Delta Smelt

Summer-Fall Habitat Action Monitoring and Science Plan

Central Valley Project, California

California-Great Basin Region

prepared by

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Background

Purpose and Need

In recent years, the potential importance of summer-fall environmental conditions for Delta Smelt has grown in recognition (e.g., Brown et al. 2014; Hammock et al. 2017; Polansky et al. 2020; Smith et al. 2021). In particular, unfavorable conditions during this period appear able to create a major environmental bottleneck, limiting recruitment of young Delta Smelt. To address this issue, summer and fall have been a focus of a substantial amount of science and monitoring. Moreover, interest is increasing in management actions that can improve habitat conditions during this period, as reflected in the Delta Smelt Summer-Fall Habitat Action (SFHA), which intends to enhance Delta Smelt recruitment, growth, and survival by improving habitat quantity and quality and food supply.

The Delta Smelt Summer-Fall Habitat Action and its components are implemented pursuant to: (1) the US Bureau of Reclamation (USBR) and California Department of Water Resources (DWR) 2019 Biological Assessment's Proposed Action, Section 4.10.5.11, for the Coordinated Long-Term Operation of the Central Valley Project (CVP) and State Water Project (SWP), dated October 2019; (2) the corresponding Biological Opinions (BiOps) issued pursuant to section 7 of the federal Endangered Species Act by the U.S. Fish and Wildlife Service (USFWS) and the National Marine Fisheries Service, dated October 21, 2019; and (3) pursuant to Section 9.1.3 of the California Department of Fish and Wildlife's ITP issued to DWR for SWP operations, dated March 31, 2020. The environmental and biological goals of the SFHA are to: (1) maintain low salinity habitat in Suisun Marsh and Grizzly Bay when water temperatures are suitable; (2) manage the low salinity zone to overlap with turbid water and available food supplies; and (3) establish contiguous low salinity habitat from Cache Slough Complex to the Suisun Marsh. Performance over a 4-year time period will be evaluated using the following metrics specified in the 2019 USFWS BiOp: (1) habitat acreage; (2) Delta Smelt (DS) presence/absence in target and other areas; and (3) DS recruitment projections.

This Monitoring and Science Plan has two primary purposes: (1) meet the specific requirements of the 2019 USFWS BiOp to develop a multi-year monitoring plan to support the SFHA science and management activities using a structured decision-making process; and (2) to create a framework to organize science activities for summer-fall actions to support Delta Smelt conservation. As such, this document has been developed to build a systematic and transparent approach to new and ongoing summer-fall habitat monitoring and research and to provide a collaborative framework that engages multiple agencies, partners, and stakeholders in prioritizing research needs for Delta Smelt.

Delta Coordination Group

The 2019 USFWS BiOp and ITP created a new interagency and stakeholder group, the Delta Coordination Group (DCG), to coordinate and implement summer-fall actions and associated science. This group was formed in summer 2020, and has since met monthly to learn, discuss, and provide input on various technical aspects of the SFHA. The SFHA Guidance Document (Appendix A) provides detailed information about the group's purpose, membership, activities, and projects. The Guidance Document (Pg. 4 and 5) identified using structured decision-making (SDM) to implement the Delta Smelt SFHA. Critically Dry years are non-action years; however, science and monitoring activities to collect baseline data or address knowledge gaps may still occur. Agencies and stakeholders participating in the DCG identified the PrOACT decision support tool as the structured decision-making (SDM) process to use in informing the Delta Smelt SFHA. The DCG did not engage in SDM for 2021 SFHA decision-making due to 2021 being a critically dry year. However, performance measures identified by the DCG were quantified and presented in a consequences table and described in associated performance measure information sheets as an example of the kind of information that can be provided for SDM.

Starting in August 2021, the DCG engaged in a formal SDM process for 2022 SFHA decision-making, guided by Jennie Hoffman (Adaptation Insight) and in collaboration with Compass Resource Management; the latter to allow for exchange between the DCG SDM process and the Collaborative Science and Adaptive Management Program SDM process that Compass oversees. To assist the DCG in technical evaluation, research needs, and expert opinions related to SFHA and an annual SDM processes, two technical subteams of the DCG were created in early 2021, including the science and monitoring working group (SMWG) and hydrology and operations work group (HOWG). The DCG agreed on process principles, identified the decision scope, context and objectives, and drafted a preliminary influence diagram for the SFHA

(Table 1). The DCG created several alternatives organized under the following themes: minimize resource costs, maximize Delta Smelt benefits, maximize learning, and minimize water resource costs. Each alternative includes different combinations of flow, food, monitoring, and science actions. At this writing, the DCG and technical subteams are engaged in an iterative process of refining the decision scope, objectives, and influence diagram and finalizing candidate performance measures. Subgroups will identify data and model availability and gaps to begin scoring performance measures quantitatively or, where gaps exist, using expert elicitation.

Conceptual Model

The SFHA actions have generally followed the Management Analysis and Synthesis Team models ("MAST") developed by Baxter et al. (2015). These models illustrate how species responses integrate with environmental conditions, larger scale drivers, and landscape attributes. The focus of the current effort is the seasonal models developed for summer (younger juveniles) and fall (older juveniles or 'subadults'). More details about how the MAST model is used in conjunction with other conceptual models can be found in individual work plans for studying potential actions.

Plan Structure

The SFHA Monitoring and Science Plan is organized as follows. An "Actions Work Plans" section provides an overview of each of the specific flow and food-web enhancement actions and activities identified within the SFHA. These descriptions may include discussion points collected during recent DCG meetings to consider as potential modifications to future work plans. The section, "Topics for Potential Action Work Plan Modifications or Directed Research," describes potential cross-action research needs and approaches that are beyond just the scope of current work plans but were identified for discussion and consideration through future implementation of SFHA component's work plans or directed studies. Finally, the plan includes schedules of the activities and deliverables for meeting BiOp and ITP requirements.

