow over three weeks at Lisbon Weir, and a total volume of 12,700 AF (Figure 2-1, 2016). Although the total volume was well below the 2016 target of 20,000 AF, DWR detected changes in biovolume of specific phytoplankton taxa (resulting from productivity and/or transport) after the pulse in the CSC and Lower Sacramento River at Rio Vista (Figure 1-3; Frantzich et al. 2021; Davis et al. 2022). To meet adaptive management objectives of improving net flow and plankton availability, implementation of redirected Sacramento River water action may include alternative flow targets requiring flexibility in flow operations that will be coordinated with project collaborators (e.g., local irrigation and reclamation districts). Alternative flow targets may include a longer duration (4-6 weeks) but lower intensity (400 cfs maximum daily average net flow), a shorter duration (2-weeks) and higher intensity (800 cfs), or a longer duration (4 weeks) and higher intensity (800 cfs). Lastly, redirection of Sacramento River water in the summer of lower intensity (400 cfs) may be followed by a combined agriculture drainage operation, increasing net positive flow to 6-8 weeks.

Figure 2-1 Daily averaged observed flow past Lisbon Weir between 2011 and 2019. Years with dashed lines were not included in hydrodynamic modeling (see Monitoring Chapter 3). 2016 was a MA-SR action, and 2018 and 2019 were MA-Ag actions. Figure modified from Anchor QEA (2020). A flow pulse begins when sustained daily average net flow (cfs) is positive at LIS.



AG Flow Action

For the AG action, DWR would target a flow pulse that is four- six weeks in duration with maximum daily mean net flow of 400-800 cfs at LIS, and a total volume 14,000-18,000 AF (Figure 2-1, years 2018 and 2019). Water operations are adjusted to maintain a minimum daily mean net flow of >300 cfs over the four to six-week period. These flow targets are based on historical flow data measured at LIS from 2011, 2012, and 2016 when we observed downstream plankton blooms (Figure 1-3). The 2018 flow action resulted in a pulse of 19,821 AF for roughly four weeks (Aug 28 – Sep 26) and was close to the study's target volume of 20,000 AF, although it did not reach the daily maximum flow of 700 cfs that we observed in 2012 (a non-managed flow year with downstream plankton blooms) (Table 2-1). The 2019 flow action lasted 26 days (Aug 26 - Sep 21). The pulse exceeded flow targets at 31,000 AF and an average daily net flow of 750 cfs. Similar to redirection of Sacramento River water, combining agriculture drainage in fall would be adaptively managed with flexible operations and action alternatives to meet project objectives for increasing flow and food web productivity, while accounting for real-time conditions such as acreage irrigated, drainage schedule, and weather. Alternative flow targets may include longer duration (four to six weeks) but lower intensity (400 cfs maximum), a shorter duration (two-weeks) and higher intensity (800 cfs maximum), or a longer duration (4-6 weeks) and higher intensity (800 cfs maximum). Lastly, a fall combined agriculture drainage targeting a low intensity of 400 cfs may follow a summer redirection of Sacramento River water, if feasible or determined by DWR that it may better meet objectives.

Table 2-1 Description of types of flow actions with flow targets and non-managed flow pulses: managed Sacramento River (SAC), managed agricultural (AG), and non-managed due to agricultural drainage (NF). AF is acre feet and cfs is cubic feet per second. Note that the timing and targets listed here are based on historic managed flow actions in 2016, 2018, and 2019 and modeled scenarios by the Delta Coordination Group. However, we will continue coordinating with USBR and the DCG to explore alternative flow action scenarios, such as conducting a longer duration or lower intensity flow action using sequential SAC and AG actions.

Operation Criteria	SAC	AG	NM (no-action)
Source	Sacramento River	Colusa Basin Drainage	Colusa Basin Drainage
Frequency	Once a year	Once a year	Once a year

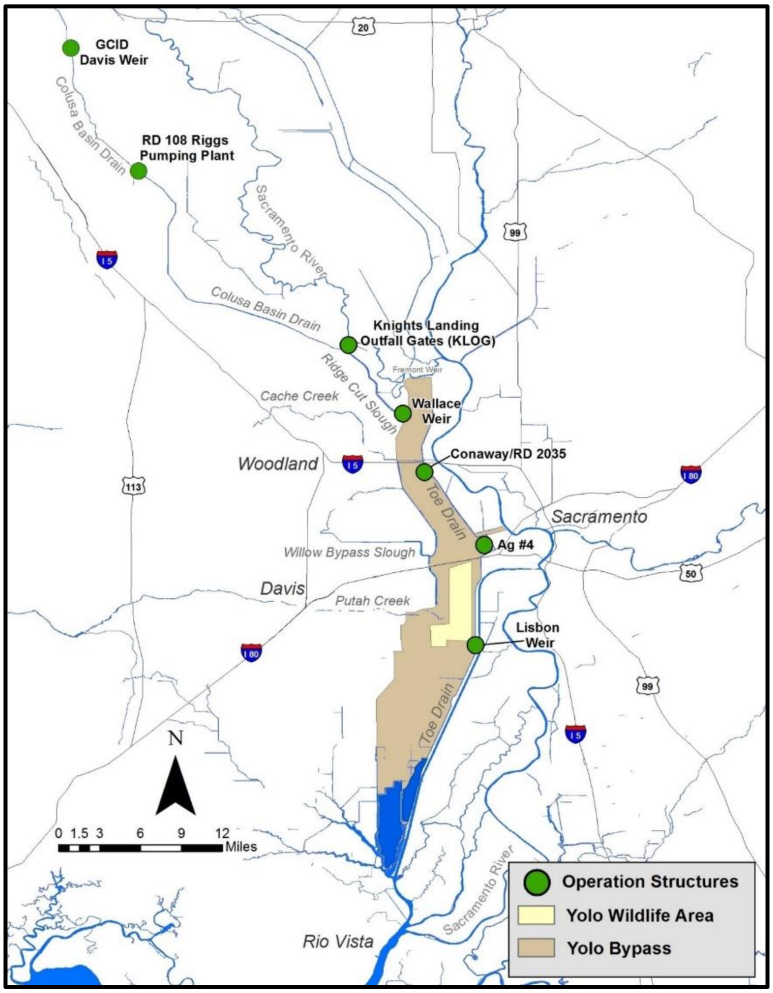
Operation Criteria	SAC	AG	NM (no-action)
Timing	2-6 weeks during late June - early August.	Between August - October. Duration and timing are dependent upon acreage planted, drainage schedule, and weather.	Between August - October. Duration and timing are dependent upon acreage planted, drainage schedule, and weather.
Duration	Until total volume is delivered.	Until agricultural drainage is completed or total volume delivered.	Until agricultural drainage is completed.
Rate of diversion	KLOG is reoperated when elevation is 26-27’ in Sacramento River. Need to maintain flows at Wilkins Slough near 5,000 cfs	KLOG is reoperated when elevation is 27’ in Sacramento River.	N/A
Location of diversions	Multiple diversions necessary by irrigation and reclamation districts north of and within Yolo Bypass (GCID, RD108, Conaway)	KLOG	N/A
Flow Pulse Criteria (conditions indicating a flow pulse is occurring)	Sustained daily net positive flow measured at LIS	Sustained daily net positive flow measured at LIS	Sustained daily net positive flow measured at LIS
Target Total Flow Volume at Lisbon Weir (Total AF)	>30,000	14,000-18,000	N/A
Target Minimum Daily Average Flow at Lisbon Weir (cfs)	>300	>300	N/A
Target Maximum Daily Average Flow at Lisbon Weir (cfs)	400-800	400-800	N/A

Operation Infrastructure

Yolo Bypass

The 24,000 ha Yolo Bypass engineered floodplain is the primary flood control system for the Sacramento Valley, as it conveys up to 80 percent of the Sacramento River basin flow through the Fremont and Sacramento Weirs during high water periods of winter and spring (Sommer et al. 2001). Although the Yolo Bypass is primarily a flood control system, it is also heavily utilized during non-inundation periods for agriculture (primarily May-Sept.) and as a seasonal and permanent wetland habitat for migratory waterfowl. In the dry season of summer and fall the waters within the Yolo Bypass are confined to the Toe Drain, a perennial man-made channel that flows along the east side of the leveed floodplain. During this low flow period the channel receives minimal inputs from several west-side tributaries (Cache Creek, Willow Bypass Slough, and Putah Creek), but much of the source water is from agricultural return flows from the Colusa Basin Drain into Ridge Cut Slough (Figure 2-2). Flows during this dry season are often net negative in the Toe Drain due to local agricultural diversions, causing water to move northward into the Cache Slough Complex and Yolo Bypass from the lower Sacramento River. Net flow becomes positive in the Toe Drain each year in late-summer and early-fall (late-August to mid-September) during periods of increased discharge of agricultural return water from local and upstream rice-field harvest. In the fall the Yolo Bypass Wildlife Area begins pumping water from the Toe Drain to fill and maintain seasonal flooded wetland habitat for migratory waterfowl.

Figure 2-2 Map of the primary operation structures for the NDFS action and the Yolo Bypass tributary inputs



Colusa Basin Drain/Davis Weir

The Colusa Basin Drain is a man-made channel that interconnects a network of historical streams within the Colusa basin and operates as the primary irrigation canal for Northern Sacramento Valley counties and several counties within the Sacramento Metro region. The Colusa Basin Drain does not have a natural outlet to the Sacramento River, but maintains periodic connection based on operations at the KLOG and through Knights Landing Ridge Cut Slough that joins the Yolo Bypass near the northernmost extent of the Toe Drain. Glenn Colusa Irrigation District (GCID), the largest irrigation district in the Sacramento Valley, is the primary water rights holder and conveyor of water throughout the Colusa Basin Drain and the complex network of interconnected canals and laterals. GCID operates a pumping station that diverts from the Sacramento River near Hamilton City and maintains the Davis Weir as a downstream water control structure. Reclamation District No. 108 (RD 108) is another water rights holder in southern Colusa County and northern Yolo County that pumps water into the Colusa Basin Drain from the Sacramento River through a series of river diversion pumping plants south of the city of Williams to the city of Woodland. RD 108 also operates several reuse pumping plants with the primary plant along the Colusa Basin Drain being the Riggs Ranch pumping plant.

Knights Landing Outfall Gates

The Knights Landing Outfall Gates (KLOG) is a gate-operated water control structure at the base of the Colusa Basin Drain. It acts as a barrier to protect the lower Colusa Basin against backwater flooding from the Sacramento River and to control water elevations in the Colusa Basin Drain for irrigation and drainage during low flow periods. KLOG is currently operated by DWR Division of Flood Management Office.

Wallace Weir

Wallace Weir was historically a mostly earthen berm with a series of manually operated slide gates to hold back water in Knights Landing Ridge Cut Slough and Colusa Basin Drain for irrigation by local farmers and RD 108 within the lower Colusa Basin and northern Yolo Bypass. This weir is the primary flow control structure between Colusa Basin Drain and the Yolo Bypass Toe Drain during low flow periods of summer and fall. In 2016, DWR contracted

with RD 108 to develop a permanent and improved Obermeyer Weir structure as part of a larger habitat restoration and fish passage improvement project included in the 2009 NMFS BiOp. This project was completed in 2018 and provides year-round automated operational control and a fish rescue facility to increase survival of salmonids that have strayed upstream. This structure is currently operated jointly by RD108 and DWR, with substantial communication with local landowners.

Reclamation District No. 2035/Conaway Ranch

Reclamation District 2035 (RD 2035), Conaway Ranch, and Woodland Davis Clean Water Agency operate and jointly own an intake on the Sacramento River just north of Interstate 5 (I5). This intake delivers water in separate pipelines to the cities of Woodland and Davis as well as for irrigation within the northern Yolo Bypass for Conaway Ranch farming operations. Conaway Ranch also operates a reuse pumping plant located just above I5 in the northern Toe Drain.

Agriculture Road Crossing #4/Swanston Ranch

The Swanston Ranch within the central Yolo Bypass maintains a primarily earthen road crossing (Ag #4) with a manually operated central culvert and upstream slide gate. This road crossing acts as both a transportation corridor and a weir to retain water in the upper Toe Drain for irrigation by local farmers in the central Yolo Bypass. This weir structure resides at the upper most extent of the tidal influence from the lower Delta. Construction is planned in 2024 to replace the old earthen crossing/culvert systems with a bridge.

Lisbon Weir/Yolo Bypass Wildlife Area

Lisbon Weir is the downstream-most weir structure within the Yolo Bypass Toe Drain and operates primarily as a tidal retention dam. A series of one-way flap gates on the west side of the weir allow tidal flows to convey water upstream during the flood tide and close on the ebb tide. The water is retained upstream of the weir, allowing upstream water users to pump water throughout the tidal cycle. Primary water users include private landowners as well as the CDFW managed Yolo Bypass Wildlife Area (YBWA). The YBWA is a 16,000-acre region of the Yolo Bypass that is managed and operated as seasonal and perennial wetland wildlife habitat, riparian woodland, and for agriculture. DWR operates a continuous, real-time telemetered stage, flow, and water quality station below the weir that is a critical element to the monitoring and assessment of the flow action (CDEC site: LIS http://cdec.water.ca.gov/dynamicapp/QueryF?s=lis).

Operators

During the dry season, the Yolo Bypass has several water users and managers starting upstream in the Northern Sacramento Valley south to the Yolo Bypass Wildlife Area. The NDFS operations require a collaborative water management strategy by reclamation districts, irrigation districts, state agencies, and local landowners (Table 2-3).

Table 2-3 Yolo Bypass primary water operators and contact information

Operation Structure	Primary Contacts	Title/Role/Property
Colusa Basin Drain/Davis Weir	Thad Bettner	GM, Glen Colusa Irrigation District
Colusa Basin Drain/Davis Weir	Jake Hancock	Water Supervisor
Colusa Basin Drain/Davis Weir	Lewis Bair	RD 108, General Manager
KLOG	Casey Lund	Superintendent Flood Management, DWR
KLOG	Mitra Emami	Flood Maintenance Office, DWR

Operation Structure	Primary Contacts	Title/Role/Property
Wallace Weir	Lewis Bair	RD 108, General Manager
Wallace Weir	Josh Martinez	Senior Environmental Scientist, DWR
Wallace Weir	Morgan Kilgour	Fish Collection Facility, CDFW Region 2 Supervisor
RD 2035/Conaway Ranch	Mike Hall	Conaway Ranch
RD 2035/Conaway Ranch	Darren Cordova	MBK Engineers, for Conaway Ranch
Ag. Crossing #4/Swanston Ranch	Mike Lear	Swanston Ranch
Yolo Bypass Wildlife Area	Joe Hobbs	Yolo Bypass Wildlife Area, CDFW Manager/Supervisor

Operations Planning and Implementation

Hydrology Affects Flow Actions

Operations for an AG or SAC action in summer and/or fall require appropriate hydrologic conditions. DWR may not pursue flow actions during the most extreme water years for both dry and wet conditions (wet or critically dry water year types) (Figure 2-5). Monitoring by DWR has shown that water availability may be insufficient to generate a flow action in critically dry years (Figure 2-8), and non-managed flow pulses during critically dry water years may have negative effects on water quality, the Delta food web, and potentially other fish species. In 2015, a critically dry year in the middle of a historic drought (2012-2016), there was a modest flow pulse based on the limited amount of water available in the Colusa Basin Drain (Table 1-1, Figure 1-3). However, low flow and stagnant water resulted in poor water quality during the pulse that caused a major fish kill near Wallace Weir. These results suggest that managed flow actions should be avoided during critically dry water years to avoid negative effects on water quality and fish. However, modeling by DWR has shown that AG actions are unlikely to negatively impact water quality in the Delta during dry water year types (Appendix 2). Moreover, managed flow actions may not provide much benefit to the food web above those provided by non-managed flow pulses during wet years, as net outflow from the Yolo Bypass is usually positive during summer without flow modifications (see 2011 in Figure 1-3). Thus, DWR is unlikely to plan flow actions during wet years, except under certain circumstances, such as a wet winter but a dry spring, or if an upstream plankton bloom is observed that a summer-fall flow pulse could help to transport to downstream habitat.

Each year during spring, DWR will assess water availability for a flow action based on hydrologic forecasting. We will hold monthly operations meetings (see Timeline, Figure 1-7) with USBR, local irrigation and reclamation districts, and DWR water operators and hydrologic modelers to assess the projected water year type, previous water year type, reservoir storage capacity, and whether there will be sufficient flow in the Sacramento River at Wilkins Slough north of the Yolo Bypass (see Figure 4-2) to conduct a SAC action. This type of action will normally be conducted in above normal or below normal years (Figure 2-5), as flow in the Sacramento River may be insufficient in dry years. If a SAC action is not feasible, we will assess hydrologic conditions and water quality for a AG action (Figure 2-5, Appendix 2), including whether the Northern Sacramento Valley and Yolo County farmers will receive adequate water to generate a fall agricultural return pulse. In a typical year, the number of acres planted can be a good indicator of water available for an AG action; however, water reductions applied to settlement contracts have, in the past, reduced acreage planted (Figure 2-3). Diminished plantings could decrease the amount of water available to generate a sufficient AG flow action. We will also assess the timing of planting and summer weather to plan the timing for a AG action (Figure 2-4). Early planting and warm weather result in earlier AG actions (Figure 2-4). The content of these operations planning meetings will be shared at monthly meetings with the DCG, and DWR and USBR will consult with the DCG to decide on the type and timing of action.

Operations Planning Meetings

Figure 2-3 Estimated irrigated crops (in acres) in Glenn Colusa Irrigation District (GCID) in 2022. Does not include crops irrigated with landowner wells which could increase 2022 values slightly. Flow pulse water for AG actions is largely sourced from rice field drainage proximal to the Colusa Basin Drain, however water reductions in 2022 resulted in significantly less acres planted (~1% of historical).