Action Work Plans

Individual SFHA actions and activities (as identified in the BiOp and ITP) are summarized below. Many of these actions are relatively new and, therefore, vary substantially in the status of project planning and the level of progress in scientific planning. For example, the Suisun Marsh Salinity Control Gate Study (below) has a relatively sophisticated work plan, with elaborate monitoring objectives and approaches, while other projects such as the Roaring River Distribution System remain at the conceptual stage. Summaries include: (1) the SFHA goals and objectives addressed; (2) current status and study plan overview; and (3) discussion points for consideration in future study plans. Full descriptions of the actions, hypotheses, predictions, and work plans are included as appendices.

Suisun Marsh Salinity Control Gates Study

Action Goals and Objectives

This action helps meet all three of the environmental and biological goals (Table 2). The primary purpose of this action is to reduce salinities in the major channels that supply Suisun Marsh, thus allowing Delta Smelt to more frequently access the marsh's complex, relatively food-rich habitat. The action expands fall operations of the SMSCG to include up to 60 days of opening the gates during ebb tides and closing gates during flood tides between June 1 and October 31. The direct, operational objective is to: (1) maximize the number of days that Belden's Landing three-day average salinity is equal to, or less than, 4 PSU in all but dry years following below normal years; or (2) maximize the number of days that Belden's Landing three-day average salinity is equal to, or less than, 6 PSU in a dry year following a below normal year (CDFW 2020; Table 1). The action directly addresses objectives to increase or maximize the overlap of transient and stationary habitat suitable for delta smelt occurring in Suisun Marsh and in so doing, addresses objectives to increase or maximize Delta Smelt condition, growth, and survival (Tables 1 and 2).

Current status

Science and monitoring activities to assess the effectiveness of the Suisun Marsh Salinity Control Gates summer operations include a combination of existing monitoring, expansion of existing monitoring, modeling studies and targeted experiments (Appendix B). These data will be compared in several ways to assess the overall benefit of the action to Delta Smelt: (1) conditions in Suisun Marsh will be compared to conditions in Grizzly Bay and the Confluence; (2) conditions during gate operations will be compared to conditions before and after the action; and (3) conditions during the action will be compared to similar historical conditions (see Sommer et al. 2020 and Beakes et al. 2021 for examples). Monitoring during no-action years (such as 2020 and 2021) will be used as additional baseline information for comparison to action years. Results from this study will be used to adaptively manage the action in future years.

Studies include a continued effort to expand zooplankton and phytoplankton monitoring in the region, collecting annual data on distribution of aquatic vegetation using hyperspectral imagery, and integration of data from new water-quality monitoring stations in Grizzly Bay. Smelt enclosures will be deployed in the Marsh and upstream at Rio Vista to compare Delta Smelt survival and health metrics between regions.

Discussion Points

Reporting Timeline:

- Ideally, complete reporting on the action will be within a 2-year timeframe. To meet this, action leaders will work with contractors to prioritize lower trophic and food web sample processing and automate the graphical presentation of data, so that interpretation of nutrient and food web results can be accelerated and available as soon as possible. In other cases, some water quality, flow, and fish data will be reported on a real-time or near-real time basis.

Integration of studies on productivity in Suisun Marsh managed wetlands will help better describe the increased habitat value of Suisun Marsh and benefit of the SMSCG action.

Sacramento Deep Water Ship Channel Study

Action Goals and Objectives

This action is designed to help meet the environmental and biological objective of managing the ship channel to produce food and then deliver it downstream to maximize its potential availability to delta smelt (Table 2). The main objective of this action is to increase Delta Smelt prey density, prey quality, and delta smelt's ability to access elevated prey by stimulating primary and secondary production in the Sacramento Deep Water Ship Channel for transport to the North Delta. This action should contribute to achieving objectives for enhanced Delta Smelt growth, survival, and recruitment (Tables 1 and 2).

Current status

Science activities in the ship channel will include continuation of pre-project tidal flow, water quality (temperature, pH, dissolved oxygen, turbidity), biogeochemical (nutrients, suspended solids, chl *a*) and biological monitoring (zooplankton and fish) (Appendix C). Also planned are several targeted activities designed to provide data needed to calibrate ecosystem models. These activities will yield estimates of vertical light extinction, whole-system scale metabolism (gross and net primary production), nutrient fluxes from bottom sediments, and zooplankton grazing rates. Fish sampling will be conducted using a mobile sampling platform equipped with a video monitoring system that eliminates the need to handle fish. The study design includes sampling near shore and in open water during daytime and nighttime and includes collection of eDNA samples to help confirm the local presence of delta smelt. All data will be published on the EDI web site.

Discussion Points

The DCG and technical team discussed the value of expanding the scope of this action to include monitoring sediment resuspension and the bioavailability of contaminants. The cost and complexity of studying contaminants was noted.

- The study plan calls for collecting sediment cores capped with overlaying water and conducting laboratory incubations to determine nutrient fluxes by measuring changes in concentration within the overlaying water; would need to find a funding partner to cover the cost of running a 'presence-absence' scale analysis on a broad suite of contaminants to determine what's there; first, need determine if the Corps has already done contaminants testing (related to their dredging program).
- Any effect on sediment resuspension from reintroducing net flow of Sacramento River water to the ship channel is possibly negligible compared to the resuspension caused by ship traffic.

- Future modeling for this action will have to include a sediment transport component to assess potential effects of flow addition on the suspended sediment concentration of the local turbidity maximum zone observed in the ship channel.

North Delta Food Subsidies and Colusa Basin Drain Study

Action Goals and Objectives

The North Delta Food Subsidy – Colusa Basin Drain Study (NDFS) is intended to help meet the environmental and biological goals to maximize Delta Smelt prey density (Table 2). The action's objective is to improve prey availability to Delta Smelt by managing flow pulses to create net positive flow through the Yolo Bypass Toe Drain and transport food from the relatively food-rich North Delta region downstream (Tables 1 and 2). Enhanced Delta Smelt growth, survival, and recruitment is anticipated to result from greater food availability. With interagency support, DWR has led three experimental NDFS actions in past years (2016, 2018, and 2019) in efforts to benefit juvenile and sub-adult Delta Smelt. The redirected flow pulses have been related to increases in food web productivity (in some cases, only local) and transport of phytoplankton and zooplankton to downstream regions, including the Cache Slough Complex and lower Sacramento River (Appendix D). Replicating the 2016 NDFS action in the future will inform adaptive management decisions by helping identify what conditions contribute to differences in food web productivity between the two types of managed flow pulse.

Current status

The NDFS monitors and evaluates the effects of flow pulses (a managed NDFS flow action or non-managed pulses as a baseline) on the Delta food web during summer or fall (Appendix D). The North Delta region is relatively rich in food resources compared to other parts of the San Francisco Estuary but negative or low flows from water diversions during summer and fall limit the delivery of these resources to downstream areas where they could benefit larger numbers of Delta Smelt. The action takes an adaptive management approach to planning and implementing annual managed flow pulses (or not) in summer or fall based on a combination of factors including evaluation of past results, predicted water year type, water availability and collaboration with supporting stakeholders.

Based on previous actions findings (2016, 2018, 2019) and predicted water year type, ideally, the next flow action is being planned to replicate 2016, rerouting Sacramento River water through the Colusa Basin Drain and Yolo Bypass to downstream regions. The ability to replicate the 2016 action will depend on collaboration with USBR, local irrigation and reclamation districts, and water availability. Redirecting Sacramento River water during summer may be feasible if 2023 is a below normal, above normal, or wet year (if a dry spring) and if the project has ESA coverage. If rerouting Sacramento River water during summer is not feasible, a fall action will be considered in fall using agriculture rice drainage as in 2018 and 2019. The action would not be conducted under a Critical water year such as 2015, when very poor water quality conditions were observed in the region and water availability is low. Decision making for these alternatives will follow the general timelines outlined in this document and in the DCG Guidance document with consideration of late-winter and early spring hydrology as assessed by the DCG during March.

Science and monitoring activities for the NDFS will be similar to past years (see past 2021 -2023 Operations and Monitoring Plan, Pg. 87) and may include focused studies to inform uncertainties:

- Assessing water quality and biological responses to the managed flow pulse in different regions of the Delta, during and after the pulse, comparing responses to those of previous managed and non-managed flow pulses,
- Hydrodynamic modeling to simulate and compare habitat changes with and without the action.
- A focused stable isotope and enclosure study is being planned for future years with NDFS actions (likely starting in 2025). Stable isotope pilot studies will be completed in 2024 characterizing the isotope landscape in the North Delta and determining if a full enclosure study is warranted and feasible. The later enclosure study aims to identify whether zooplankton transported from the Yolo Bypass are consumed by Delta Smelt during and after flow pulses and/or whether phytoplankton transported from Yolo Bypass support zooplankton in the CSC, thus indirectly supporting smelt diets. Enclosures would use cultured Delta Smelt or a surrogate (Wakasagi or Mississippi Silversides) to evaluate effects of NDFS actions on Delta Smelt diets in the Cache Slough Complex. Enclosure studies may occur over one to

three years, during a Sacramento River action, combined agriculture drainage action, and a non-managed pulse year. Zooplankton communities would be sampled inside and outside of enclosures, smelt stomach contents, and smelt tissue samples (muscle, fin clip, or liver) for stable isotope analysis. Representative members of the zooplankton and primary producer communities in the Yolo Bypass and CSC that could contribute directly or indirectly to zooplankton and smelt diets would also be sampled. Carbon, nitrogen, and sulfur (or hydrogen) stable isotope signatures of Delta Smelt, zooplankton, and primary producers would be assessed to identify the proportional contribution of primary producers from the Yolo Bypass and CSC to zooplankton and smelt diets during and after flow pulses. The implementation of this special study is contingent on pilot study results, and future actions.

- A synthesis report of past North Delta managed and non-managed pulses (2011-2019) was completed in 2022 which evaluated the effectiveness of the food subsidy action and informed management of this strategy. The final report will be available in spring 2023. Ultimately, the team hopes to develop predictive tools for lower trophic level production that have been calibrated using some of the observed data.

Discussion Points

The DCG and technical team identified the potential for NDFS leads to discuss with Wim Kimmerer (San Francisco State University) and Ed Gross (RMA) if data exist to expand their modeling efforts to provide better resolution for food web dynamics and regional transport of food.

- Kimmerer and Gross have developed a "box model" to evaluate zooplankton production, transport, and survival across regions. A similar framework could help better quantify these metrics during NDFS actions.

Roaring River Distribution System Food Subsidies Study

Action Goals and Objectives

The Roaring River Distribution System Food Subsidies Study (RRDS) was designed to help meet the environmental and biological goal of managing the low salinity zone to overlap with turbid water and available food supplies

(Table 2). The action would involve holding water in the RRDS for Delta Smelt food production. The objectives of this action are to use the distribution system to produce food-rich water and release that water into Montezuma Slough or Grizzly Bay. Enhanced Delta Smelt growth, survival, and recruitment would be anticipated to result from greater food availability (Tables 1 and 2).

Current status

To increase smelt food production in the Grizzly Bay area, as part of the Delta Smelt Resiliency Strategy, in 2018 DWR installed drain gates on the western end of the RRDS in order to provide a mechanism to drain food-rich water from the canal into Grizzly Bay. However, current maintenance needs in the system, including dredging of the channel and reinforcement of the levees prevent using the system to increase food production at this time. Therefore, the project has been put on hold indefinitely.