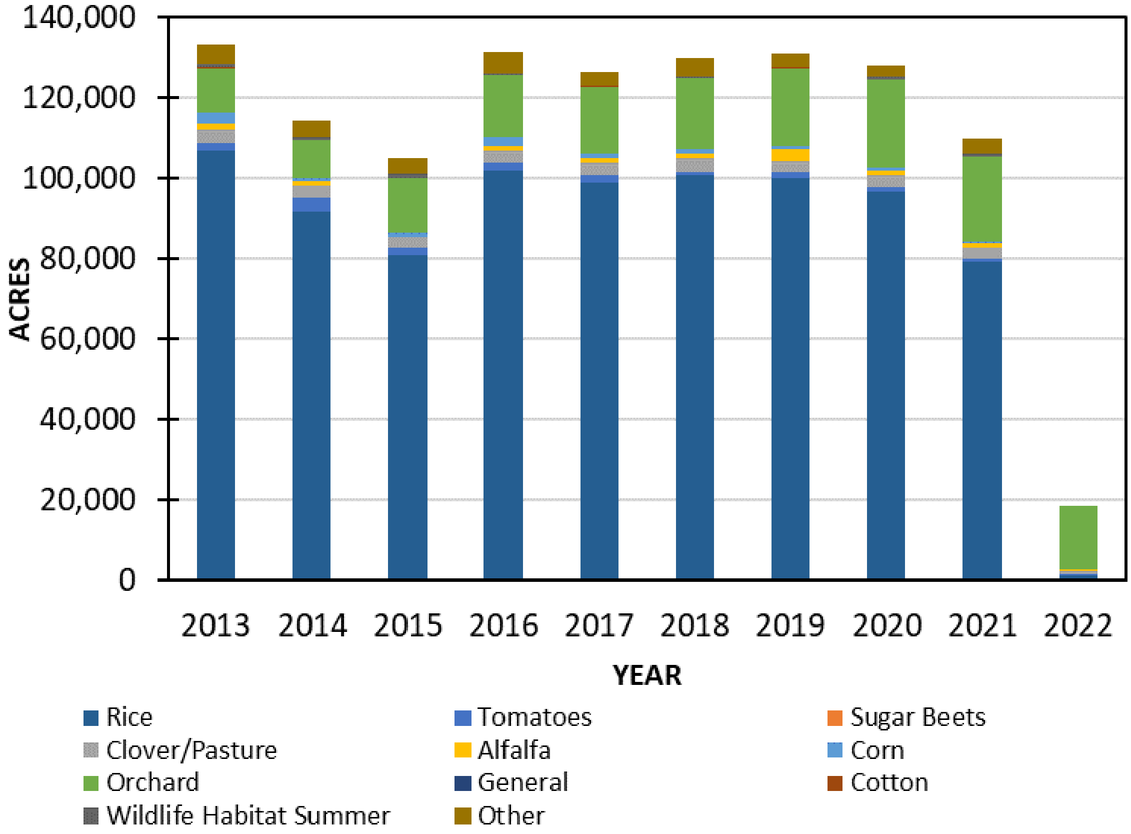
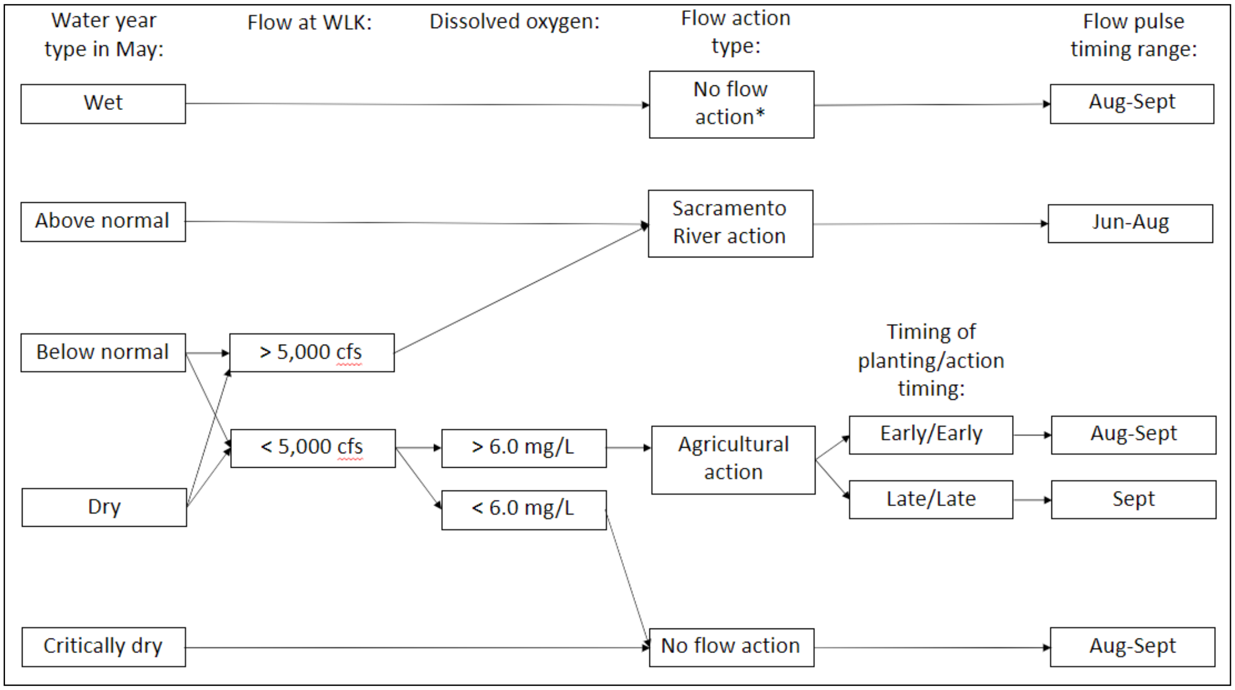


Figure 2-4 Conceptual diagram for planning a Sacramento River (SAC) vs. Agricultural (AG) flow action, based upon 2022 Structured Decision-Making outcomes of the DCG and operation feasibility. The type of flow action in any year will depend on (left to right): Projected water year type (wet to critically dry) with the final hydrologic forecast in May, flow in the Sacramento River at Wilkins Slough north of the Yolo Bypass, and water quality within the Yolo Bypass. In addition, summer air temperature and the timing of agricultural planting in the north Delta region will both affect the timing of an agricultural action. Monitoring timing depends on the type and timing of the flow action. *Note that a flow action will not normally be conducted in a wet year, except under certain circumstances such as a wet winter and a dry spring or if a wet spring shows increased productivity upstream that a pulse could transport to downstream smelt habitat. In addition to current year hydrology, DWR will consider previous year hydrology when determining which type of flow action to conduct. DWR hydrologic modelers will also assist with assessing the effects on water quality.



Local Landowner Outreach

DWR will communicate operations plans for flow actions through landowner outreach, fact sheets, and a stakeholder meeting in late spring/early summer each year. We will conduct outreach through representatives of Glenn Colusa Water Mutual Company. The DWR operations coordinator for NDFS will distribute fact sheets and conduct outreach to landowners in the region who will be immediately affected by the flow pulse. In addition, the NDFS monitoring lead will hold a stakeholder meeting late spring/early summer to disseminate the results of the previous flow pulses and monitoring and provide an overview of the next seasons' potential flow action operations plan.

During June-August, we will contact local landowners not directly involved in flow action planning. GCID and RD 108 will inform local landowners along the Colusa Basin Drain of the planned flow action, including the timing and expected changes to water operations (e.g., Davis Weir, Riggs Pumping Plant, KLOG, Wallace Weir). Josh Martinez (DWR) and/or representatives of his team will be the primary contact for Yolo Bypass landowners below Wallace Weir and will keep them informed on all planned water operations. DWR will contact the Yolo Bypass Wildlife Area manager and keep YBWA staff updated on timing and planned operation changes.

Permits

Flow action operations will comply with all water quality objectives for the Bay-Delta Estuary as implemented by the State Water Resources Control Board Water Rights Decision D-1641. In previous years with experimental actions, DWR filed a California Environmental Quality Act exemption where possible. In 2020, the NDFS action was analyzed at a project level in the Federal Environmental Impact Report (FEIR) for Long-Term Operation of the SWP (DWR 2020, State Clearinghouse No. 2019049121) for the ITP and concluded impacts of the project as approved – including impacts to ESA and CESA-listed fish and surface water quality as less than significant (See FEIR 5-57 and 5-58). An addendum to the FEIR was filed in February of 2023 describing new analysis of NDFS effects to water quality and potential effects to species (e.g., contaminants, dissolved oxygen). In addition, the NDFS project will abide by listed species and critical habitat criteria set forth by the 2019 BiOp for the Long-Term Operations of the Central Valley and State Water Project (SWP), and will require additional consultation with FWS and NMFS given previous effects analyzed programmatically.

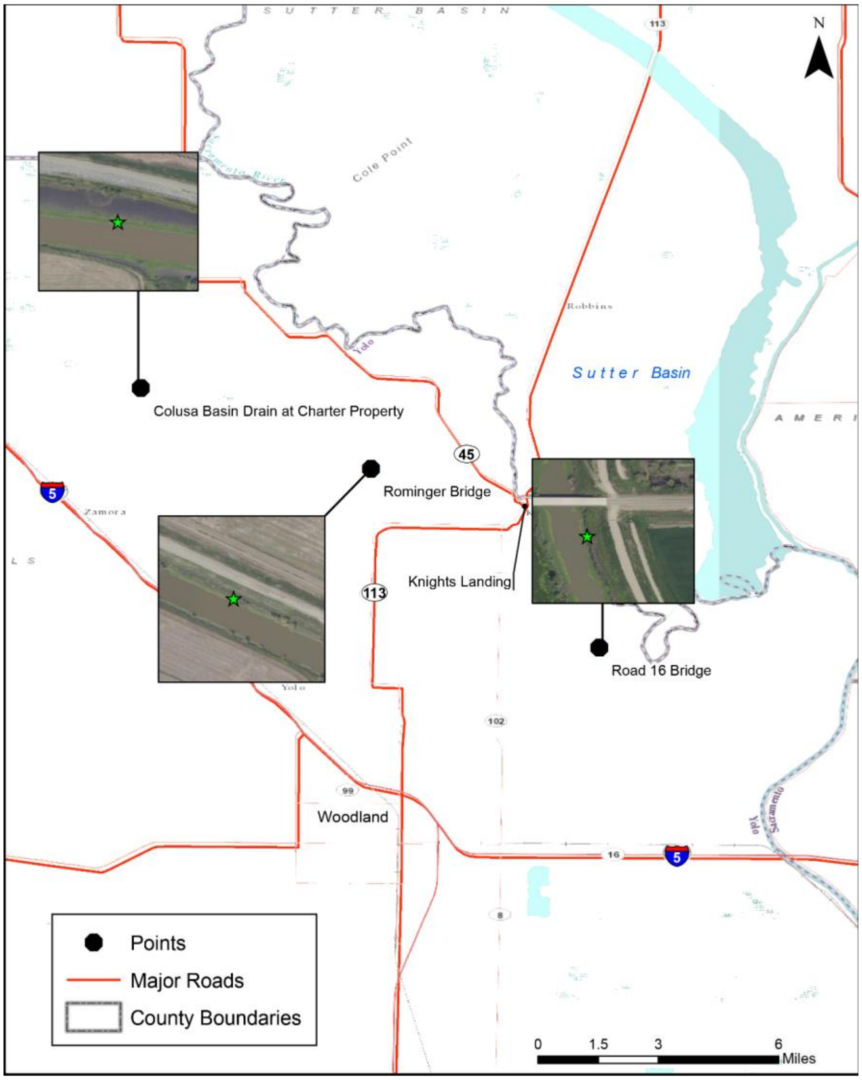
Flow Monitoring

During flow actions, water level (i.e., stage) and flow will be monitored closely at 5 potential locations detailed in Table 2-3 and Figure 2-5 to make real-time adjustments to operations and communicate water conditions of the action to landowners. Monitoring will be conducted by a contractor. The gauges will be downloaded periodically throughout the flow action.

Table 2-3 Monitoring of stage (in ft, Datum NAVD88) and flow (cfs) in lower Colusa Basin Drain and Ridge Cut Slough. Sites are subject to vary.

Site Name	Description	Lat.	Long.
Colusa Basin Drain at Charter Property	Stage	38.842001	-121.858371
Colusa Basin Drain at Rominger Bridge	Stage	38.812877	-121.775346
Ridge Cut Slough at Road 16 Bridge	Stage	38.748206	-121.69298
Wallace Weir (Upstream)	Flow/Stage	38.722179	-121.663679
Wallace Weir (Downstream)	Flow/Stage	38.722179	-121.663679

Figure 2-5 North Delta Food Subsidies monitoring sites for water level (stage). Two additional sites at Wallace Weir are not included in the map (Image provided by CBEC Eco Engineering).



Operations Plan for SAC Flow Action

See Figure 2-2 (above) and Table 2-4 (below) for an overview of operations.

1. Monitor flow at Sacramento River at Wilkins Slough

   To initiate the flow action, flow at Wilkins Slough must be no less than 4,000 cfs (with 5,000 cfs preferred) to enable further project actions downstream (Figure 1-1). In 2016, USBR modified operations at Shasta-Keswick dam to achieve these additional flows. However, additional diversions from upstream reservoirs will not be necessary in most years, because flow at Wilkins Slough normally exceeds 5,000 cfs during the summer/fall period in most water year types except critically dry (Figure 2-7).

2. Additional diversions by GCID, RD108, and RD-2035/Conaway

   The minimum Wilkins Slough flow (discussed above) provides river stage high enough to enable GCID and RD 108 to pump additional water from the Sacramento River into Colusa Basin Drain north of the Yolo Bypass (Figure 2-2). Additional pumping of Sacramento River water by RD 2035/Conaway Ranch in the northern Yolo Bypass is required to achieve target flows at Lisbon Weir, as RD 108 is unable to pump a large enough volume due to contractual requirements for water delivery to their users upstream of the Yolo Bypass.

3. KLOG Elevation and Wallace Weir Operations

   In the past, the KLOG elevation was set to a target of 26’ to allow for additional upstream flows to be diverted into Ridge Cut Slough, through the Wallace Weir, and downstream into the Yolo Bypass; however, for future flow actions the target elevation must be set to 27’ to overcome the influence of aquatic weeds on flow. Levels downstream will not exceed 25’. The flow pulse begins when average daily net flow after accounting for tidal effects is positive on consecutive days at Lisbon Weir in the Yolo Bypass (Figure 2-1). Although sustained net positive flow at LIS is the criterion used to define a flow pulse, our operations target a minimum daily average flow > 300 cfs (Table 2-1).

Figure 2-6 Flow magnitude of the 2016 SAC Action at Wilkins Slough (WLK), north of Yolo Bypass, and Lisbon Weir (LIS) in the Yolo Bypass, measured in cubic feet per second (cfs). Broken black lines indicate the magnitude of flow required to trigger a flow pulse (sustained positive, daily average net flow) measured at LIS.

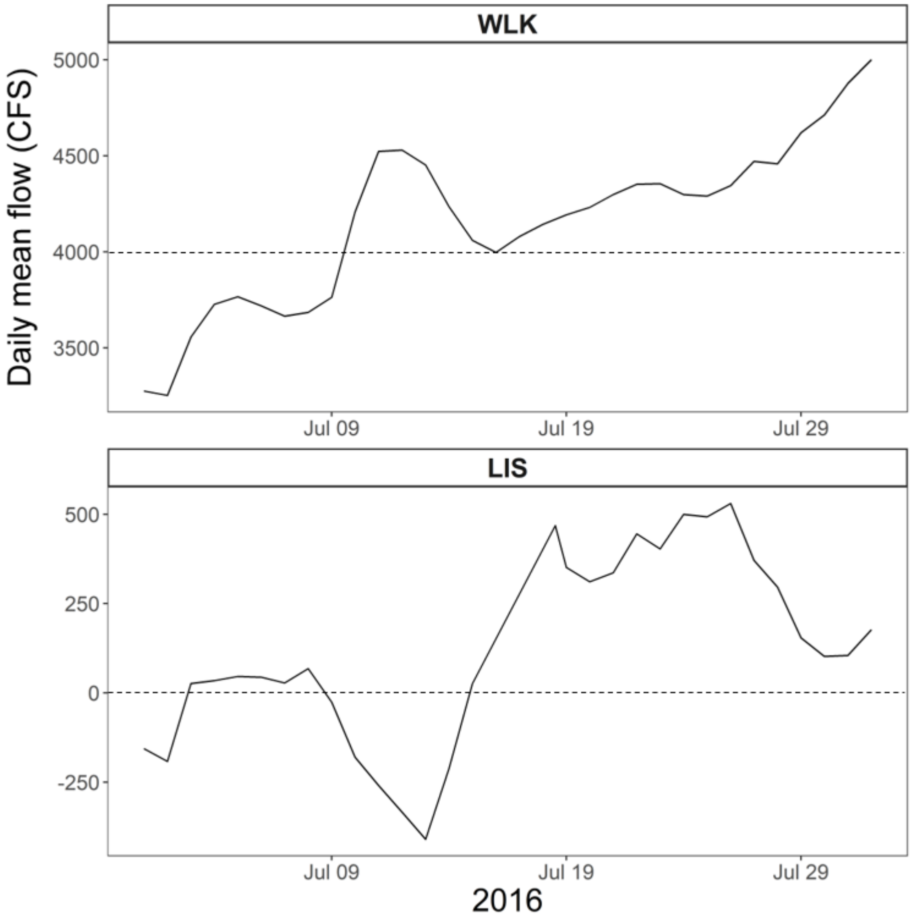


Figure 2-7 Daily mean flow (CFS) measured at Sacramento River below Wilkins Slough (WLK) from 2000-2022. Years are grouped by the Sacramento Valley Water Year Index as Critical (C), Dry (D), Below Normal (BN), Above Normal (AN) and Wet (W). The red line indicates the minimum flow threshold at WLK of 4000 cfs required for a Sacramento River action to be operationally feasible, with ~5000 cfs preferred for upstream reclamation districts.