Suisun Managed Wetlands Food Subsidies Study

Action Goals and Objectives

The Suisun Managed Wetlands Food Subsidies Study (Managed Wetlands Study) is designed to help meet the environmental and biological goal of managing the low salinity zone to overlap with turbid water and available food supplies (Table 2). The action would involve coordinating the flood and drain schedule of managed wetlands for Delta Smelt food production. The objectives of this action are to produce food-rich water and release that water into channels within Suisun Marsh. Enhanced Delta Smelt growth, survival, and recruitment would be anticipated to result from greater food availability (Tables 1 and 2).

Current Status

In summer of 2022, DWR contracted with the University of California, Davis, Dr. John Durand, to conduct a series of studies on productivity of managed wetlands in Suisun Marsh to assess the feasibility of using managed wetlands to increase Delta Smelt food supply (See workplan, Appendix F). This project will compare phytoplankton and zooplankton production, and identify drivers of production, in wetlands across seasons and across the landscape. Researchers will observe three wetland types (tidally restored, muted tidal, and managed) over two consecutive water years to understand how different management schemes affect pelagic food production. The third year will be dedicated towards sample and data analysis and reporting. Aquatic fish food production will be measured as phytoplankton and zooplankton biomass and rates of production. Researchers will use biotic and abiotic features of the wetlands to understand how rates of production vary across wetlands types, including nutrient and organic carbon concentrations, water quality parameters, water exchange, and site geomorphology and management. Such findings will help inform wetland management to complement tidal and tidally-restored counterparts in providing both food (managed wetlands) and refuge (tidal wetlands) to pelagic fishes. The rates of production developed during this projects can then be used to parameterize the zooplankton and Delta Smelt bioenergetics models used for the Delta Coordination Group's Structured Decision Making Process.

Discussion Points

There will have to be significant outreach to wetland managers to implement this at scale. There may need to be incentives to change management.

Directed Outflow Project

Action Goals and Objectives

The Directed Outflow Project (DOP) was established to test a set of hypothesized impacts of summer outflow and Yolo Bypass Toe Drain actions on Delta Smelt habitat, growth, condition, and survival. The DOP is a continuing integrated study effort among state, federal and interested groups focused on a series of surveys and experiments to aid in evaluating the benefits of outflow alteration for Delta Smelt. The collective aim of these efforts is to better inform management actions that stabilize and improve the Delta Smelt population. Hypotheses are largely based on the conceptual models within Baxter et al. (2015) and predictions in Brown et al. (2014). DOP studies overlap temporally and spatially with the SFHA and, thus, spans all three of the SFHA environmental and biological goals and most of the SFHA abiotic and biotic objectives (Tables 1 and 2).

Current Status

In 2023, the DOP will shift from high frequency, spatially expansive sampling conducted in coordination with the USFWS Enhanced Delta Smelt Monitoring Program to more temporally and spatially focused monitoring.

Understanding effectiveness of summer-fall hydrologic and food subsidy actions in stimulating or transporting primary productivity and zooplankton prey production has been limited by an inability to implement actions over multiple years and the low probability of detecting a response measured by zooplankton relative abundance. Evaluating the hypothesized benefits of these actions on Delta Smelt growth and survival is hindered by low abundance and thus capture of Delta Smelt.

The DOP will continue to conduct habitat and lower trophic monitoring in the North Delta, lower Sacramento River, Confluence, and Suisun Marsh and Bay regions. Monitoring will be more directed to support SFHA actions such as Fall X2, SMSCG, NDFS, and SDWSC. Directed monitoring will include high frequency sampling around NDFS actions to improve the statistical power to detect effects. It will also focus effort and resources in regions most likely to be influenced by a Fall X2 action. Finally, monitoring and laboratory work may be used to enhance studies already underway to better understand the mechanisms underlying actions aimed at stimulating and subsidizing lower food web production and biomass, particularly in Cache Slough and the SDWSC. Specific study plans for monitoring, research, and data analyses will be developed during fall 2023.

Topics for Potential Action Work Plan Modifications or Directed Studies

As part of the DCG discussions on the current science and monitoring surrounding SFHA components, additional science and monitoring topics and activities were identified that might improve information for quantitative scoring of SDM performance measures and/or provide a better understanding of current and proposed management actions. Sources of uncertainty for decision objectives were identified by the DCG and Science and Monitoring Work Group, followed by a discussion of potential science and monitoring activities or directed studies that could be conducted to reduce those uncertainties. Sources of uncertainty and potential science and monitoring activities are described below. A subset of these science and monitoring activities could be included in the learning objective alternatives for SDM. Other summer and fall management activities that could affect habitat conditions, such as habitat restoration and the Sacramento Regional Wastewater Treatment Plan upgrade, are beyond the scope of the SFHA but other entities have plans to evaluate the ecological responses to these actions. The results of these other studies may be considered in a general way as part of synthesis efforts but will not be the subject of stand-alone work plans here.

Suitable Habitat

Habitat suitability for Delta Smelt depends on a combination of physical habitat conditions including temperature, salinity, and turbidity and prey available to fish via bioenergetic relationships. A Delta Smelt Habitat Suitability Index (HSI) can be calculated in multiple ways, with disagreement over which approach is "best." Confidence in the ability to dynamically model turbidity in response to potential SFHA actions is low in comparison to the ability to model salinity and temperature. Water temperature can be particularly important for predictions of habitat suitability when temperatures approach optimal conditions for growth and/or exceed critical thresholds for sustaining vital physiological processes (e.g., respiration). Science activities to improve our understanding of physiological response thresholds were not discussed perhaps because a lot is known about delta smelt physiology related to water temperature. Potential science activities for this objective include: (1) describing the relative benefit of the size of the low salinity zone with and without consideration of temperature; and (2) including prey and/or competitors into a habitat suitability performance measure.

Contaminant Toxicity

Sources of uncertainty surrounding contaminants include the following: (1) how the SFHAs affect contaminant loading, concentrations, dispersal and toxicity to Delta Smelt; (2) impacts of new contaminants or contaminant mixtures on zooplankton productivity; (3) Delta Smelt responses in comparison to model species used in experiments; and (4) multi-generational or population-level effects of any of the above. Potential science activities include ones that would improve the ability to model the impacts of contaminants on Delta Smelt growth and survival, and increased field sampling to better understand if the SFHA actions affect Delta Smelt or efforts to increase their prey density through toxic pathways. A peer-reviewed relative risk model for some contaminants should be available in Spring 2023.

Zooplankton Biomass

Sources of uncertainty include underlying mechanisms that affect zooplankton, including developing a better understanding of the relationship between chlorophyll a and zooplankton population growth and of the nutritional values of zooplankton for Delta Smelt. Predicting dynamic zooplankton availability to Delta Smelt is complicated by high variability/patchiness in zooplankton occurrence, diel or tidal vertical migration, and species-specific zooplankton responses to changing environmental conditions as well as how environmental conditions affect Delta Smelt's physiological demand for prey, their ability to perceive prey, and their ability to gauge their risk of predation while foraging, etc. Potential science activities include additional zooplankton data analyses to better understand the effect of outflow and other environmental covariates on zooplankton productivity and transport. Potential modeling activities should focus on the role of wetlands and managed flow pulses in zooplankton production and transport/export. Options may include the following: 1) further develop the simple copepod biomass per unit effort model developed by Resource Management Associates for the food subsidy actions (Appendix E); 2) support data collection and modeling to develop a zooplankton

Individual Based Model for the Cache Slough Complex to evaluate wetland contributions to open waters, including in response to managed flow pulses; and/or 3) collect baseline zooplankton data Suisun Marsh managed wetlands and model the potential benefit of changes to Roaring River operations for food web support.

Delta Smelt Growth and Survival

Observing Delta Smelt responses to SFHA actions to validate model predictions is hampered by a lack of field data due to the scarcity of wild fish. Instead, for the time being, the DCG may need to trust model predictions until in situ cage experiments, or experiments using releases of captively-propagated fish can be used to validate (or refute) predictions of existing models. The Delta Smelt Individual Based Model (IBM) (Rose et al. 2013a and b) and the USFWS derivatives of it can be used to estimate growth and survival in different regions and under differing conditions. However, sources of uncertainty in the model are numerous and include the mechanistic effects of abiotic factors such as temperature and turbidity on Delta Smelt consumption and bioenergetics, which have yet to be validated. The USFWS submitted a manuscript for publication in December 2022 that highlights these uncertainties and suggests studies that would improve Delta Smelt bioenergetics modeling. Another source of uncertainty is if and how often Delta Smelt will move throughout the Delta in response to changed habitat conditions. For instance, a new study would be needed to assess whether the SMSCG action transports Delta Smelt into Suisun Marsh. If experimentally released fish successfully spawn in the wild, existing monitoring may begin to generate catches of delta smelt high enough to support inferences about movement because the fish are tagged and their initial location was observed.

Impacts to Salmonids and Other Native Fish Species

Discussions about impacts to other species have focused on how the redistribution of stored water to support the SFHA might affect stranding of juvenile spring-run Chinook Salmon in the Feather River and egg mortality of winter-run Chinook Salmon below Keswick Dam. Concerns and uncertainties include the impact of ramping rates associated with release of 100 TAF from Oroville on spring-run Chinook Salmon in the Feather River. The potential for the NDFS action to increase attraction flows for adult salmon that end up stranding them in the Yolo Bypass remains a concern. An analysis by DWR relating NDFS implementation and salmon straying is forthcoming. Ramping rate models were identified as ways to explore some of these concerns.

Informal Evaluation of Uncertainty and Potential Science Activities

An informal poll of DCG and Science and Monitoring Work Group members in December of 2021 provided rough rankings of SDM objectives based on degree of uncertainty and of science activities that would be most useful in reducing uncertainty. Only 12 people responded and responses were variable. Some general observations based on the results include greater confidence in the ability to model water costs and suitable habitat, particularly salinity and water temperature. The poll indicated lower confidence in the ability to model zooplankton biomass, contaminants, and impacts to salmonids and other fish species. Science activities ranked as having greater potential to improve understanding include all three zooplankton activities. Activities ranked as having less potential to improve understanding include potential transport of Delta Smelt or invasive aquatic vegetation by the SMSCG action and modeling Delta Smelt and salmonid impacts simultaneously. The DCG has not yet decided if and how to use this information to determine which science activities or directed studies to pursue.

Schedule and Deliverables

The specific processes, deliverables, and timelines for an annual SFHA cycle include evaluation, planning, decision-making, implementation, and reporting (shown as arrows in Figure 1), which culminates in later review by a panel of independent scientists. Key activities and deliverables, individual reporting requirements, and deadlines for each step in the process are described below and in Figure 1 and Table 3. A major consideration is that different data sets are available at different times, making the integration of all of the information at the end of each calendar year to inform the following year's planning cycle extremely difficult. Data are reported in the annual report as available, such that some data collected in one year (e.g., 2020) may appear in the 2020 annual report and other data collected that year may not appear until the 2021 annual report. To help address this issue, samples from actions specifically required by the 2019 USFWS BiOp and the ITP will be given the highest priority for processing and reporting. These information sources will then link into the SDM process for actions in subsequent years.