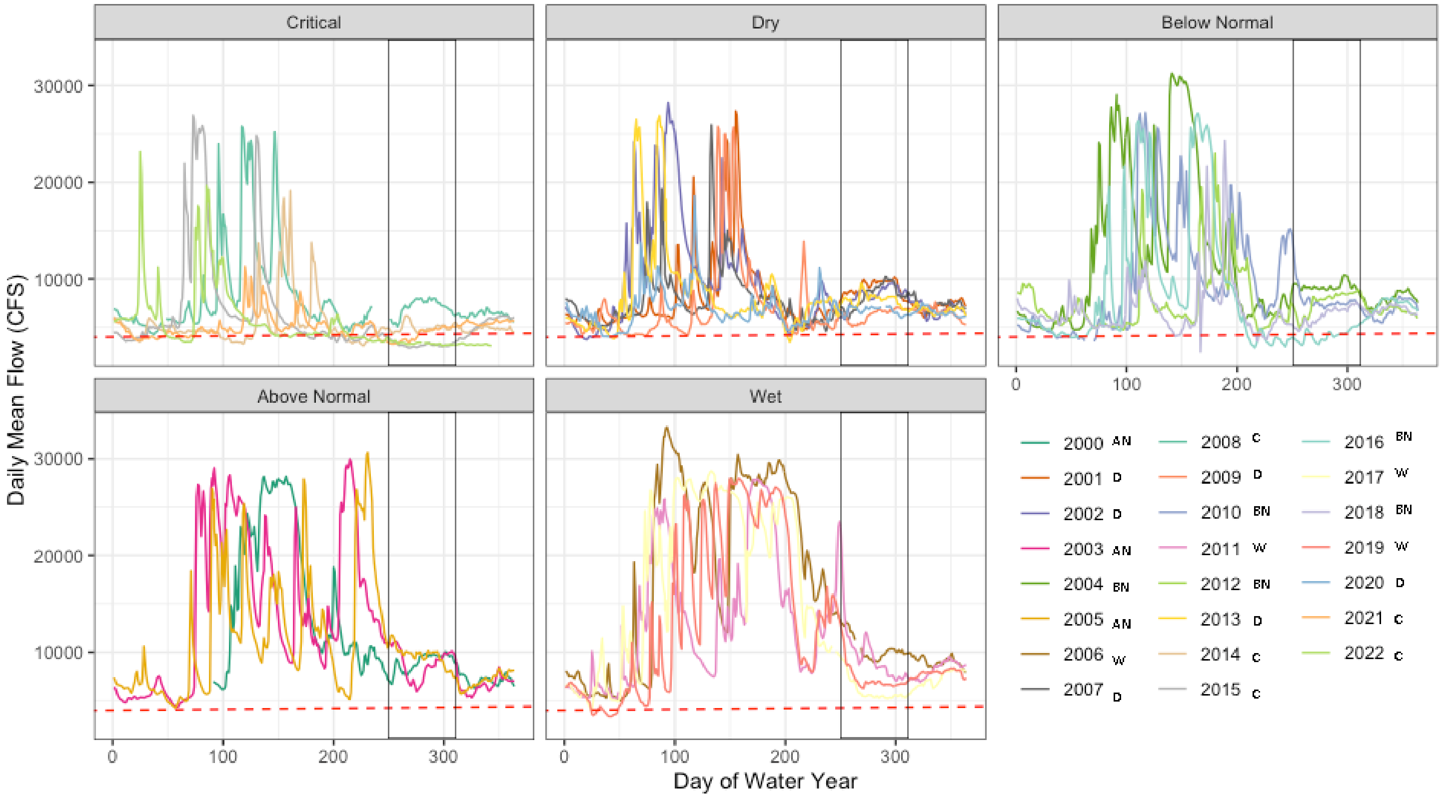


Table 2-4 **An example of diversions and timing of operations for the SAC action (data from the 2016 action). Before the 2016 action, flow at Wilkins Slough was below 4,000 cfs, necessitating additional releases of water from Shasta – Keswick Dam to increase the stage of the Sacramento River north of the Yolo Bypass and allow additional diversions of Sacramento River water into the Yolo Bypass.**

Key structures and diversions (north to south)	Flow (cfs) Daily Average (min-max)	Total volume (AF)	Start date	End date
Shasta - Keswick Dam	10500	—	8-Jul	—
GCID	314 (125-350)	9978	—	—
Baker Creek Supply	38 (15-40)	1190	11-Jul	26-Jul
Willets Supply	75 (33-80)	2387	11-Jul	26-Jul
Stone Corral Supply	74 (17-80)	2355	11-Jul	26-Jul
Lateral 49-2	0	0	—	26-Jul
Salt Creek Supply	0	0	—	26-Jul
Spring Creek Supply	79 (22-89)	2355	12-Jul	26-Jul
Morning Star / Lift #1	61 (30-75)	1690	13-Jul	26-Jul
TCCC Wasteway Supply	140 (50-150)	4166	12-Jul	26-Jul
Davis Weir	480 (52-853)	25746	1-Jul	27-Jul
RD-108/CBD	—	880.5	—	—
Pumped	—	616.7	12-Jul	21-Jul
Gravity	—	263.8	15-Jul	21-Jul
Knights Landing Outfall Gates	—	elevation set to 27' for pulse	12-Jul	28-Jul
Wallace Weir	—	opened for pulse	13-Jul	28-Jul
RD-2035/Conaway	—	4160	—	—

Key structures and diversions (north to south)	Flow (cfs) Daily Average (min-max)	Total volume (AF)	Start date	End date
—	—	Tule canal gates opened for pulse	—	1-Aug
Agriculture Crossing #4	—	opened for pulse	—	—
Total water diverted by GCID, RD-108 and RD-2035	—	*15,018*	—	—
Measured Flow at Lisbon Weir	300-550	12,752	14-Jul	1-Aug

Operations Plan for AG Drainage Flow Action

See Figure 2-2 for an overview of operations.

1. KLOG Elevation Set

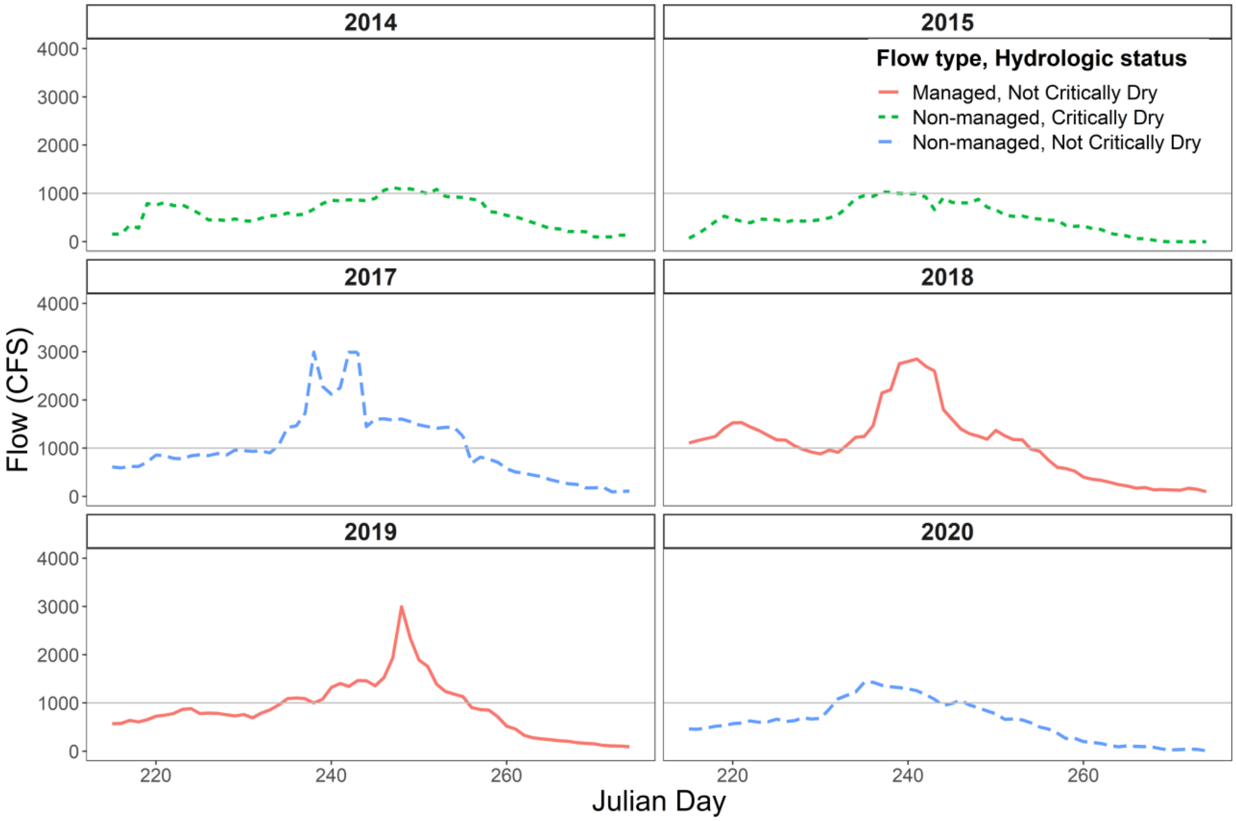
   The elevation at KLOG will be set to 27’ by DWR’s Division of Flood Management one-two weeks prior (mid-August) to the flow action. This will be timed to coincide with increased agricultural return flows in the Colusa Basin Drain as reported by GCID and RD 108 based on the upstream flow gauges at Davis Weir. The trigger for beginning a AG action is 1,000 cfs of flow past Davis Weir (Figure 2-8). This action will also be coordinated with planned water operations at Wallace Weir.

2. Wallace Weir Operations

   Knagg’s Ranch and RD 108 will coordinate with DWR KLOG operators and local landowners to identify potential operational changes at Wallace Weir to create a backwater of agricultural return water above the weir in mid-August for one-two weeks prior to the flow action. In mid-August, RD 108 will notify downstream water users, including Swanston Ranch, the operator of Ag #4, of the proposed operational change. Modifications to Ag #4 culverts will be made to prepare and allow for the increased flow through the Toe Drain. In late-August and early-September, RD

108 will open Wallace Weir to allow a pulse of water to flow into the Yolo Bypass Toe Drain. Wallace Weir will be kept open for the duration of the peak fall Colusa Basin Drain agricultural return period (late August to end of September).

Figure 2-8 Flow (cfs) measured at Davis Weir during the 2014-2020 non-managed and managed agricultural flow pulses. The gray line denotes 1,000 cfs of flow past Davis Weir, which is the requirement for beginning am AG action. Note that flows were sufficient in 2017 to generate a managed flow action but were insufficient during critically dry years (2014-2015). In addition, some years with sufficient flow past Davis Weir may be insufficient to generate positive flow downstream of LIS in the target habitat of Cache Slough Complex. Julian Day represents the day of year from 0 (Jan 1) to 365 (Dec 31). Here, the x-axis is restricted to the period of fall pulses (August to September). Davis Weir flow data courtesy of GCID.

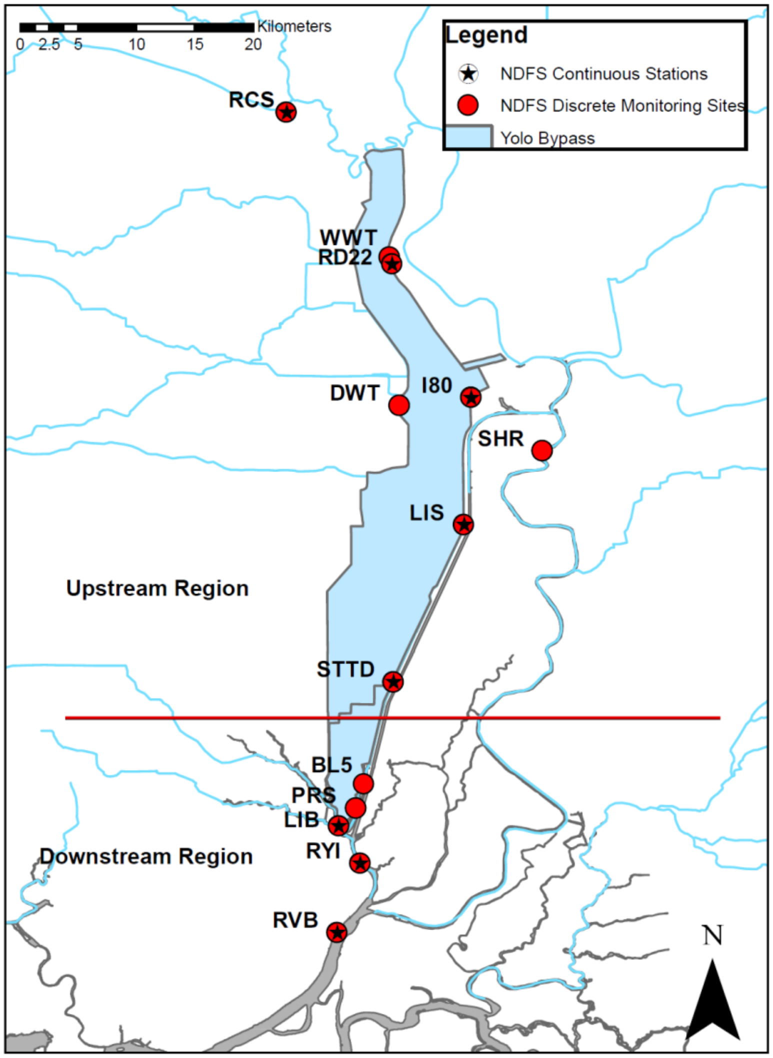


3 Monitoring Plan

Summary

The North Delta Food Subsidies – Colusa Basin Drain Study monitors and evaluates the effects of managed and non-managed flow pulses in the Yolo Bypass on the Delta food web. Managed and non-managed flow pulses, science and monitoring activities, and assessments have occurred almost annually since 2011 in summer and/or fall depending on water year and resources with support from DWR's Aquatic Ecology Unit. The general hypothesis for the NDFS is that augmented flows resulting from summer/fall managed flow pulses increase positive net flow from Yolo Bypass to downstream habitats and food availability for juvenile and sub-adult Delta Smelt in the North Delta compared with non-managed flow pulses. Each year, the study will monitor the lower trophic food web in the Yolo Bypass (upstream region) and downstream regions of CSC and the lower Sacramento River (Figure 3-1), before, during, and after managed or non-managed flow pulses. We will quantify changes in food availability through measurements of chlorophyll, phytoplankton biomass, zooplankton density, and plankton community composition. In addition, we will monitor changes in flow, nutrients, pesticides, and other water quality parameters to identify the mechanisms by which managed flow pulses may affect the lower trophic food web. Below we present a science monitoring plan for 2023-2025, a budget, and summaries of reporting and inter-agency coordination.

Figure 3-1 Map of the North Delta Food Subsidies Study area. Monitoring sites for discrete water quality, habitat, and biological responses to flow pulses are shown with red circles, and sites with continuous water quality monitoring are overlayed with a star. The site Sacramento River at Sherwood Harbor (SHR) is a control site for biological monitoring. Upstream sites for monitoring include RCS, WWT, RD22, DWT, YBI80, LIS. Downstream sites include STTD, BL5, PRS, LIB, RYI, RVB. Abbreviations are as below (see Time Period and Study Area).



Objectives

Our monitoring objectives are to assess abiotic and biotic responses to managed and non-managed flow pulses in different regions of the Delta (Study Objective 1), during and after flow pulses (Study Objective 2), and compare food web responses across different flow pulse types (Study Objective 3) and water year types (Study Objective 4). These objectives aim to evaluate project hypotheses and predictions described below; however, we acknowledge not all hypotheses and predictions may be confirmed or include uncertainties.

Hypotheses

The overarching hypothesis for the North Delta Food Subsidies Study is that summer or fall managed flow actions increase net flow from the Yolo Bypass to the CSC and lower Sacramento River, thereby increasing food availability for juvenile and sub-adult Delta Smelt in the North Delta compared to non-managed flow pulses. However, with the adaptive management changes of the project and development of NDFS alternatives (i.e. implementation options) the DCG has outlined specific hypotheses for evaluation (described in the 2023 SHFA Plan). The different magnitude-duration implementation options test the hypotheses that longer residence time will result in greater productivity. Agricultural versus Sacramento River pulse water tests the hypothesis that agricultural water is higher in contaminants, will negatively impact zooplankton survival and reproduction, or Delta Smelt's growth response.

1. Augmented flow pulses of varied magnitudes and durations result in similar transport and redistribution of water and lower trophic resources in the Yolo Bypass to the Cache Slough Complex.
2. A longer duration, lower flow pulse redistributes phytoplankton from upstream, but results in longer water residence times that support a greater zooplankton response to the newly available primary production than short-duration pulses.
3. Delta smelt will have higher growth and survival with a food subsidy.
4. A Sacramento River flow pulse will result in a greater increase in zooplankton biomass and Delta Smelt growth per unit of flow than an agricultural return water pulse because the latter is higher in contaminants.