Action evaluation using SDM

- January: USBR and DWR will provide a synthesis of potential updates to the science and monitoring plan annually based on available data and analysis from prior years.
- March: the DCG, through the SDM process, will develop an initial habitat action proposal that includes the hypotheses to be tested, the suite of actions and operations to test the hypotheses, potential off-ramps, and expected outcomes based on: (1) water year hydrology and temperature forecasts; (2) numerical model simulations for different combinations of water year types and actions; and (3) additional models deemed necessary by the DCG that are developed.

Operations Forecast and Action Plan

- February: DWR will work collaboratively with CDFW to develop a draft Delta Outflow Operations Plan for ITP-related actions, with a final plan to be submitted at least 15 days prior to the start date of operational requirements.

- April: In each dry, below normal, above normal and wet water year, USBR and DWR will develop a Habitat Action Plan in collaboration with the DCG.

Action Implementation

- June-October: During action and no-action years, monitoring will be conducted per individual action study plans and modeling deemed useful to future action evaluation could be completed before it is needed in out years. Monthly status updates will be provided to the DCG.

Outcome Reporting and Evaluation

- December: USBR and DWR will produce a seasonal report, which combines both operations and action reporting.
- October of the following year: USBR will provide the DCG with a synthesis of the action and outcomes.

Discussion Points

CDFW suggests that the habitat action proposal include actions that are required to be implemented by the ITP, in addition to actions associated with specific hypotheses.

Water year hydrology and current and forecasted water temperatures are likely to be more important than the numerical modeling simulations in developing the habitat action proposal. The ITP relies on the DCG to use these forecasts and current year information in determining the best way to implement the SFHA; i.e., when to start operating the SMSCG, when and how to implement available blocks of water, etc.

Updates to Monitoring and Science Plan

As this monitoring and science plan is being implemented, necessary revisions to the document will be made to provide further clarification and refinement. USBR and DWR, along with technical assistance from agencies and stakeholders in the DCG, commit to reviewing this planning document following each water year, at a minimum, to identify and incorporate any necessary revisions.

References

Baxter, R., L. R. Brown, G. Castillo, L. Conrad, S. Culberson, M. P. Dekar, M. Dekar, F. Feyrer, T. Hunt, K. Jones, J. Kirsch, A. Mueller-Solger, M. Nobriga, S. B. Slater, T. Sommer, and K. Souza. 2015. An updated conceptual model of Delta Smelt biology: our evolving understanding of an estuarine fish. Technical Report 90 to the Interagency Ecological Program for the San Francisco Bay/Delta Estuary. 224 p.

Beakes, M. P., C. Graham, J. L. Conrad, J. R. White, M. Koohafkan, J. Durand, and T. Sommer. 2021. Large-scale flow management action drives estuarine ecological response. *North American Journal of Fisheries Management* 41(1): 64-77. https://doi.org/10.1002/nafm.10529

Brown, L.R., Baxter, R., Castillo, G., Conrad, L., Culberson, S., Erickson, G., Feyrer, F., Fong, S., Gehrts, K., Grimaldo, L., Herbold, B., Kirsch, J., Mueller-Solger, A., Slater, S., Souza, K., and Van Nieuwenhuyse, E. 2014. Synthesis of studies in the fall low-salinity zone of the San Francisco Estuary, September–December 2011. U.S. Geological Survey Scientific Investigations Report 2014–5041, 136 p., https://doi.org/10.3133/sir20145041.

CDFW. 2020. Incidental Take Permit for Long-Term Operation of the State Water Project in the Sacramento-San Joaquin Delta (2081-2019-066-00). California Department of Fish and Wildlife to the California Department of Water Resources, Sacramento, CA.

California Natural Resources Agency. 2016. Delta Smelt Resiliency Strategy. 11 pp.

Hammock, B.G., S.B. Slater, R.D. Baxter, N. A. Fangue, D. Cocherell, A. Hennessy, T. Kurobe, C.Y. Tai, S.J. Teh. 2017. Foraging and metabolic consequences of semi-anadromy for an endangered estuarine fish. PLoS ONE 12(3): e0173497. https://doi.org/10.1371/journal.pone.0173497

Polanksy, L., K. B. Newman, and L. Mitchell. 2020. Improving inference for nonlinear state-space models of animal population dynamics given biased sequential life stage data. *Biometrics* 2020:1-10. https://doi.org/10.1111/biom.13267.

Reed, D. J. 2019. Science plan to assess the effects of ambient environmental conditions and flow-related management actions on Delta Smelt. Collaborative Adaptive Management Team Report. 59 pp.

Rose, K.A., Kimmerer, W.J., Edwards, K.P. and Bennett, W.A., 2013a. Individual-based modeling of Delta Smelt population dynamics in the upper San Francisco Estuary: I. Model description and baseline results. *Transactions of the American Fisheries Society* 142:1238-1259.