5. A managed flow pulse will result in similar effects to species (e.g., salmonids) as non-managed pulses that occur in the bypass.

Research Approach

Our approach to evaluating the hypotheses and effects of flow actions on the food web includes four types of comparisons described below. We will use multiple lines of evidence to evaluate each type of comparison, including qualitative examinations of trends in continuous monitoring data, quantitative analysis of continuous and discrete data, and special studies (See Monitoring and Evaluation, below).

Within-Year Comparisons

1. *Habitat comparisons (Study Objective 1)*: Assess abiotic and biotic responses to the flow pulse across regions of the North Delta including: (north to south) the Colusa Basin Drain/Ridge Cut Slough and the Yolo Bypass (hereafter, upstream region, see Figure 3-1), and Cache Slough Complex and the lower Sacramento River (hereafter, downstream region). These regional comparisons will allow us to evaluate how flow pulses alter water quality and food web productivity at the food source (upstream region) and in downstream Delta Smelt habitats (downstream region). We also compare responses to those in the upper Sacramento River at a control site that is not affected by the flow pulse (SHR in the middle Sacramento River).
2. *Before-During-After (Study Objective 2)*: Assess abiotic and biotic responses by sampling before, during, and after flow pulses. We will also consider the effects of seasonal confounding on food web responses.

Across-Year Comparisons

1. *Comparison of food web responses to different flow pulses and water years (Study Objectives 3 and 4)*: The food web responses to 2023-2025 flow pulses will be compared to previous (2011-2022) and future years with varied water year types (e.g., wet vs. dry) and other habitat conditions, flow pulse types (non-managed vs. high intensity, short-duration or low intensity, long-duration AG or SAC vs. combined SAC/AG) and flow pulse magnitude. Results from these comparisons will help us evaluate the efficacy of different managed flow actions under varied environmental conditions. Relevant habitat conditions for comparison include current and antecedent water year type,

temperature, dissolved oxygen, conductivity, nutrients, antecedent chlorophyll *a* and phytoplankton biomass and composition, and pesticides.

2. *With and without managed flow pulse (Study Objective 3)*: As in previous years, we will use a hydrodynamic model to simulate habitat conditions in the Yolo Bypass, Cache Slough Complex, and lower Sacramento River with and without a managed flow pulse.

Predictions

Based on the Delta Smelt conceptual model (Figure 1-4) and our hypotheses, we developed predictions of abiotic and biotic responses to managed flow actions for the upstream and downstream regions of our study area. In addition, we derived predictions from fundamental knowledge of the Delta ecosystem, scientific literature, and results from previous flow pulses and food web responses (Frantzich et al. 2018, 2019, Twardochleb at al. 2021, Davis et al. 2022). Predictions are described below and in Table 3-1. We provide overarching predictions relevant to our four study objectives as well as predictions for each food web component.

Most of our predictions include the combined effects of season and the flow pulse, as a key challenge of the North Delta Food Subsidies Study has been differentiating food web responses to season versus managed flow actions. In a recent synthesis study, we worked to disentangle the effects of these two drivers on the Delta food web by comparing habitat and food web conditions (Table 3-1) before, during, and after non-managed flow pulses to those measured during previous (2016, 2018, 2019) managed flow actions (Davis et al. 2022). We expect that most habitat and food web conditions downstream of Yolo Bypass will respond to season but not substantially to non-managed flow pulses. If we detect a greater magnitude of change in conditions during and after flow pulses in years with managed flow actions, we could interpret that those larger changes were due to managed flow actions rather than season.

Overarching Predictions

Study Objectives 1 and 2 (Within-Year Comparisons)

Overall, we predict that we will detect food web changes during and after non-managed flow pulses only within the upstream region, whereas we expect food web responses in the downstream region in response to managed flow actions (Table 3-1). We anticipate observing the largest increases in food availability (measured as continuous chlorophyll fluorescence, phytoplankton, and zooplankton biomass) during managed flow pulses at the lower sites of the upstream region (e.g., LIS and STTD) and upper sites of the downstream region (e.g., BL5, PRS, LIB). This result would suggest that disturbance and transport of plankton are the mechanisms responsible for increasing food production, as these sites receive most of the pulse water. By contrast, the lower sites in the downstream region (e.g., RYI, RVB) are much more affected by tidal mixing and less influenced hydrodynamically by flow pulses. Therefore, large increases in plankton production at RYI and RVB would suggest an alternative mechanism for stimulating the food web (Davis et al. 2022). We propose to test the disturbance and transport hypothesis in the future using stable isotope analysis and smelt enclosure studies (see Proposed Special Studies, below).

Study Objective 3 (Across-Year Comparisons)

We hypothesize that low intensity, long duration actions are more efficacious for increasing food availability than short duration, high intensity actions due to longer residence time enabling greater phytoplankton growth and potentially lessened contaminants that are mobilized that could affect zooplankton. We also predict that SAC actions produce greater food web benefits than AG actions, partly because SAC actions have lower pesticide concentrations in the pulse water (Davis et al. 2022).

Study Objective 4 (Across-Year Comparisons)

Actions conducted in dry and below normal water years may have greater benefits for increasing food availability than above normal and wet years when flow may be sufficient through the Yolo Bypass to stimulate food production without a managed flow pulse. However, actions conducted during above and below normal water years may have fewer negative effects on the food web than dry years, when there is the potential for low dissolved oxygen at some upstream sites to be transported downstream (Davis et al. 2022).

Habitat Conditions

In the absence of flow augmentation, typical net flow in the lower Yolo Bypass and upper Cache Slough Complex is very low or negative (i.e., net upstream) due to low inflow and water diversions. Managed flow actions are designed to increase the *average daily net flow* from the Yolo Bypass to the Cache Slough Complex, which subsequently returns to net negative flow (i.e., neutral conditions) after the completion of the managed pulse (e.g., Figure 2-7, 2016, 2018, 2019). Qualitatively similar, but lower magnitude changes in flow are expected during years with non-managed flow pulses resulting from agricultural return flows (e.g., Figure 2-7, 2011 and 2017). As a result, we expect that non-managed flow pulses will cause some changes in habitat conditions, including water quality in the upstream region, whereas managed flow pulses will cause changes in water quality, including temperature, nutrients, and pesticides in the upstream and downstream regions (see synthesis report, Davis et al. 2022).

Table 3-1 Predicted ecosystem responses to managed and non-managed flow pulses in the North Delta region. The upstream region includes the Colusa Basin Drain south to the base of the Yolo Bypass Toe Drain, and the downstream region includes the CSC (Prospect Slough, Liberty Island and Ryer Island), and the lower Sacramento River at Rio Vista. See previous NDFS reports for more details about predictions (Frantzich et al. 2018, 2019, Orlando et al. 2019, Twardochleb et al. 2021, Davis et al. 2022). *Increase or decrease is due to seasonal change.

Abiotic and Biotic Parameter Responses	Non-managed flow pulses		Managed flow pulses	
	Upstream	Downstream	Upstream	Downstream
Habitat Conditions				
Average Daily Net Flow	Increase	Neutral	Increase	Increase
Temperature	Variable*	Variable*	Variable*	Variable*
Turbidity	Decrease	Neutral	Decrease	Decrease
Water clarity	Increase	Neutral	Increase	Increase
Conductivity	Increase	Neutral	Increase	Increase
Average Dissolved Oxygen	Decrease	Neutral	Decrease	Neutral
Average Dissolved Organic Carbon	Increase	Neutral	Increase	Neutral
Average Ammonium Concentration	Increase	Neutral	Increase	Neutral
Average Nitrate Concentration	Increase	Neutral	Increase	Neutral
Average Phosphorous Concentration	Increase	Neutral	Increase	Increase

Abiotic and Biotic Parameter Responses	**Non-managed flow pulses**		**Managed flow pulses**	
	Upstream	**Downstream**	**Upstream**	**Downstream**
Contaminants	Increase	Neutral	Increase	Increase
Lower Trophic Food Web				
Chlorophyll *a*	Increase	Neutral	Increase	Increase
Phytoplankton				
Phytoplankton Biomass	Increase	Neutral	Increase	Increase
Diatom Biomass	Increase	Neutral	Increase	Increase
Zooplankton				
Zooplankton Biomass	Increase	Neutral	Increase	Increase
Cyclopoid copepods	Increase	Neutral	Increase	Increase
Calanoid copepods	Increase	Neutral	Increase	Increase
Cladocerans	Increase	Neutral	Increase	Increase
Fish				
Salmonid catch	Increase*	—	Increase*	—

Lower Trophic Food Web

Managed flow pulses are predicted to influence the lower trophic food web during and after the flow pulse (relative to conditions before the action and to conditions during non-managed flow pulses) in upstream and downstream regions (Frantzich et al. 2018, 2019). Based on previous years of the North Delta Food Subsidies Study, we expect that there will be a decrease in chlorophyll a, phytoplankton, and zooplankton (Figure 1-5) in the upstream region during the flow pulse, followed by an increase in each of those measures after the pulse (Frantzich et al. 2019, Twardochleb et al. 2021, Davis et al. 2022). We expect increases in chlorophyll a, phytoplankton, and zooplankton downstream in the CSC and lower Sacramento River after the flow pulse, with greater increases in years with SAC actions than years with AG actions (Figure 1-3) (Frantzich et al. 2018, 2019, Twardochleb et al. 2021, Davis et al. 2022). We will also monitor changes in blooms of harmful algae such as Microcystis. We expect that Microcystis blooms may be more intense in years with non-managed flow pulses because of lower flow (Lehman et al. 2008, 2020).

Fish Responses

While the primary goal of the NDFS is to improve transport of water and availability of food resources in the downstream region of our study area for Delta Smelt, it is challenging to evaluate the benefits of management actions on this species because it is rarely detected by monitoring surveys, and because there are numerous seasonal and ecological conditions that make it difficult to identify signals from individual actions. In the NDFS, we rely on indirect tools to evaluate management implications of the flow pulse for Delta Smelt: 1) monitoring changes in habitat quality and plankton, and 2) using hatchery Delta Smelt within enclosures to determine impacts on growth, diets, and survival in the study area before and after the management action. Delta Smelt enclosure studies in 2019 at Rio Vista showed 75% and 92.2% survival in August and October (before and after the flow pulse), respectively (Kwan et al. 2020). However, these results do not necessarily indicate that the managed flow pulse benefited Delta Smelt, because its effects were confounded by seasonal changes in temperature and dissolved oxygen (Twardochleb et al. 2021) that would have enhanced survival of Delta Smelt (IEP-MAST 2015). The effects of managed flow actions on growth, diets, survival, and tissue contaminant concentrations of Delta Smelt may be monitored in some years (see Proposed Special Studies, below).

Delta Smelt are not typically abundant in the upstream region of the NDFS study area, although they have historically been caught there (Interagency Ecological Program et al. 2019). Therefore, non-managed flow pulses, where ecological benefits are primarily observed in the upstream region, are not expected to improve habitat quality for Delta Smelt as outlined in the 2016 Resiliency Strategy (CNRA 2016). Overall, we expect improved habitat quality for Delta Smelt in years with managed flow pulses in the upstream and downstream regions.

It is beyond the scope of our study to monitor the effects of flow pulses on the overall fish community and the health and survival of salmonids. However, a recent synthesis study of the effects of managed and non-managed flow pulses on the north delta food web between 2011 and 2019 demonstrated no statistically significant differences among flow pulses periods, flow pulse types, or years on fish assemblages (Davis et al. 2022). Therefore, we do not provide predictions about responses of fish overall or salmonid health or survival to flow pulses.

We rely on data from collaborators to monitor the effects of flow pulses on salmonid catch in the Yolo Bypass. We do not expect that NDFS actions will affect emigrating juvenile Chinook Salmon and/or steelhead (O. mykiss) because they are usually not present in the upper estuary during the study period. Although we also do not expect the study to affect listed winter- or spring-run adult Chinook Salmon, it could affect adult fall-run Chinook Salmon and Steelhead that migrate during this time into the study area. Strong tidal flow of Sacramento River water at the base of Cache Slough likely enhances straying of adult Salmon into the Yolo Bypass corridor, where there is no upstream passage during drier months (Sommer et al. 2013). As evidence of straying, the Yolo Bypass Fish Monitoring Program (YBFMP) has caught adult fall-run Chinook salmon in the fyke trap in September, with the majority of catch in October and November (Sommer et al. 2013). To address straying, CDFW has seasonally operated an upstream fyke trap below Wallace Weir since 2014 to rescue straying fish. In 2018, CDFW observed fall-run Chinook Salmon mortality in the project area during late September; however, it is uncertain if the flow action contributed to increased straying. During the 2019 NDFS managed flow action, CDFW operated the new Fish Rescue Facility at Wallace Weir to monitor and mitigate impacts of flow pulses on straying.

More research is warranted to investigate the effects of managed flow actions on salmon straying. During and after future flow pulses, CDFW will monitor salmon in the Yolo Bypass using the Wallace Weir Fish Rescue Facility (given temperature constraints), and DWR will examine behavior using acoustic tagging of adult fall-run Chinook Salmon collected at the base of Yolo Bypass. This continued monitoring of salmon, combined with water quality monitoring of the North Delta Food Subsidies Study, will help identify whether managed flow actions have greater impacts on fall-run Chinook Salmon through increased straying compared to years without managed flow. In our 2011-2019 synthesis study, we found no evidence of flow pulses effects on salmonid straying into the Yolo Bypass, and concluded straying is influenced by a number of factors (Davis et al. 2022). Therefore, we expect that salmonid catch is higher during and after managed and non-managed flow pulses compared to before flow pulses due to the seasonal timing of migration (Table 3-1). We also predict that managed flow actions result in further upstream migration of tagged fish than periods before or after or years with less flow (e.g., years without managed flow actions, such as 2020) (Johnston et al. 2020).

Study Design

Time Period and Study Area

Monitoring of the North Delta food web will begin between late June and early August, depending on the type and timing of flow pulse (Figure 2-4). In years with non-managed flow pulses, monitoring will begin in July to capture baseline conditions before the start of normal agricultural return flows and continue through early October to capture the full temporal range of the flow pulse’s effects on the food web. In years with SAC actions, monitoring will begin in June or early July and run through September. The timing of monitoring for AG actions will depend on the agricultural planting schedule and summer weather (Figure 2-4). During years with early planting and hot weather, monitoring will likely begin in July and extend through September, whereas in late/cool years, we will likely monitor the food web between August and October.

The study area spans 2 regions (Table 3-2). We will monitor and sample abiotic and biotic components of the Delta food web at 12 sites (Table 3-3). We provide an accounting of the specific parameters, where they are monitored, and by whom (e.g., DWR or collaborators, such as USGS, SFSU, USFWS, AnchorQEA) in Table 3-3. Sites span from north to south across the study region and include the following, Upstream region sites: 1) Ridge Cut Slough at Highway 113 (RCS), 2) Woodland Wastewater Treatment Discharge (WWT), 3) Toe Drain at Road 22 (RD22), 4) Davis Wastewater Treatment Discharge (DWT), 5) Toe Drain at I80 (YBI80), 6) Toe Drain below Lisbon Weir (LIS), 7) Screw Trap at Toe Drain (STTD); Downstream region sites: 8) Below Toe Drain in Prospect Slough (BL5), 9) Prospect Slough (PRS), 10) Base of Liberty Island (LIB), 11) Cache Slough at Ryer Island (RYI), 12) Sacramento River at Rio Vista Bridge (RVB). One additional site will be added in the Cache Slough Complex, likely south of BL5 in Prospect Slough.

Table 3-2 Sampling sites for the North Delta Food Subsidies Study grouped by region and subregions. We provide site codes, site access (land or boat), and geocoordinates (WGS84) for each site. Depending on sampling conditions (e.g., dry conditions, aquatic vegetation), sites may be adjusted.

Region	Subregion	Site Name	Site Code	Site Access	Latitude	Longitude
Upstream	Colusa Drain/Ridge Cut	Ridge Cut Slough at Hwy. 113	RCS	Land	38.793457	-121.725447
Upstream	Upper Yolo Bypass	Woodland Wastewater Discharge at Toe Drain	WWT	Land	38.681621	-121.645775
Upstream	Upper Yolo Bypass	Toe Drain at Rd. 22	RD22	Land	38.676367	-121.643972
Upstream	Upper Yolo Bypass	Davis Wastewater Discharge at Toe Drain	DWT	Land	38.567057	-121.638239
Upstream	Upper Yolo Bypass	Toe Drain at I80	I80	Land	38.573111	-121.582958
Upstream	Lower Yolo Bypass	Toe Drain below Lisbon Weir	LIS	Land	38.474816	-121.588584
Upstream	Lower Yolo Bypass	Screw Trap at Toe Drain	STTD	Boat	38.353461	-121.642975
Downstream	Cache Slough Complex	Below Toe Drain in Prospect Slough	BL5	Boat	38.274460	-121.665652
Downstream	Cache Slough Complex	Prospect Slough	PRS	Boat	38.255839	-121.671797
Downstream	Cache Slough Complex	Base of Liberty Island	LIB	Boat	38.242100	-121.684900
Downstream	Cache Slough Complex	Cache Slough at Ryer Island	RYI	Boat	38.213167	-121.668591
Downstream	Lower Sacramento River	Sacramento River at Rio Vista Bridge	RVB	Boat	38.159737	-121.686355

Table 3-3 Abiotic and biotic parameters that may be monitored for responses to flow pulses, dependent on actions and resources. We describe the sampling locations, time-period, and data source and/or agency. The Yolo Bypass Fish Monitoring Program (YBFMP), Environmental Monitoring Program (EMP), Yolo Bypass Habitat Restoration Program, and Bryte Lab are groups at DWR. CBEC Eco Engineering (CBEC), Anchor QEA LLC. and BSA Environmental Services, Inc. (BSA) are contractors/consultants that DWR has previously contracted with (and may again in the future). U.S. Geological Survey (USGS) is a collaborator providing long-term multiparameter continuous water quality data and pesticide analysis. See Table 3-2 for abbreviations and descriptions of sampling locations.