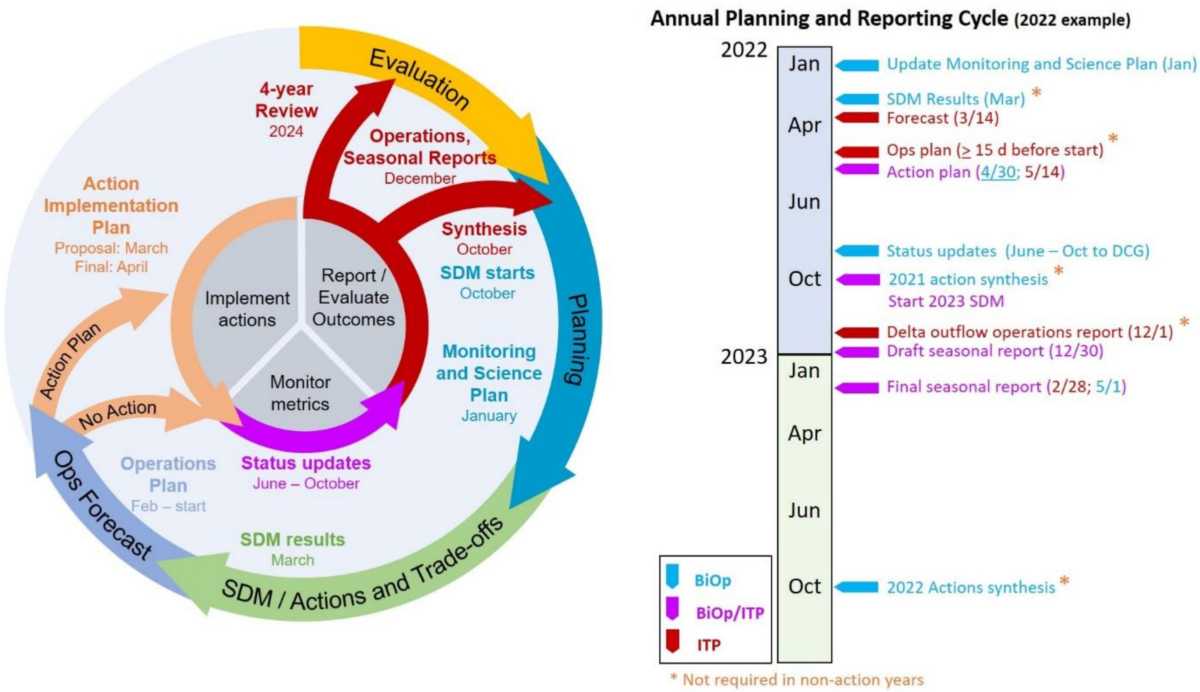
Rose, K.A., Kimmerer, W.J., Edwards, K.P. and Bennett, W.A., 2013b. Individual-based modeling of Delta Smelt population dynamics in the upper San Francisco Estuary: II. Alternative baselines and good versus bad years. *Transactions of the American Fisheries Society* 142:1260-1272.

Smith, W.E., L. Polansky, and M.L. Nobriga. 2021. Disentangling risks to an endangered fish: using a state-space life cycle model to separate natural mortality from anthropogenic losses. Canadian Journal of Fisheries and Aquatic Sciences 78: 1008-1029. http://dx.doi.org/10.1139/cjfas-2020-0251

Sommer, T., R. Hartman, M. Koller, M. Koohafkan, J. L. Conrad, M. MacWilliams, A. Bever, C. Burdi, A. Hennessy, M. Beakes. 2020. Evaluation of a large-scale flow manipulation to the upper San Francisco Estuary: Response of habitat conditions for an endangered native fish. *Plos One* 15: e0234673. https://doi.org/10.1371/journal.pone.0234673.

Figures

Figure 1 Summer-Fall Habitat Action implementation, reporting, and evaluation cycle and timeline.



Tables

Table 1 2022 DCG SDM draft objectives and subobjectives, current to 3/1/2022

Objective	Subobjectives	Description, importance
DS Growth and Survival	Individual growth Individual survival	The primary goal and driver of the decision process is to improve individual Delta smelt growth and survival in the summer-fall period, which will contribute to overall DS recruitment and persistence. Increasing delta smelt survival is the ultimate aim of the SFHAs. Growth and survival are correlated at times, but growth is more readily estimable at present so both metrics have been retained.
DS Food and Habitat	Food Habitat	The fundamental scientific hypothesis that underlies the SFHA is that targeted actions to increase feeding success of delta smelt in key locations can replace more water-costly actions like Delta outflow requirements. This is the rationale for separating “food” from “habitat” because habitat is shorthand here for physical habitat attributes like salinity, temperature, and turbidity, among others.
DS Contaminant effects	—	Some SFH actions have the potential to increase or decrease Delta Smelt exposure to contaminants, either through changing contaminant concentrations in areas where DS are expected to be and/or by affecting the overlap of suitable habitat for DS and areas of lower contaminant concentrations (e.g., Suisun Marsh and Suisun Bay have generally lower contaminant concentrations compared to other areas used by DS). Contaminant exposure could affect individual growth and survival as well as have potential multi-generational sublethal effects.

Objective	Subobjectives	Description, importance
Resource costs (water, money)	Water costs Financial costs	As resources are limited, there is an interest in using resources efficiently and improving the cost-effectiveness of achieving Delta Smelt benefits. Water costs represent any CVP or SWP water that is used to support an action, e.g., reservoir releases or export reductions. Financial costs include any expenditures on capital and operating costs for implementing an action (e.g., costs related to operating the gates more frequently, monitoring, special studies, etc.)
Water supply reliability	—	This objective reflects the importance of year-to- year water availability for a range of human uses.
Effects on other native species	—	SFHA may have positive or negative effects on other native and nonnative species. Of particular concern are ESA- and CESA-listed species including winter- and spring-run Chinook Salmon, steelhead, and Longfin Smelt, as well as fall-run Chinook Salmon, which are not ESA-listed.
—	Upstream of Delta (Sacramento River basin)	Some alternatives may decrease reservoir storage and associated cold water pool availability which may result in warmer water temperatures and, consequently, less suitable spawning conditions, increased salmonid egg mortality, and less suitable rearing conditions. Changes in reservoir operations to support SFHA could impact winter- and spring-run salmon in the Sacramento and Feather rivers, respectively. The conservation of winter-run salmon is acutely tied to water storage in Shasta Reservoir because egg incubation occurs over the summer when air temperatures are very high and must be mitigated using coldwater releases from the reservoir. Any action that increases demand on Shasta storage has the potential to impact the survival of winter-run eggs and fry. Some of these detrimental effects may occur in the water year of the SFHA action; others in the subsequent year depending on whether or not reservoirs are refilled.