Abiotic or Biotic Parameter	Data Source	Sampling Locations	Time Period
Habitat Conditions			
Average Daily Net Flow	Continuous sensors – this study, USGS, AnchorQEA	RCS, Yolo Bypass near Woodland (near RD22), LIS, LIB, RYI, RVB	July - Oct
Temperature, Turbidity, Average Dissolved Oxygen, Conductivity, Chlorophyll	Continuous – this study, EMP, USGS Discrete – this study, EMP	Continuous: RCS, RD22, YBI80, LIS, STTD, BL5, LIB, RYI, RVB Discrete: RCS, WWT, RD22, DWT, YBI80, LIS, STTD, BL5, PRS, LIB, RYI, RVB	Continuous: June -Nov Discrete: July - Oct
Water Clarity	Discrete – this study	RCS, WWT, RD22, DWT, YBI80, LIS, STTD, BL5, PRS, LIB, RYI, RVB	July - Oct
Average Dissolved Organic Carbon, Average Ammonium Concentration, Average Nitrate Concentration, Average Phosphorus Concentration, fluorescent dissolved organic matter (fDOM)	Continuous – this study and USGS Discrete – this study with DWR Bryte lab and SFSU Wilkerson/Dugdale Lab	Continuous: RCS, RD22, YBI80, LIS, STTD, BL5, LIB, RYI, RVB Discrete: RCS, WWT, RD22, DWT, YBI80, LIS, STTD, BL5, PRS, LIB, RYI, RVB	Continuous and Discrete: July - Oct
Pesticides in water and zooplankton	Discrete – this study with USGS Pesticide Fate Lab	RCS, RD22, STTD, BL5, LIB, RYI	July - Oct

Abiotic or Biotic Parameter	Data Source	Sampling Locations	Time Period
Lower Trophic Food Web Responses			
Phytoplankton Biovolume, Community Composition	This study, YBFMP with BSA	RCS, RD22, YBI80, LIS, STTD, BL5, PRS, LIB, RYI, RVB	July - Oct
Productivity & Nutrient Uptake Rates	This study in collaboration with SFSU	RCS, RD22, YBI80, LIS, STTD, BL 5, PRS, LIB, RYI, RVB	July - Oct
Zooplankton Catch Per Unit Effort (CPUE), Community Composition	This study, YBFMP with BSA	RCS, RD22, YBI80, LIS, STTD, BL5, PRS, LIB, RYI, RVB	July - Oct
Fish Responses			
Salmonid catch	This study, Yolo Bypass Habitat Restoration Section, CDFW	Wallace Weir, Yolo Bypass (Figure 10)	Sept - Dec

Monitoring and Evaluation

Hydrology

In non-managed flow years, we expect to observe a small flow pulse from agricultural return flows with daily averaged net flows from 200 to 400 cfs between late August and September (e.g., 2011, 2013, 2014, Figure 2-6, Table 1-1). In years with managed flow, we expect flow pulses of similar magnitude and duration to previous flow actions (e.g., 2016, 2018, 2019, Figure 2-6, Table 1-1). We will monitor flow at 6 sites within our study area (Figure 3-1, Table 3-3). Sites within the upstream region include: 1) Ridge Cut Slough at Knights Landing (RCS) and 2) Yolo Bypass at Lisbon (LIS) (maintained and calibrated by the DWR North Central Region Office Flow Monitoring); and 3) Yolo Bypass near Woodland (near RD22) (acquired from USGS). The flow monitoring stations within the downstream region include: 4) Liberty Island at approximately center South End (LIB), 5) Cache Slough at Ryer Island (RYI) maintained and calibrated by DWR; and 6) Sacramento River at Rio Vista Bridge (RVB) that is operated and calibrated by USGS.

Habitat Conditions

Continuous Water Quality

We will collect continuous water quality data with a YSI EXO2 internal data logging sonde at each continuous water quality station (Table 3-3). Sondes will record water temperature, dissolved oxygen (DO), pH, specific conductance, turbidity, total chlorophyll fluorescence, and fluorescent dissolved organic matter as a proxy for dissolved organic carbon (except the EMP station) at 15-minute intervals. These parameters help to characterize the physical chemistry of the water flowing through the Toe Drain of the Yolo Bypass. We will replace sondes every three to four weeks with new, pre-calibrated sondes. During each of these visits, we will also sample water quality using handheld instruments (YSI ProDSS or EXO2 sonde) to compare with measurements recorded by the YSI EXO2 sondes. We will check the calibration accuracy of each retrieved sonde using YSI calibration methods and data quality assessment procedures adopted from USGS (Wagner et al. 2006). Data will undergo further QA/QC by Water Quality Evaluations Staff (DWR North Central Region Office) and be uploaded to a HYDSTRA data management system.

To gain high resolution data on how chlorophyll concentrations vary in the Yolo Bypass spatially and temporally, and with respect to other measures of water quality, we will place one continuous water quality station at RCS above KLOG to monitor the source water, and four additional stations within the Toe Drain of the Yolo Bypass (Figure 3-1, Table 3-3). The four Toe Drain sites will be located (progressing southward) at RD22, I80, LIS, and STTD. The STTD site is approximately three miles north of the terminus of the Toe Drain and will provide water quality data within the tidally influenced section of the Toe Drain below LIS. In addition, we will collect continuous water quality data from USGS stations in the downstream region including LIB and RYI. RVB continuous water quality will be collected by DWR Environmental Monitoring Program. Starting in 2023, the RD22 continuous water quality station will be telemetered in the spring of each year to evaluate dissolved oxygen levels in the upper bypass. This real-time station data will be used in planning and decision making for potential negative flow pulse effects to salmonids.

Discrete Water Quality, Nutrients, and Chlorophyll a

We will measure discrete water quality parameters every two weeks before, during, and after the flow pulse at each site (Figure 3-1, Table 3-3). Water quality parameters include temperature, DO, conductivity, pH, and turbidity, measured using a handheld YSI (ProDSS). We will also measure Secchi depth to gauge water clarity. Concurrent with YSI measurements, we will collect water samples for nutrients, including the analytes listed in Table 3-4, and chlorophyll. We will use a Nasco 12' Extendible Swing Sampler to collect water samples at land sites and a Van Dorn sampler at boat sites (Table 3-2) at a depth of 1 meter. All parameters will be measured every two weeks at the 7 sites in the upstream region and 5 sites from the downstream region (Figure 3-1, Table 3-2 and Table 3-3), except that we will not sample chlorophyll, dissolved organic carbon or total organic carbon at WWT and DWT (Table 3-3).

For each batch of nutrient samples, we will analyze multiple blank samples with variable primary targets as a control to account for the effects of field collection and lab procedures on nutrient concentrations. Similarly, we will analyze two replicate samples for chlorophyll-a from each sample taken in the field. Sample collection, storage, and analysis procedures will follow those of IEP Bay-Delta Monitoring and Analysis Section and Standard Methods for the Examination of Water and Waste Water (APHA, 2005; DWR, 2011). Concentrations of chlorophyll-a/phaeophytin-a will be determined through the Standard Method 10200 H Spectrophotometric Determination of Chlorophyll (APHA, 2005). The DWR Bryte laboratory will be responsible for nutrient and chlorophyll sample analysis as described in Table 3-4.

In addition to submitting water samples to Bryte laboratory for the constituents listed in Table 3-4, we will submit water samples and blanks to the Wilkerson-Dugdale Lab at SFSU for analysis of ammonium, nitrate/nitrite, and dissolved orthophosphate where they will be analyzed following methods of Bran Luebbe, Inc. (1999) for nitrate/nitrite and dissolved orthophosphate and Solorzano (1969) and Liddicoat et al. (1975) for ammonium. Due to low ammonium concentrations in the Yolo Bypass during the summer/fall, >60% of ammonium samples submitted to Bryte Lab have concentrations below the reporting limit. The Wilkerson-Dugdale Lab has a method detection limit of 0.002 mg/L for ammonium, which is substantially lower than the reporting limit of 0.05 mg/L from Bryte Lab.

Contrary to previous data, in 2021 and 2022, low concentrations of key nutrients including ammonia and nitrate/nitrite at upstream monitoring locations was observed. It remains unclear why nutrient regimes in the upper Yolo Bypass have shifted. In 2023, additional effort will be spent investigating changes in upstream nutrients, influences of agricultural inputs (or lack of, during drought years) and assessments of both Bryte Lab and Wilkerson-Dugdale Lab analyses.

Table 3-4 Water sample constituents to be quantified in the DWR Bryte laboratory and associated methods.

Constituent/Inorganic Analyte	Method
Dissolved Ammonia	EPA 350.1 (1993 Rev 2.0)
Dissolved Calcium	EPA 200.7 (1994 Rev 4.4)
Dissolved Chloride	EPA 300.0 (1993 Rev 2.1)
Dissolved Nitrate + Nitrite	STD METHOD 4500-NO3-F-2011
Dissolved Organic Carbon	EPA 415.3 Rev 1.2
Dissolved Organic Nitrogen	EPA 351.2 (1993 Rev 2.0)
Dissolved Ortho Phosphate	EPA 361.1 (1993 Rev. 2.0)
Dissolved Silica	EPA 200.7 (1994 Rev 4.4)
Dissolved Total Kjeldahl	EPA 351.2 (1993 Rev 2.0)
Total Dissolved Solids	STD METHOD 2540 C-2011
Total Kjeldahl Nitrogen	EPA 351.2 (1993 Rev 2.0)
Total Organic Carbon	STD METHOD 5310C-2011
Total Phosphorus	EPA 365.4 (1974)
Total Suspended Solids	STD METHOD 2540D-2011
Volatile Suspended Solids	STD METHOD 2540E-2011

Pesticides

We will determine the concentrations of a suite of 178 current-use pesticides in water and zooplankton (Appendix 1. Table of Current-Use Pesticides), by collecting water samples and zooplankton samples at 6 sites within our upstream and downstream regions: 1) RCS, 2) RD22, 3) STTD, 4) BL5, 5) LIB, 6) RYI, and at the control site, SHR, on the middle Sacramento River (Table 3-3). Pesticide sample collection procedures will follow standard methods of the USGS Organic Chemistry Research Laboratory's Quality Assurance Program Plan. We will collect duplicate, near surface water samples in 1-liter, amber glass bottles by submerging the bottle completely and closing the lid under water. Additional samples will be collected for quality assurance and will include a minimum of one each of the following: a trip blank, field replicate, field matrix spike, and field matrix spike replicate. We will collect zooplankton samples using 5-minute surface tows as described below (see *Zooplankton*), except that samples will be placed on ice until they are delivered to the USGS laboratory in Sacramento, CA within 24 hours of collection. All samples will then be processed and analyzed following published methods (Hladik et al. 2008, 2009, Hladik and McWayne 2012, and Hladik and Calhoun 2012).

Lower Trophic Food Web

Phytoplankton

To determine phytoplankton species composition and biomass, we will collect samples at ten sites (Figure 3-1, Table 3-2, and Table 3-3) using a subsample of homogenized water collected for nutrient sampling. All samples will be stored in 50 mL amber glass bottles and preserved using Lugol’s solution. When collecting phytoplankton samples, we will qualitatively evaluate Microcystis index using a visual rank system. The Microcystis Index consists of a range from 0-4, with 0 representing no detection and 4 describing thick algal mats.

Phytoplankton samples will be analyzed under a contract with the DWR Yolo Bypass Fish Monitoring Program and phytoplankton biovolume will be estimated for each sample. Phytoplankton will be identified to at least the genus level using the Utermöhl method (Utermöhl 1958) and at least four hundred total algal units will be counted in each sample, including one hundred units of the dominant taxa. Length (μm) will be recorded for the first 25 units of major phytoplankton taxa and the first 5 units of minor taxa to calculate biovolume (μm3/mL), a surrogate for biomass, from formulas given for different algal shapes by Kellar et al. (1980).

In addition to baseline monitoring of phytoplankton densities and composition, we will use two experiments to determine the health of the phytoplankton ‘seed’ in the Yolo Bypass and downstream. These studies include 1) primary productivity and nutrient uptake rates, and 2) bioassays outlined below, that will be conducted by SFSU Estuarine and Ocean Science Center (EOS) researchers between July and October, before, during, and after the flow pulse through 2022.

1) Primary productivity and nutrient uptake rates (contingent on action and resources): We will use a series of incubations to calculate primary productivity and nutrient uptake rates by phytoplankton in surface water samples collected on six occasions between July and October at 10 sites (Figure 3-1, Table 3-3). We will collect near-surface water in 1L containers and hold them in coolers filled with ambient water. Incubations will be conducted outdoors, at EOS, under natural solar irradiance. A submersible water heater will be used to maintain incubations at ambient Delta water temperatures (i.e., temperatures measured at collection sites). For each site (i.e., water sample), 24 h duplicate isotope tracer primary production incubations will be carried out in 160-ml bottles with additions of 13C-bicarbonate to obtain rates of primary production (mg C m^{-3} d^{-1}) by the phytoplankton community (Wilkerson et al. 2015). We will then calculate assimilation number (chlorophyll-specific rates of primary productivity, mg C (mg chl-*a*)$^{-1}$ d^{-1}, using estimates of biomass (e.g., chl-*a*) provided by DWR. We will also calculate dissolved inorganic carbon (DIC) concentrations from water sampled for productivity measurements as DIC is needed for calculating primary production rates. DIC will be measured in 20-ml samples using a Monterey Bay Research Institute-clone DIC analyzer with acid-sparging and non-dispersive infrared analysis (Friederich et al. 2002; Parker et al. 2006) following preservation with 200 µL of 5% w/v HgCl2.

We will run these primary productivity incubations in duplicate, adding either $15NO_3$ or $15NH_4$ to the 13C-bicarbonate incubations to determine what form of nitrogen (nitrate or ammonium) phytoplankton uptake during growth. We will also measure concentrations of particulate carbon and particulate nitrogen in the incubated water samples with mass spectrometry. Water samples will be incubated at 50% of surface solar irradiance by screening the bottles in bags of window screening. After 24 h, samples are filtered onto pre-combusted GF/F filters, and frozen until they are analyzed with a PDZ Europa TracerMass mass spectrometer. Nutrient uptake and primary productivity rates will then be calculated according to Dugdale and Wilkerson (1986) and Legendre and Gosselin (1996).

2*) Bioassays (contingent on action and resources):* We will use a series of bioassays to determine if the water quality of the Colusa Basin source water negatively impacts phytoplankton productivity. The bioassays will examine if the source water has a low phytoplankton ‘seed’ or “unhealthy” phytoplankton, limited by nutrients. We will conduct bioassays using water samples from a site north of Lisbon Weir (to be determined, likely RCS, STTD, and LIB. We will fill two 10-L polycarbonate cubitainers with surface water at each site. Enclosures will be returned to EOS and held in large tanks filled with SF Bay water for 5 days under 50% screening at in-situ temperatures. Researchers will sample water in the enclosures each morning for chlorophyll, nutrients (nitrate, ammonium), and DIC, and for primary productivity and nutrient uptake rates using 4 -hour incubations with ^{13}C-bicarbonate and ^{15}N-nitrate or ^{15}N-ammonium. Uptake methods and analyses are described above. Ammonium will be measured spectrophotometrically following Solorzano (1969), and nitrate will be measured using an AutoAnalyzer according to Bran Luebbe (1999). Chlorophyll will be measured using in vitro extraction with 90% acetone according to Arar and Collins (1992). These measures indicate the “health” and growth potential of the phytoplankton with optimal light (50% screening), no grazing, and no flow effects.

Zooplankton

To determine the species composition and densities of zooplankton, we will collect zooplankton samples every two weeks during the monitoring period at our discrete monitoring sites (Figure 3-1, Table 3-3). We will sample zooplankton using 5-minute surface tows moving upstream with a 150 µm mesh zooplankton net, with 0.5 m diameter mouth opening, attached to a 150 µm mesh cod end (Sea-Gear Corporation, Melbourne, FL, USA). The zooplankton net will be affixed with a flow meter fitted with a low flow rotor (General Oceanics, Miami, FL, USA). Zooplankton tows will be collected either from a boat (boat sites) or kayak (land sites). We will fix zooplankton samples in 10% formalin with rose Bengal, and after a minimum of 2 weeks in fixative, transfer samples to 8% Lugol’s solution.

Samples will be processed by a contractor. Zooplankton samples will be sub-sampled, and a minimum of 200 individuals counted per sample for mesozooplankton and then identified to at least the order level, dependent on the taxon and life stage. Zooplankton count will be calculated as follows: subsample count/[(subsample volume*number of subsamples)/total sample volume]. We will then convert zooplankton counts to catch per unit effort (CPUE), a measure of density (Equation 3-1), by dividing zooplankton counts by the volume of water sampled (m^3). Volume will be determined by multiplying the net mouth area by the tow distance, where d is the net diameter and x = 57560 is the low flow rotor meter constant.

Equation 3-1 Calculation of catch per unit effort (CPUE) for zooplankton. Zooplankton count is divided by the volume of water sampled (m^3), which is calculated by multiplying the net mouth area by the distance, where d = diameter of the net and x=57560 is the low flow rotor constant.

$$CPUE = zooplankton\ count / \left(\left(\frac{3.14 * (d)^2}{4} \right) * \left(\frac{(EndMeter - StartMeter) * x}{999999} \right) \right)$$

Fish Responses

Flow pulses may improve habitat conditions for Delta Smelt by increasing habitat connectivity and productivity in the CSC and lower Sacramento River. We will monitor if any fish surveys such as the FWS Enhance Delta Smelt Monitoring program detect Delta Smelt in the study area or potentially use a surrogate species such as the non-native congener Wakasagi. Prior to experimental releases of cultured Delta Smelt beginning in 2021, no smelt had been detected in the study area for some years. However, in the summer-fall season of 2022, six Delta Smelt were detected in the lower Sacramento River, Sacramento Deepwater Shipping Channel and Suisun, demonstrating presence.

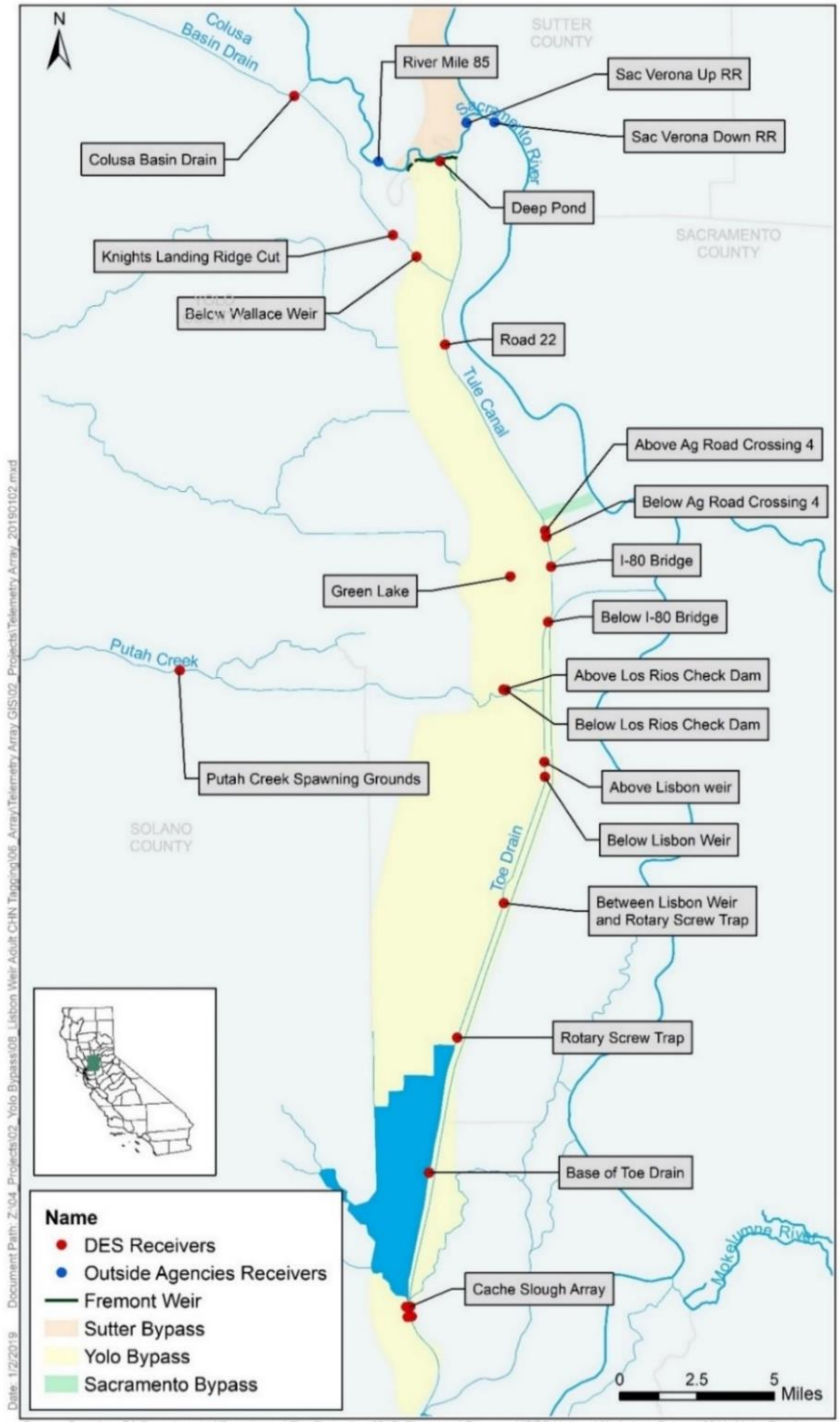
Salmonid Catch

We will monitor the effects of the flow pulse on salmonid straying in collaboration with CDFW Wallace Weir salmonid salvage and DWR Yolo Bypass Fish Monitoring Program fyke trap salmonid catch data, and DWR Yolo Bypass Habitat Restoration Program, Adult Fall-Run Chinook Salmon Telemetry Study. At the Wallace Weir, CDFW regularly conducts fish salvage from September through June using the newly constructed Wallace Weir Fish Rescue Facility. CDFW uses attraction flows to corral the fish into the structure, dip net the fish into a portable holding tank, and release them back into the Sacramento River. CDFW or DWR staff will be on site daily to monitor for water quality parameters and salmonid presence at the Wallace Weir.

The Yolo Bypass Fish Monitoring Program operates a fyke trap in the Toe Drain just downstream of Lisbon Weir (Sommer et al. 2013; IEP 2018). The 10’ diameter fyke trap is designed to examine species composition and the timing and duration of large-bodied fish migrations through the Yolo Bypass relative to different physical conditions. The focus has been on anadromous fish species (i.e., adult Chinook Salmon and sturgeon); however useful data is also collected on other fishes. The objectives are to (1) examine adult species composition; (2) identify general timing and duration of anadromous species use relative to different physical conditions; and (3) to compare timing and duration of species captured in the Yolo Bypass to those captured in other Sacramento Valley tributaries. The trap is generally checked on weekdays from October – June of each water year. This roughly equates to 96 hours of trap fishing each week. Any adult Chinook Salmon or Steelhead caught in the trap are measured, caudal fin clipped for genetic sampling, and floy tagged on both sides of the dorsal fin. In addition to the fyke trap providing data on salmonids straying into the Yolo Bypass, adult fall-run Chinook salmon caught in the fyke trap will also be acoustically tagged if temperatures do not exceed 21 degrees Celsius prior to release, as part of the telemetry study (see below).

The Habitat Restoration Program conducts the Yolo Bypass Adult Fall-Run Chinook Salmon Telemetry Study to meet monitoring requirements for restoration projects that are being implemented to achieve compliance with the NMFS 2019 BiOp. This acoustic telemetry study informs fish passage operations and adaptive management for Yolo Bypass fish passage projects, including the completed Wallace Weir Fish Rescue Facility and Fremont Weir Adult Fish Passage Project. The data are used to continue developing a conceptual model on fish movement in the Yolo Bypass to inform DWR and USBR management strategies such as the North Delta Food Subsidies Study. The use of surrogate species is necessary due to the scarcity and special status of the Federally listed species that were identified in the Reasonable and Prudent Alternative Actions specific to the Yolo Bypass in the NMFS 2019 BiOp. The Central Valley fall-run Chinook Salmon evolutionarily significant unit (ESU) will serve as a surrogate to Sacramento River winter-run Chinook Salmon ESU, Central Valley spring-run Chinook Salmon ESU, and Central Valley steelhead DPS. Fall-run Chinook salmon capture, procedures, and release will be covered under this specific-use scientific collecting permit (see Sample Collection and Permitting below). Capture methods will include the use of gill nets and DWR’s Yolo Bypass Fish Monitoring Program’s fyke trap (see above and Sommer et al. 2013). Procedures that will be performed on adult fall-run Chinook Salmon include taking measurements, taking a fin clip for genetic sampling, inserting a floy tag, and surgically affixing coded ultrasonic beacon tags (V9, 69 kHz, Vemco Ltd) below the dorsal fin. Acoustically tagged salmon will then be released back into the Toe Drain where their movements can be tracked using the 21 acoustic telemetry receivers that are deployed throughout the Yolo Bypass and nearby tributaries (Figure 3-2). The detection data collected from this study will provide the necessary information to evaluate impacts of managed flow pulses, as well as adaptively manage Yolo Bypass adult fish passage projects, and to appropriately design future restoration projects in the Yolo Bypass.

Figure 3-2 Map of Yolo Bypass Acoustic telemetry array study area for Chinook Salmon. Provided by the Yolo Bypass Habitat Restoration Section, DWR.



Source: Counties, CA Department of Forestry and Fire Protection 2015; Rivers and Streams, USGS National Hydrology Dataset 2011; Major Roads, CA Department of Transportation 2011; Sutter Bypass, Yolo Bypass, and Sacramento Bypass, DWR 2014; Remaining Project Features, DWR 2018

Proposed Special Studies

Recent analyses have highlighted key knowledge gaps about the efficacy and mechanisms by which the NDFS action influences the North Delta food web. For example, a power analysis conducted by USBR to examine our ability to detect changes in zooplankton density during and after flow actions found that we have low statistical power to observe responses in zooplankton using our current monitoring design. In fact, power is low enough that we would likely need to conduct ten managed flow actions to detect an effect on zooplankton when comparing monitoring data across years (Brandon et al. in prep). It is critical that we find other means to evaluate responses of zooplankton to flow actions, because zooplankton biomass is a primary measure of action efficacy that is considered by the DCG annually when evaluating actions using SDM. Our inability to detect changes in zooplankton biomass could suggest that the NDFS action has no effect on zooplankton when biomass increases following flow actions. In addition, we may be under-sampling Calanoid Copepods such as *Pseudodiaptomus forbesi*, a key prey species for Delta Smelt, due to conducting zooplankton surface tows during the day, which likely under-samples adult copepods (Yelton et al. 2022).

Other knowledge gaps for this study that have been identified by the DCG SMT include indirectly testing the effects of flow actions on Delta Smelt, due to low smelt abundances in the study region, and not testing the effects of contaminant concentrations on Delta Smelt behavior, growth, and survival. Moreover, we acknowledge that we have very little information about the mechanisms by which the NDFS action increased productivity during previous years (e.g., 2016 Sacramento River action), which makes it difficult to adaptively manage the action to increase its efficacy. Below we outline two special studies that could fill these knowledge gaps that are difficult to address with our current monitoring design. We (DWR and USBR) developed proposals for these studies in collaboration with USGS, CDFW, and Metropolitan Water District during 2022 and presented them to the DCG Science and Monitoring Workgroup for feedback and refinement.

Smelt Enclosure Study

We propose to use smelt enclosure experiments with hatchery reared Delta Smelt to assess effects of managed and non-managed flow pulses on Delta Smelt growth, diets, and contaminant concentrations in the Cache Slough Complex, using the Sacramento Deep Water Ship Channel as a reference location not under influence of flow pulses. While we propose conducting experiments over three years, during a non-managed flow (reference) year, a Sacramento River flow action, and an agricultural flow action; we realize we may only have the opportunity for a single year enclosure study which we would plan for a Sacramento River action. Enclosures would be deployed for four to six weeks in the "during" and "after" flow pulse periods. To assess effects of flow pulses on smelt diets we would sample the zooplankton communities inside and outside of enclosures, smelt stomach contents, and smelt muscle tissue samples for stable isotope analysis (see *Stable Isotope Analysis Study*, below). We would also sample smelt tissues for pesticide concentrations and measure and weigh Delta Smelt during and after flow pulses to assess growth rates. This study would address several knowledge gaps by directly assessing effects of flow pulses, including potential negative effects of contaminant concentrations in the flow pulse water, on Delta Smelt diets, growth, and survival.

Stable Isotope Analysis Study

Inclusion of stable isotope analysis with the smelt enclosure study could ameliorate some limitations of our zooplankton monitoring, especially low statistical power to detect changes in zooplankton biomass and under-sampling adult Calanoid Copepods, by enabling an assessment of resource use by Delta Smelt integrated over the full period of the flow pulse. The goal of this study would be to identify whether prey resources from the Yolo Bypass are consumed by Delta Smelt during and after flow pulses, rather than relying on snapshots of prey availability from our discrete monitoring to indirectly assess flow pulse benefits to Delta Smelt.

We propose to assess resource use by zooplankton and Delta Smelt during and after flow pulses by sampling smelt tissue from hatchery Delta Smelt in enclosures in the Cache Slough Complex, and zooplankton and primary producers at the base of the food web in the Yolo Bypass and Cache Slough Complex, before, during, and after flow pulses (see Bell-Tilcock et al. 2021 for a similar diet study using stable isotopes and salmon in enclosures). We would sample all primary producers that could contribute directly to zooplankton diets, and indirectly to smelt diets: terrestrial detritus, and aquatic littoral and pelagic primary producers, including particulate organic matter as a proxy for phytoplankton, submerged and emergent aquatic vegetation, and benthic algae. We would then assess carbon, nitrogen, and sulfur stable isotope signatures of Delta Smelt, zooplankton, and primary producers. Then, using Bayesian isotope mixing models, we would identify which primary producers from the Yolo Bypass and Cache Slough Complex contributed to zooplankton and smelt diets (e.g., Young et al. 2021) during and after flow pulses. This study could help us assess whether flow pulses transport primary producers and zooplankton from the Yolo Bypass into Cache Slough Complex and whether those zooplankton are then consumed by Delta Smelt. For example, isotopic signatures of zooplankton and Delta Smelt in CSC should more closely resemble those of Yolo Bypass primary producers and zooplankton if transport is the primary mechanism for increasing smelt food availability in the CSC.

Data Analysis

Hydrodynamic Modeling

Anchor QEA will perform hydrodynamic modeling using the three-dimensional UnTRIM Bay-Delta model (MacWilliams et al. 2015, Anchor QEA 2020) to evaluate hydrodynamics of managed and non-managed flow pulses. The UnTRIM model predicts water flow and transport throughout the Bay-Delta and has been validated using time series of flow, stage, and specific conductance in the Yolo Bypass and CSC (MacWilliams et al. 2015). The UnTRIM Bay-Delta model takes advantage of the grid flexibility allowed in an unstructured mesh by gradually varying grid cell sizes, beginning with large grid cells in the Pacific Ocean and gradually transitioning to finer grid resolution in the smaller channels of the Sacramento-San Joaquin Delta. This approach offers significant advantages both in terms of numerical efficiency and accuracy and allows for local grid refinement for detailed analysis of local hydrodynamics in the Yolo Bypass and Cache Slough Complex, while still incorporating the overall hydrodynamics of the larger estuary in a single model.

We previously used this model to evaluate 2011-2019 managed and non-managed flow pulses (Anchor QEA 2020). Simulations will incorporate observed inflow (daily averaged), water temperature, and salinity in the Yolo Bypass. We will simulate the movement, age and fate of water originating from the flow pulse and other water masses such as CSC to downstream stations, and the lower Sacramento River at Rio Vista (Anchor QEA 2020). Our basic prediction is that managed flow actions will improve downstream transport through the Cache Slough Complex. Hence, we will evaluate two simulations for managed flow pulses: 1) Action: including the managed flow pulse, and 2) No Action: with the managed flow pulse removed from the inflow hydrograph. The model boundary conditions will be updated and extended to span through December 2023, and the model will be used to simulate baseline conditions during 2021-2023 for mid-June to mid-August or mid-September. These simulations will evaluate the potential effects of non-managed and managed flow pulses on flow from the Yolo Bypass to CSC and the lower Sacramento River.

Water Quality and Biological Modeling

Each year, we will evaluate how the managed or non-managed flow pulse affects individual water quality parameters, chlorophyll, and phytoplankton biomass and zooplankton density between the upstream and downstream regions, before, during, and after the pulse. We will use two-way Analysis of Variance, followed by Tukey post-hoc tests, with region and flow pulse period as categorical predictors. Similarly, we will use one-way ANOVA with the flow pulse period as the categorical predictor to assess the effects of the flow pulse on pesticide concentrations. We will use multivariate analysis methods such as permutational multivariate analysis of variance, principal component analysis, non-metric multidimensional scaling, or Canonical Correspondence Analysis to assess the effects of the flow pulses on phytoplankton, zooplankton, and fish communities, and on overall water quality. We will analyze the effects of flow pulses and water quality on continuous chlorophyll data using autoregressive models.

Our biological modeling approach for phytoplankton biomass remains to be determined, but we expect that it will be predominately based on the conceptual and mathematical models used by Lucas et al. (2009). Phytoplankton productivity will be based on data collected on chlorophyll a and direct phytoplankton productivity and growth rates from SFSU. The phytoplankton biomass gradient among the defined regions will be captured using discrete data and continuous chlorophyll measurements that will allow for deciphering if regions have any intra-daily variability due to tidal or diel cycles. Phytoplankton growth rate will be calculated by using the modeling approach described in Lucas et al (2012). This modeling approach is based on the Delta productivity relationship of Jassby et al. (2002). The loss rates for phytoplankton will be estimated by the conversion of zooplankton biomass to a grazing rate (see above). Finally, transport time scales (e.g., residence time, age, flushing time, etc.) from the UnTRIM Bay-Delta model from Anchor QEA (described below) will be used to examine the variability of exposure time to grazers and estimate overall biomass flux amongst each defined region. Due to the presence of variable tidal phase a range of transit times will be assessed using the UnTRIM Bay-Delta model to properly characterize each region. The flux of phytoplankton will be calculated using equations from Kimmerer et al. (1998), utilizing velocity of the channel, abundance of planktonic organisms, and the average cross-sectional area over time.

Learning from Monitoring

We will evaluate our hypotheses and address our study objectives using four approaches for comparison: *habitat comparisons (Study Objective 1), before-during-after (Study Objective 2)*, *comparison of food web responses to different flow pulses, with and without managed flow pulse (Study Objective 3), and comparison across different water year types (Study Objective 4)* and share the results of these assessments with the DCG to inform adaptive management and the SDM process for the Summer-Fall Habitat Action (SFHA). Here, we provide examples of how we can learn from science monitoring to improve implementation of the NDFS action.