Objective	Subobjectives	Description, importance
—	Upstream of Delta (San Joaquin River basin)	Some alternatives may decrease New Melones storage and associated cold water pool availability which may result in warmer water temperatures (most likely during the summer) and, consequently, less suitable rearing conditions for steelhead in the Stanislaus River. Some of these detrimental effects may occur in the water year of the SFHA action; others in the subsequent year depending on whether or not New Melones Reservoirs is refilled.
—	South of Delta	Wildlife refuges south of the Delta rely on exported water for some of their water supplies that are used to create habitat opportunities for migratory birds and other wildlife. SFHA that lower exports may impact water availability to refuges.
—	Estuarine	Adult fall-run salmon migrating into the Delta cue on their natal rivers by smelling the source water. Re-routing Sacramento River water into the Yolo Bypass per some NDFS alternatives may increase straying of salmon into the bypass where they cannot spawn and may not find a path back into the river. 100 TAF may affect Longfin Smelt, and, depending on timing, Spring-run Chinook. A potential for delayed effects if an action reduces storage that is not refilled and leads to reduced winter/spring Delta outflow in the water year following the SFHA action.

Objective	Subobjectives	Description, importance
Learning	Inform the development of new actions Understand the magnitude of effects	Learning is important for improving understanding of the fundamental hypothesis underlying the SFHA including how effectively and efficiently actions can be taken that will increase DS growth and survival. There are two main types of learning that are of interest (1) learning on new potential management actions that could be implemented in the future (e.g., food production in Roaring River and SDWSC), and (2) understanding the magnitude of effects of actions that are currently being implemented (e.g., NDFS, SMSCG). In particular, learning may help to identify opportunities to increase efficiency, i.e., to lower resource costs for the same magnitude of benefit.

Table 2 Abiotic and biotic objective categories and responses measured by Summer-Fall Habitat Action science and monitoring activities and aligned with SFHA performance metrics (as described in the Biological Opinion). F = field-collected fish; E = fish contained in enclosures; * = response only measured in some years.

SFHA Goal	SFHA Objective	Response Type	DOP	SMSCG	NDFS	SDWSC	RR	BiOp Performance Metric
Maintain low salinity habitat in Suisun Marsh and Grizzly Bay	Increase the overlap of suitable salinity, turbidity, temperature, and hydrodynamics for Delta Smelt (DS)	Hydrodynamics Salinity Temperature Turbidity Other abiotic conditions	X	X				Habitat Acreage *Quantity*
	Maximum time period when salinity is at or below 4 ppt at Belden's Landing		X	X				
Establish contiguous low salinity habitat from Cache Slough Complex to the Suisun Marsh	Increase the overlap of suitable salinity, turbidity, temperature, and hydrodynamics for DS	Hydrodynamics Salinity Temperature Turbidity Other abiotic conditions	X	X	X	X		DS presence / absence in target and other areas
		DS presence/absence	X	X	X	X		

SFHA Goal	SFHA Objective	Response Type	DOP	SMSCG	NDFS	SDWSC	RR	BiOp Performance Metric
		DS life history diversity	X	X				
Manage the low salinity zone to overlap with turbid water and available food supplies	Maximize DS prey density	Nutrients	X	X	X	X		Habitat Acreage *Quality*
		Nutrient uptake rate			X			
		Chl a	X	X	X	X	X	
		Phytoplankton abundance, biomass	X	X	X	X	X	
		Phytoplankton composition	X	X	X	X	X	
		Phytoplankton productivity			X	X	X	
		Microcystis biomass	X	X	X		X	

SFHA Goal	SFHA Objective	Response Type	DOP	SMSCG	NDFS	SDWSC	RR	BiOp Performance Metric
		Zooplankton abundance, biomass	X	X	X	X	X	
Manage the low salinity zone to overlap with turbid water and available food supplies	Maximize DS prey density	Zooplankton composition	X	X	X	X	X	Habitat Acreage *Quality*
		Clam abundance, biomass	X	X	X*	X	X	
	Minimize exposure to contaminant effects	Contaminants	X		X		X	Recruitment projections
	Maximize DS individual growth and survival	Diet	X		E*			
	(X= field collected fish; E = enclosure fish)	Growth	X	X/E*	E*			
		Condition	X/E*	X/E*	E*			
		Fecundity	X	X/E*				

SFHA Goal	SFHA Objective	Response Type	DOP	SMSCG	NDFS	SDWSC	RR	BiOp Performance Metric
		Recruitment	X	X				
		Survival	X	X/E*	E*			
		Fish spp. relative abundance	X	X	X	X		

Table 3 SWP ITP timeline for operations, planning, implementation, and reporting

Date	Operations & Planning	Science
January	—	—
February	DWR work collaboratively with DFW to prepare a draft Delta Outflow Operations Plan	—
	Provide comments to DWR about Summer-Fall Synthesis Report (Feb 28)	
March	DCG collaboratively assess hydrologic, climate, and fish data (March 15)	—
	DFW-DWR continue to refine Draft Delta Outflow Operations Plan based on late-winter and early spring hydrology	
April	Draft Summer-Fall Action Plan due to DCG that includes deployment of blocks of water anticipated to be available (April 15)	Planned science and monitoring for Summer-Fall Action Plan (April 15)
May	DCG reviews of Summer-Fall Action Plan due (May 1)	
	Final Summer-Fall Action Plan due to DCG (May 15)	—
	DFW and DWR integrate final schedule for deployment of blocks of water into the Delta Outflow Operations Plan.	
June	—	—
July	*Potential Actions*	—

Date	Operations & Planning	Science
August	—	*Field Sampling*
September	—	—
October	Delta Outflow Operations Report to DFW (Oct 31)	—
November	—	—
December	—	Summer-Fall Action Synthesis Report due to DCG (Dec 31)