Study Objectives 1 and 2 (Within-Year Comparisons)

We predict that we will detect food web changes in the downstream region in response to managed flow actions (Table 3-1), with the largest increases at the lower sites of the upstream region (e.g., LIS and STTD) and upper sites of the downstream region (e.g., BL5, PRS, LIB), resulting from disturbance and transport of plankton. Discrete and continuous monitoring, stable isotope analysis, and smelt enclosure studies will provide complementary sources of information about whether flow actions increase prey biomass by transporting plankton downstream. For example, increases in continuous chlorophyll fluorescence, phytoplankton, and zooplankton biomass after flow actions at lower Yolo Bypass (LIS and STTD) and upper CSC (BL5, PRS, LIB) sites, but not at lower CSC (RYI) and Sacramento River (RVB) sites, would suggest flow actions transport plankton biomass downstream. Moreover, if results of smelt enclosure studies in the CSC indicate that smelt body condition increases and smelt muscle isotopic signatures more closely resemble signatures of Yolo Bypass prey after flow actions, we may conclude that flow actions transport prey to the CSC to benefit Delta Smelt. These lines of evidence together would indicate that the NDFS action is achieving the goal of increasing prey biomass in the CSC. In addition, we could infer whether these prey subsidies are available to wild Delta Smelt by examining whether the distribution of experimental hatchery release Delta Smelt overlaps with the lower Yolo Bypass and upper CSC sites. The DCG would then weigh the evidence for benefits against the potential negative effects of increasing contaminant concentrations in water, zooplankton, and smelt tissue when recommending whether to continue implementing the NDFS action.

Study Objectives 3 and 4 (Across-Year Comparisons)

Using comparisons of food web responses across years, we will test the following predictions: 1) managed flow actions provide greater food web benefits than non-managed flow pulses, 2) low intensity, long duration actions are more efficacious for increasing food availability than short duration, high intensity actions, and 3) SAC actions are more beneficial than AG actions. As with the within-year comparisons, we will use multiple lines of evidence to draw inference about the efficacy of different action types, using continuous and discrete monitoring, stable isotope analysis, and smelt enclosure studies to examine changes in prey biomass, transport of prey, and Delta Smelt condition and survival in response to flow actions. We will also use across-year comparisons to evaluate whether actions conducted in dry and below normal water years are more beneficial than actions conducted in above normal and wet years. Food web benefits will be weighed against the evidence for whether water quality (e.g., dissolved oxygen, contaminant concentrations) is poorer.

This information will be used by the DCG to make recommendations about which action types to conduct by water year type. For example, the DCG may recommend only long duration, low intensity SAC actions be conducted in below normal or above normal years if they are more effective at increasing prey biomass in the CSC and have fewer unintended consequences than AG actions. However, the DCG may still recommend conducting AG actions in dry years if science monitoring and the SDM process suggest that the food web benefits outweigh the potential risks.

Reporting

We will produce a range of deliverables depending on format and audience (see Figure 1-7).

1. A technical summary of the North Delta Food Subsidies Study in December of each year, for inclusion with the Delta Smelt Summer/Fall Seasonal Report required by the 2019 BiOp and 2020 ITP.
    a. This draft will not include phytoplankton and zooplankton data, which will be included with the Summer/Fall Seasonal Report in the following year.
2. Publications of findings in the IEP Newsletter or peer-reviewed journals, when feasible.
3. Data publication and/or version update to Environmental Data Initiative containing all past data from the North Delta Food Subsidies Study.
4. Short summary documents (i.e., factsheets) to communicate results of actions to stakeholders and managers in the spring of every year (e.g., CAMT, NDFS Stakeholders meetings).
5. Oral briefings and presentations will include a short presentation of the study for managers and stakeholders late spring/early summer of every year (e.g., CAMT, North Delta Stakeholders), and presentations at major conferences including the IEP Workshop, and/or the Bay-Delta Science Conference.

Budget

Estimated costs for the North Delta Food Subsidy action are described in Table 3-5. The project budget includes operation costs such as reimbursement for reclamation and irrigation district diversions/pumping of water, operations monitoring and communications of water stage and velocity for upstream landowners, physical and biological monitoring collections and analysis, and special studies and program support (e.g., field collection, analysis, reporting) which may be variable dependent on action alternatives.

Table 3-5 Approximate budget of the North Delta Food Subsidy action in years when a SAC or AG action would occur and years when an action does not occur. The SAC action includes a range of costs given different implementation/operation alternatives.

	SAC Action	AG Action	SAC + AG Action	
Cost	(2 alternatives)	(1 alternative)	(2 alternatives)	No-action
Operations/diversions	$150,000 – $300,000	$0	$150,000 – $300,000	$0
Operations monitoring	$20,000	$20,000	$35,000	$0
Water quality monitoring	$60,000	$60,000	$100,000	$60,000
Plankton	$125,000	$75,000	$150,000	$75,000
Contaminants	$150,000	$150,000	$200,000	$150,000
Hydrodynamic modeling	$100,000	$100,000	$100,000	$0
FWS sampling support	$20,000	$20,000	$20,000	$20,000
Special Studies (Isotopes/Enclosures)	$200,000	$200,000	$200,000	$60,000
Program management and support	$300,000	$300,000	$300,000	$300,000
TOTAL	$1,025,000 – $1,275,000	$925,000	$1,355,000 – $1,505,000	$616,000

Sample Collection and Permitting

The monitoring and analysis described in this work plan includes many elements that do not require additional permitting or take such as water quality, phytoplankton, and pesticide sampling; however, this study is included in the State Water Project EIR, BiOp and ITP. Data collections and/or sources are provided in Table 3-3. Monitoring of changes in fish assemblages, and Salmon telemetry are included under the SCP and take coverage to the DWR Yolo Bypass Fish Monitoring Program (SCP #S-182970002-19100-001, Yolo Bypass Fish Monitoring Program, Nicole Kwan, California Department of Water Resources [Renewed 2022]), and FMWT and EDSM permits to USFWS. Incidental take of Delta Smelt during tows is covered in the DWR Yolo Bypass Fish Monitoring Program CESA MOU (MOU ID: 2021-0006-R3_Kwan). Monitoring information on Chinook Salmon will be covered under specific permits secured under the Yolo Bypass Adult Fall-Run Chinook Salmon Telemetry Study, DWR.

Data Management and Accessibility

All data are stored on DWR shared drives and cloud-based drives. All datasheets and databases are housed in DWR facilities on servers in electronic form. These servers experience data back-ups daily. DWR is currently in the process of developing a new enterprise-wide database and data management framework. When completed, data will be migrated to this new platform. Data initially go into the following databases: 1) HYDSTRA database: HYXPLORE.exe for Continuous water quality data; 2) Access database for Lower Trophic samples of zooplankton, chlorophyll and water quality: LowerTrophicSampling_Yolo2015_DB.mdb;3) acoustic telemetry data of Chinook Salmon is in a VEMCO Vue database: YB_2019.vdb; and 4) nutrients and chlorophyll will be in the Water Data Library. Water quality, nutrients, zooplankton, phytoplankton, continuous water quality, and pesticide datasets will be maintained, and available as excel spreadsheets (.xls, .xlsx, and .csv).

Zooplankton, phytoplankton, chlorophyll, discrete and continuous water quality, and nutrients metadata are available on the DWR website (IEP Data and Metadata Table; https://iep.ca.gov/Data/IEP-Survey-Data). Zooplankton, chlorophyll, and associated water quality are listed under Yolo Bypass Fish Monitoring Program: Lower Trophic. Nutrients and phytoplankton are listed under the Environmental Monitoring Program. Metadata for special analysis of primary productivity, and pesticides tasks are available upon request by SFSU (Wilkerson) and USGS (Orlando) task leads. USGS Organic Chemistry Research Laboratory, Pesticide Fate Research Group: https://www.usgs.gov/centers/ca-water/science/pesticide-fate-research-group-pfrg?qt-science_center_objects=0#qt-science_center_objects.

All datasets and metadata described above are published through Environmental Data Initiative (EDI) in flat-file format (.csv). EDI uses Ecological Metadata Language standards [.xml], and the study will follow IEP DUWG's Open Data suggestions.

IEP Coordination

A key part of the adaptive management of this project will be outreach and coordination. As noted above, the primary vehicles for coordination will be the Delta Coordination Group and the North Delta Food Subsidies Stakeholder group. The former includes the major decision makers involved in the project, and the latter represents a public forum for all parties interested in the projects. Both groups will be reviewing this monitoring plan.

This project is highly consistent with the Restoring Native Species and Communities section of the IEP Science Strategy. Specifically, the "Flow modifications and benefits" topic for smelts. The approach is also consistent with the stated goal of the IEP Science Strategy to use a suite of methods (Monitoring, Experiments, Modeling) to answer management questions. Additionally, the project addresses the specific mandates in the ITP and Biological Opinion to increase science to understand Delta Smelt Habitat in the summer and fall and implement a science and monitoring program surrounding the Summer-Fall Habitat Action. Lastly, NDFS project aims to improve key historical Delta Smelt habitat such as Cache Slough Complex and Lower Sacramento River, both of which have detected Delta Smelt in recent years, likely as a result from experimental releases beginning in 2021.

The NDFS project is included annually in the IEP Work Plan as Project Element Number 281 (PEN 281). The project will also coordinate with existing IEP monitoring and specific projects that are either already collecting data in the region or have planned studies. Examples include:

- Summer Townet Survey (CDFW)
- Fall Midwater Trawl (CDFW)
- EMP (DWR)
- EDSM (USFWS)
- USGS sampling
- Directed Outflow Project (USBR)

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Appendix 1. Table of Current-Use Pesticides

Table 1-1 178 current-use pesticides. Abbreviations: GC/MS, gas chromatograph with mass spectrometry; LC/MS/MS, liquid chromatography with tandem mass spectrometry; ng/L, nanograms per liter; NWIS, National Water Information System.

No.	Compound	CAS Number	Pesticide Type	Instrument	Matrices	Reporting Limit (ng/L)	Limit of Detection (ng/L)
1	Dichloroaniline, 3,4-	95-76-1	Herbicide	LC-MS/MS	Water & Zooplankton	3.0	1.0
2	Dichloroaniline, 3,5-	626-43-7	Herbicide	LC-MS/MS	Water & Zooplankton	6.0	2.0
3	Acetamiprid	135410-20-7	Insecticide	LC-MS/MS	Water & Zooplankton	1.5	0.5
4	Acetochlor	34256-82-1	Herbicide	LC-MS/MS	Water & Zooplankton	3.0	1.0
5	Acibenzolar-S-Methyl	135158-54-2	Fungicide	GC-MS/MS	Water & Zooplankton	6.0	2.0
6	Allethrin	584-79-2	Insecticide	GC-MS/MS	Water & Zooplankton	6.0	2.0
7	Atrazine	1912-24-9	Herbicide	LC-MS/MS	Water & Zooplankton	1.5	0.5
8	Atrazine, Desethyl	6190-65-4	Herbicide	LC-MS/MS	Water & Zooplankton	3.0	1.0
9	Atrazine, Desisopropyl	1007-28-9	Herbicide	LC-MS/MS	Water & Zooplankton	3.0	1.0
10	Azoxystrobin	131860-33-8	Fungicide	LC-MS/MS	Water & Zooplankton	1.5	0.5
11	Benefin (Benfluralin)	1861-40-1	Herbicide	GC-MS/MS	Water & Zooplankton	1.5	0.5
12	Bentazon	25057-89-0	Herbicide	LC-MS/MS	Water	3.0	1.0
13	Benzobicyclon	156963-66-5	Herbicide	LC-MS/MS	Water & Zooplankton	3.0	1.0
14	Benzovindiflupyr	1072957-71-1	Fungicide	LC-MS/MS	Water & Zooplankton	1.5	0.5

No.	Compound	CAS Number	Pesticide Type	Instrument	Matrices	Reporting Limit (ng/L)	Limit of Detection (ng/L)
15	Bifenthrin	82657-04-3	Insecticide	GC-MS/MS	Water & Zooplankton	1.5	0.5
16	Boscalid	188425-85-6	Fungicide	LC-MS/MS	Water & Zooplankton	3.0	1.0
17	Boscalid Metabolite - M510F01 Acetyl	661463-87-2	Fungicide	LC-MS/MS	Water & Zooplankton	1.5	0.5
18	Broflanilide	1207727-04-5	Insecticide	LC-MS/MS	Water & Zooplankton	1.5	0.5
19	Bromuconazole	116255-48-2	Fungicide	LC-MS/MS	Water & Zooplankton	3.0	1.0
20	Butralin	33629-47-9	Herbicide	LC-MS/MS	Water & Zooplankton	3.0	1.0
21	Carbaryl	63-25-2	Insecticide	LC-MS/MS	Water & Zooplankton	1.5	0.5
22	Carbendazim	10605-21-7	Fungicide	LC-MS/MS	Water	1.5	0.5
23	Carbofuran	1563-66-2	Insecticide	LC-MS/MS	Water & Zooplankton	1.5	0.5
24	Chlorantraniliprole	500008-45-7	Insecticide	LC-MS/MS	Water & Zooplankton	1.5	0.5
25	Chlorfenapyr	122453-73-0	Insecticide	GC-MS/MS	Water & Zooplankton	6.0	2.0
26	Chlorothalonil	1897-45-6	Fungicide	GC-MS/MS	Water & Zooplankton	15.0	5.0
27	Chlorpyrifos	2921-88-2	Insecticide	LC-MS/MS	Water & Zooplankton	3.0	1.0
28	Chlorpyrifos Oxon	5598-15-2	Insecticide	LC-MS/MS	Water & Zooplankton	1.5	0.5
29	Clomazone	81777-89-1	Herbicide	LC-MS/MS	Water & Zooplankton	1.5	0.5
30	Clothianidin	210880-92-5	Insecticide	LC-MS/MS	Water & Zooplankton	1.5	0.5
31	Clothianidin Desmethyl	135018-15-4	Insecticide	LC-MS/MS	Water & Zooplankton	3.0	1.0
32	Coumaphos	56-72-4	Insecticide	LC-MS/MS	Water & Zooplankton	3.0	1.0
33	Cyantraniliprole	736994-63-1	Insecticide	LC-MS/MS	Water & Zooplankton	3.0	1.0

No.	Compound	CAS Number	Pesticide Type	Instrument	Matrices	Reporting Limit (ng/L)	Limit of Detection (ng/L)
34	Cyazofamid	120116-88-3	Fungicide	LC-MS/MS	Water & Zooplankton	1.5	0.5
35	Cyclaniliprole	1031756-98-5	Insecticide	LC-MS/MS	Water & Zooplankton	3.0	1.0
36	Cycloate	1134-23-2	Herbicide	LC-MS/MS	Water & Zooplankton	3.0	1.0
37	Cyfluthrin	68359-37-5	Insecticide	GC-MS/MS	Water & Zooplankton	1.5	0.5
38	Cyhalofop-Butyl	122008-85-9	Herbicide	GC-MS/MS	Water & Zooplankton	1.5	0.5
39	Cyhalothrin (all isomers)	68085-85-8	Insecticide	GC-MS/MS	Water & Zooplankton	1.5	0.5
40	Cymoxanil	57966-95-7	Fungicide	LC-MS/MS	Water & Zooplankton	3.0	1.0
41	Cypermethrin	52315-07-8	Insecticide	GC-MS/MS	Water & Zooplankton	1.5	0.5
42	Cyproconazole	94361-06-5	Fungicide	LC-MS/MS	Water & Zooplankton	1.5	0.5
43	Cyprodinil	121552-61-2	Fungicide	LC-MS/MS	Water	1.5	0.5
44	DCPA	1861-32-1	Herbicide	GC-MS/MS	Water & Zooplankton	1.5	0.5
45	DCPMU	3567-62-2	Herbicide	LC-MS/MS	Water	3.0	1.0
46	DCPU	2327-02-8	Herbicide	LC-MS/MS	Water	3.0	1.0
47	Deltamethrin	52918-63-5	Insecticide	GC-MS/MS	Water & Zooplankton	3.0	1.0
48	Desthio-Prothioconazole	120983-64-4	Fungicide	LC-MS/MS	Water & Zooplankton	1.5	0.5
49	Diazinon	333-41-5	Insecticide	LC-MS/MS	Water & Zooplankton	1.5	0.5
50	Diazinon Oxon	962-58-3	Insecticide	LC-MS/MS	Water & Zooplankton	1.5	0.5
51	Dichlorvos	62-73-7	Insecticide	LC-MS/MS	Water & Zooplankton	3.0	1.0
52	Difenoconazole	119446-68-3	Fungicide	LC-MS/MS	Water & Zooplankton	3.0	1.0

No.	Compound	CAS Number	Pesticide Type	Instrument	Matrices	Reporting Limit (ng/L)	Limit of Detection (ng/L)
53	Dimethomorph	110488-70-5	Fungicide	LC-MS/MS	Water & Zooplankton	1.5	0.5
54	Dinotefuran	165252-70-0	Insecticide	LC-MS/MS	Water & Zooplankton	3.0	1.0
55	Dithiopyr	97886-45-8	Herbicide	GC-MS/MS	Water & Zooplankton	1.5	0.5
56	Diuron	330-54-1	Herbicide	LC-MS/MS	Water & Zooplankton	1.5	0.5
57	EPTC	759-94-4	Herbicide	LC-MS/MS	Water & Zooplankton	6.0	2.0
58	Esfenvalerate	66230-04-4	Insecticide	GC-MS/MS	Water & Zooplankton	1.5	0.5
59	Ethaboxam	162650-77-3	Fungicide	LC-MS/MS	Water & Zooplankton	3.0	1.0
60	Ethalfluralin	55283-68-6	Herbicide	GC-MS/MS	Water & Zooplankton	1.5	0.5
61	Etofenprox	80844-07-1	Insecticide	GC-MS/MS	Water & Zooplankton	1.5	0.5
62	Etoxazole	153233-91-1	Insecticide	LC-MS/MS	Water & Zooplankton	1.5	0.5
63	Famoxadone	131807-57-3	Fungicide	LC-MS/MS	Water	30.0	10.0
64	Fenamidone	161326-34-7	Fungicide	LC-MS/MS	Water & Zooplankton	1.5	0.5
65	Fenbuconazole	114369-43-6	Fungicide	LC-MS/MS	Water & Zooplankton	1.5	0.5
66	Fenhexamid	126833-17-8	Fungicide	LC-MS/MS	Water & Zooplankton	30.0	10.0
67	Fenpropathrin	39515-41-8	Insecticide	GC-MS/MS	Water & Zooplankton	3.0	1.0
68	Fenpyroximate	134098-61-6	Insecticide	LC-MS/MS	Water & Zooplankton	1.5	0.5
69	Fipronil	120068-37-3	Insecticide	LC-MS/MS	Water & Zooplankton	1.5	0.5
70	Fipronil Desulfinyl	205650-65-3	Insecticide	LC-MS/MS	Water & Zooplankton	1.5	0.5
71	Fipronil Desulfinyl Amide	1115248-09-3	Insecticide	LC-MS/MS	Water & Zooplankton	3.0	1.0

No.	**Compound**	**CAS Number**	**Pesticide Type**	**Instrument**	**Matrices**	**Reporting Limit (ng/L)**	**Limit of Detection (ng/L)**
72	Fipronil Sulfide	120067-83-6	Insecticide	LC-MS/MS	Water & Zooplankton	1.5	0.5
73	Fipronil Sulfone	120068-36-2	Insecticide	LC-MS/MS	Water & Zooplankton	1.5	0.5
74	Flonicamid	158062-67-0	Insecticide	LC-MS/MS	Water & Zooplankton	3.0	1.0
75	Florpyrauxifen-Benzyl	1390661-72-9	Herbicide	LC-MS/MS	Water & Zooplankton	1.5	0.5
76	Fluazinam	79622-59-6	Fungicide	LC-MS/MS	Water & Zooplankton	1.5	0.5
77	Fludioxonil	131341-86-1	Fungicide	LC-MS/MS	Water & Zooplankton	3.0	1.0
78	Flufenacet	142459-58-3	Herbicide	LC-MS/MS	Water & Zooplankton	1.5	0.5
79	Fluindapyr	1383809-87-7	Fungicide	LC-MS/MS	Water & Zooplankton	1.5	0.5
80	Flumetralin	62924-70-3	Other	LC-MS/MS	Water & Zooplankton	3.0	1.0
81	Fluopicolide	239110-15-7	Fungicide	LC-MS/MS	Water & Zooplankton	1.5	0.5
82	Fluopyram	658066-35-4	Fungicide	LC-MS/MS	Water & Zooplankton	1.5	0.5
83	Fluoxastrobin	193740-76-0	Fungicide	LC-MS/MS	Water & Zooplankton	1.5	0.5
84	Flupyradifurone	951659-40-8	Insecticide	LC-MS/MS	Water & Zooplankton	1.5	0.5
85	Fluridone	59756-60-4	Herbicide	LC-MS/MS	Water & Zooplankton	1.5	0.5
86	Flutolanil	66332-96-5	Fungicide	LC-MS/MS	Water & Zooplankton	1.5	0.5
87	Flutriafol	76674-21-0	Fungicide	LC-MS/MS	Water & Zooplankton	1.5	0.5
88	Fluxapyroxad	907204-31-3	Fungicide	LC-MS/MS	Water & Zooplankton	1.5	0.5
89	Halauxifen-Methyl Ester	943831-98-9	Herbicide	LC-MS/MS	Water & Zooplankton	1.5	0.5
90	Hexazinone	51235-04-2	Herbicide	LC-MS/MS	Water & Zooplankton	1.5	0.5

No.	Compound	CAS Number	Pesticide Type	Instrument	Matrices	Reporting Limit (ng/L)	Limit of Detection (ng/L)
91	Imazalil	35554-44-0	Fungicide	LC-MS/MS	Water & Zooplankton	1.5	0.5
92	Imidacloprid	138261-41-3	Insecticide	LC-MS/MS	Water & Zooplankton	1.5	0.5
93	Imidacloprid Desnitro	127202-53-3	Insecticide	LC-MS/MS	Water	3.0	1.0
94	Imidacloprid Olefin	115086-54-9	Insecticide	LC-MS/MS	Water & Zooplankton	3.0	1.0
95	Imidacloprid Urea	120868-66-8	Insecticide	LC-MS/MS	Water & Zooplankton	1.5	0.5
96	Imidacloprid, 5-Hydroxy	380912-09-4	Insecticide	LC-MS/MS	Water & Zooplankton	3.0	1.0
97	Indaziflam	950782-86-2	Herbicide	LC-MS/MS	Water & Zooplankton	1.5	0.5
98	Indoxacarb	173584-44-6	Insecticide	LC-MS/MS	Water & Zooplankton	3.0	1.0
99	Ipconazole	125225-28-7	Fungicide	LC-MS/MS	Water & Zooplankton	1.5	0.5
100	Iprodione	36734-19-7	Fungicide	LC-MS/MS	Water & Zooplankton	3.0	1.0
101	Isofetamid	875915-78-9	Fungicide	LC-MS/MS	Water & Zooplankton	1.5	0.5
102	Kresoxim-Methyl	143390-89-0	Fungicide	LC-MS/MS	Water & Zooplankton	1.5	0.5
103	Malathion	121-75-5	Insecticide	LC-MS/MS	Water & Zooplankton	1.5	0.5
104	Malathion Oxon	1634-78-2	Insecticide	LC-MS/MS	Water & Zooplankton	1.5	0.5
105	Mandestrobin	173662-97-0	Fungicide	LC-MS/MS	Water & Zooplankton	1.5	0.5
106	Mandipropamid	374726-62-2	Fungicide	LC-MS/MS	Water & Zooplankton	1.5	0.5
107	Metalaxyl	57837-19-1	Fungicide	LC-MS/MS	Water & Zooplankton	1.5	0.5
108	Metalaxyl Alanine Metabolite	85933-49-9	Fungicide	LC-MS/MS	Water & Zooplankton	1.5	0.5
109	Metconazole	125116-23-6	Fungicide	LC-MS/MS	Water & Zooplankton	1.5	0.5

No.	Compound	CAS Number	Pesticide Type	Instrument	Matrices	Reporting Limit (ng/L)	Limit of Detection (ng/L)
110	Methoprene	40596-69-8	Insecticide	GC-MS/MS	Water	6.0	2.0
111	Methoxyfenozide	161050-58-4	Insecticide	LC-MS/MS	Water & Zooplankton	1.5	0.5
112	Metolachlor	51218-45-2	Herbicide	LC-MS/MS	Water & Zooplankton	1.5	0.5
113	Myclobutanil	88671-89-0	Fungicide	LC-MS/MS	Water & Zooplankton	1.5	0.5
114	Naled (Dibrom)	300-76-5	Insecticide	LC-MS/MS	Water	30.0	10.0
115	Napropamide	15299-99-7	Herbicide	LC-MS/MS	Water & Zooplankton	1.5	0.5
116	Nitrapyrin	1929-82-4	Other	GC-MS/MS	Water & Zooplankton	1.5	0.5
117	Novaluron	116714-46-6	Insecticide	LC-MS/MS	Water & Zooplankton	6.0	2.0
118	Oryzalin	19044-88-3	Herbicide	LC-MS/MS	Water & Zooplankton	6.0	2.0
119	Oxadiazon	19666-30-9	Herbicide	LC-MS/MS	Water & Zooplankton	3.0	1.0
120	Oxathiapiprolin	1003318-67-9	Fungicide	LC-MS/MS	Water & Zooplankton	1.5	0.5
121	Oxyfluorfen	42874-03-3	Herbicide	LC-MS/MS	Water & Zooplankton	3.0	1.0
122	p,p'-DDD	72-54-8	Insecticide	GC-MS/MS	Water & Zooplankton	1.5	0.5
123	p,p'-DDE	72-55-9	Insecticide	GC-MS/MS	Water & Zooplankton	1.5	0.5
124	p,p-DDT	50-29-3	Insecticide	GC-MS/MS	Water & Zooplankton	1.5	0.5
125	Paclobutrazol	76738-62-0	Fungicide	LC-MS/MS	Water & Zooplankton	3.0	1.0
126	Pendimethalin	40487-42-1	Herbicide	LC-MS/MS	Water & Zooplankton	3.0	1.0
127	Penoxsulam	219714-96-2	Herbicide	LC-MS/MS	Water & Zooplankton	3.0	1.0
128	Pentachloroanisole (PCA)	1825-21-4	Insecticide	GC-MS/MS	Water & Zooplankton	3.0	1.0

No.	Compound	CAS Number	Pesticide Type	Instrument	Matrices	Reporting Limit (ng/L)	Limit of Detection (ng/L)
129	Pentachloronitrobenzene (PCNB)	82-68-8	Fungicide	GC-MS/MS	Water & Zooplankton	3.0	1.0
130	Penthiopyrad	183675-82-3	Fungicide	LC-MS/MS	Water & Zooplankton	1.5	0.5
131	Permethrin	52645-53-1	Insecticide	GC-MS/MS	Water & Zooplankton	3.0	1.0
132	Phenothrin	26002-80-2	Insecticide	GC-MS/MS	Water & Zooplankton	6.0	2.0
133	Phosmet	732-11-6	Insecticide	LC-MS/MS	Water & Zooplankton	1.5	0.5
134	Picarbutrazox	500207-04-5	Fungicide	LC-MS/MS	Water & Zooplankton	1.5	0.5
135	Picoxystrobin	117428-22-5	Fungicide	LC-MS/MS	Water & Zooplankton	1.5	0.5
136	Piperonyl Butoxide	51-03-6	Other	LC-MS/MS	Water & Zooplankton	1.5	0.5
137	Prodiamine	29091-21-2	Herbicide	LC-MS/MS	Water & Zooplankton	6.0	2.0
138	Prometon	1610-18-0	Herbicide	LC-MS/MS	Water & Zooplankton	1.5	0.5
139	Prometryn	7287-19-6	Herbicide	LC-MS/MS	Water & Zooplankton	1.5	0.5
140	Propanil	709-98-8	Herbicide	LC-MS/MS	Water & Zooplankton	3.0	1.0
141	Propargite	2312-35-8	Insecticide	LC-MS/MS	Water	1.5	0.5
142	Propiconazole	60207-90-1	Fungicide	LC-MS/MS	Water & Zooplankton	1.5	0.5
143	Propyzamide	23950-58-5	Herbicide	LC-MS/MS	Water & Zooplankton	3.0	1.0
144	Pydiflumetofen	1228284-64-7	Fungicide	LC-MS/MS	Water & Zooplankton	1.5	0.5
145	Pyraclostrobin	175013-18-0	Fungicide	LC-MS/MS	Water & Zooplankton	1.5	0.5
146	Pyridaben	96489-71-3	Insecticide	LC-MS/MS	Water & Zooplankton	1.5	0.5
147	Pyrimethanil	53112-28-0	Fungicide	LC-MS/MS	Water & Zooplankton	1.5	0.5

No.	Compound	CAS Number	Pesticide Type	Instrument	Matrices	Reporting Limit (ng/L)	Limit of Detection (ng/L)
148	Pyriproxyfen	95737-68-1	Other	LC-MS/MS	Water & Zooplankton	1.5	0.5
149	Quinoxyfen	124495-18-7	Fungicide	LC-MS/MS	Water & Zooplankton	1.5	0.5
150	Sedaxane	874967-67-6	Fungicide	LC-MS/MS	Water & Zooplankton	1.5	0.5
151	Simazine	122-34-9	Herbicide	LC-MS/MS	Water & Zooplankton	3.0	1.0
152	Sulfoxaflor	946578-00-3	Insecticide	LC-MS/MS	Water & Zooplankton	3.0	1.0
153	Tebuconazole	107534-96-3	Fungicide	LC-MS/MS	Water & Zooplankton	1.5	0.5
154	Tebuconazole t-Butylhydroxy	212267-64-6	Fungicide	LC-MS/MS	Water & Zooplankton	1.5	0.5
155	Tebufenozide	112410-23-8	Insecticide	LC-MS/MS	Water & Zooplankton	1.5	0.5
156	Tebupirimfos	96182-53-5	Insecticide	LC-MS/MS	Water & Zooplankton	1.5	0.5
157	Tebupirimfos Oxon	1035330-36-9	Insecticide	LC-MS/MS	Water & Zooplankton	1.5	0.5
158	Tefluthrin	79538-32-2	Insecticide	GC-MS/MS	Water & Zooplankton	1.5	0.5
159	Tetraconazole	112281-77-3	Fungicide	LC-MS/MS	Water & Zooplankton	1.5	0.5
160	Tetramethrin	7696-12-0	Insecticide	GC-MS/MS	Water & Zooplankton	3.0	1.0
161	t-Fluvalinate	102851-06-9	Insecticide	GC-MS/MS	Water & Zooplankton	1.5	0.5
162	Thiabendazole	148-79-8	Fungicide	LC-MS/MS	Water	1.5	0.5
163	Thiacloprid	111988-49-9	Insecticide	LC-MS/MS	Water & Zooplankton	1.5	0.5
164	Thiamethoxam	153719-23-4	Insecticide	LC-MS/MS	Water & Zooplankton	1.5	0.5
165	Thiamethoxam Degradate (CGA-355190)	902493-06-5	Insecticide	LC-MS/MS	Water & Zooplankton	1.5	0.5
166	Thiamethoxam Degradate (NOA-407475)		Insecticide	LC-MS/MS	Water	3.0	1.0

No.	Compound	CAS Number	Pesticide Type	Instrument	Matrices	Reporting Limit (ng/L)	Limit of Detection (ng/L)
167	Thiobencarb	28249-77-6	Herbicide	LC-MS/MS	Water & Zooplankton	1.5	0.5
168	Tolfenpyrad	129558-76-5	Insecticide	LC-MS/MS	Water & Zooplankton	1.5	0.5
169	Triadimefon	43121-43-3	Fungicide	LC-MS/MS	Water & Zooplankton	3.0	1.0
170	Triadimenol	55219-65-3	Fungicide	LC-MS/MS	Water & Zooplankton	3.0	1.0
171	Triallate	2303-17-5	Herbicide	LC-MS/MS	Water & Zooplankton	6.0	2.0
172	Tribufos	78-48-8	Herbicide	LC-MS/MS	Water & Zooplankton	1.5	0.5
173	Trifloxystrobin	141517-21-7	Fungicide	LC-MS/MS	Water & Zooplankton	1.5	0.5
174	Triflumizole	68694-11-1	Fungicide	LC-MS/MS	Water & Zooplankton	1.5	0.5
175	Trifluralin	1582-09-8	Herbicide	GC-MS/MS	Water & Zooplankton	1.5	0.5
176	Triticonazole	131983-72-7	Fungicide	LC-MS/MS	Water & Zooplankton	1.5	0.5
177	Valifenalate	283159-90-0	Fungicide	LC-MS/MS	Water & Zooplankton	1.5	0.5
178	Zoxamide	156052-68-5	Fungicide	LC-MS/MS	Water & Zooplankton	3.0	1.0

Appendix 2. AG Action Effects on Delta Water Quality in Dry Water Years

Produced by DWR Division of Operations and Maintenance and Delta Compliance Program

North Delta Flow Action Evaluation

The purpose of the North Delta Food Subsidy Action is to increase food entering the North Delta by flushing flow from the Colusa Drain into the Yolo bypass and North Delta.

DSM2 was run to assess the effect of this action on North Delta Water Quality (Figure 2-1). The 25% exceedance February DCO (SWP allocation study) was used to develop the hydrologic boundary conditions for the modeling. This study was chosen as it was the most current forecast with a WSI indicating a Dry hydrology, and this action would only be applicable in a Dry year. The current March 25% exceedance

WSI is Critical, and thus no March DCO allocation with a Dry hydrology was available for this assessment.

Based on flow actions of the previous years, two flow management scenarios were formulated and evaluated. Each has a flow pulse of 500 cfs to Yolo Bypass. For Scenario 1, the flow pulse occurs during Aug 15 – Sep 15. For Scenario 2, the flow pulse occurs during Sep 1 – Sep 30. These pulses are summarized in Table1 and Table 2.

Table 2-1 **Summary of scenarios**

Scenario	Date Range (start/end of flow pulse)
Base Case	NA
Scenario 1	Aug 15 – Sep 15
Scenario 2	Sep 1 – Sep 30

Table 2-2 Summary of flows in each scenario

	Freeport Flow (cfs)			Yolo Bypass Flow (cfs)		
Date Range	Base Case	Scenario 1 (Aug 15 – Sep 15 pulse)	Scenario 2 (Sep 1 – Sep 30 Pulse)	Base Case	Scenario 1	Scenario 2
Aug 15 – Aug 31	11271	10771	11271	-100	400	-100
Sep 1 – Sep 15	11075	10575	10575	-100	400	400
Sep 15 – Sep 30	11075	11075	10575	-100	-100	400

Figure 2-1 Results of this assessment are summarized for a number of North Delta water quality compliance locations. The action had no modeled effect on water quality locations other than the North Delta.