Work Plan for Monitoring and Assessment of Proposed Suisun Marsh Salinity Control Gates Action, 2018-2020

By Department of Water Resources Division of Environmental Services

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Figures

Tables

Abbreviations

20-mm	20-mm survey
AMP	Adaptive management plan
BiOp	Biological Opinion
BPUE	Biomass per unit effort
CDFW	California Department of Fish and Wildlife
CDWR	California Department of Water Resources
CVP	Central Valley Project
Delta	Sacramento-San Joaquin Delta
DSRS	Delta Smelt Resilience Strategy
FLaSH	Fall low salinity habitat
FMWT	Fall Midwater Trawl
HSG	Habitat Study Group
IEP	Interagency Ecological Program
LSH	Low salinity habitat
LSZ	Low salinity zone
MAF	Million acre feet
MAST	Management, Analysis, and Synthesis Team
NRC	National Research Council
NTU	Nephelometric turbidity unit
OMR	Old and Middle River
POD	Pelagic organism decline
PSU	Practical Salinity Unit
RPA	Reasonable and Prudent Alternative
SFE	San Francisco Estuary
SKT	Spring Kodiak trawl
SRDWSC	Sacramento River Deep Water Ship Channel
SSC	Suspended sediment concentration
Suisun Bay	Suisun Bay and associated embayments
SWP	State Water Project
SWRCB	State Water Resources Control Board

USFWS	U.S. Fish and Wildlife Service
TNS	Summer townet survey
UCD	University of California at Davis
X2	The location of the near-bottom 2 PSU salinity isohaline measured in kilometers from the Golden Gate, following the river channel

Introduction

The following work plan describes the basis and design for monitoring and evaluation of a potential management action during drier seasons (e.g. Summer-Fall of 2018) to benefit the Delta Smelt *Hypomesus transpacificus,* a federal and state listed species endemic to the San Francisco Estuary (Figure 1). Specifically, we propose to operate the Suisun Marsh Salinity Control Gates (SMSCG) in summer to improve salinity and habitat conditions for Delta Smelt. The concept of altering outflow and operations to benefit rearing stages of Delta Smelt is not new. Action 4 of the Biological Opinion (BiOp) on the Long-Term Operational Criteria and Plan for coordination of the Central Valley Project (CVP) and the State Water Project (SWP) (USFWS 2008) explicitly directs augmentation of Delta outflow during the fall to improve fall habitat for Delta Smelt, when the water year is above normal. Since the BiOp, there has been increased interest in targeted flow & habitat actions during other times of the year. During spring/summer of 2016 the Delta Smelt Resiliency Strategy (DSRS) (CNRA 2016) was circulated and a final draft released in July 2016. The DSRS is a science-based approach to voluntarily address both immediate and near-term needs of Delta Smelt, and promote their resiliency to drought conditions as well as future variations in habitat conditions. The document relies on concepts from a new conceptual model of Delta Smelt ecology (IEP-MAST 2015) and articulates a suite of actions that could be implemented in the next few years to benefit Delta Smelt. Included in these actions was pilot operation of the SMSCG in summer to improve salinity and habitat conditions for Delta Smelt. This action was included as part of a suite of other actions such as aquatic weed removal, flow-related experiments (North Delta Food Web, Summer Flow Augmentation), and habitat restoration (CNRA 2016).

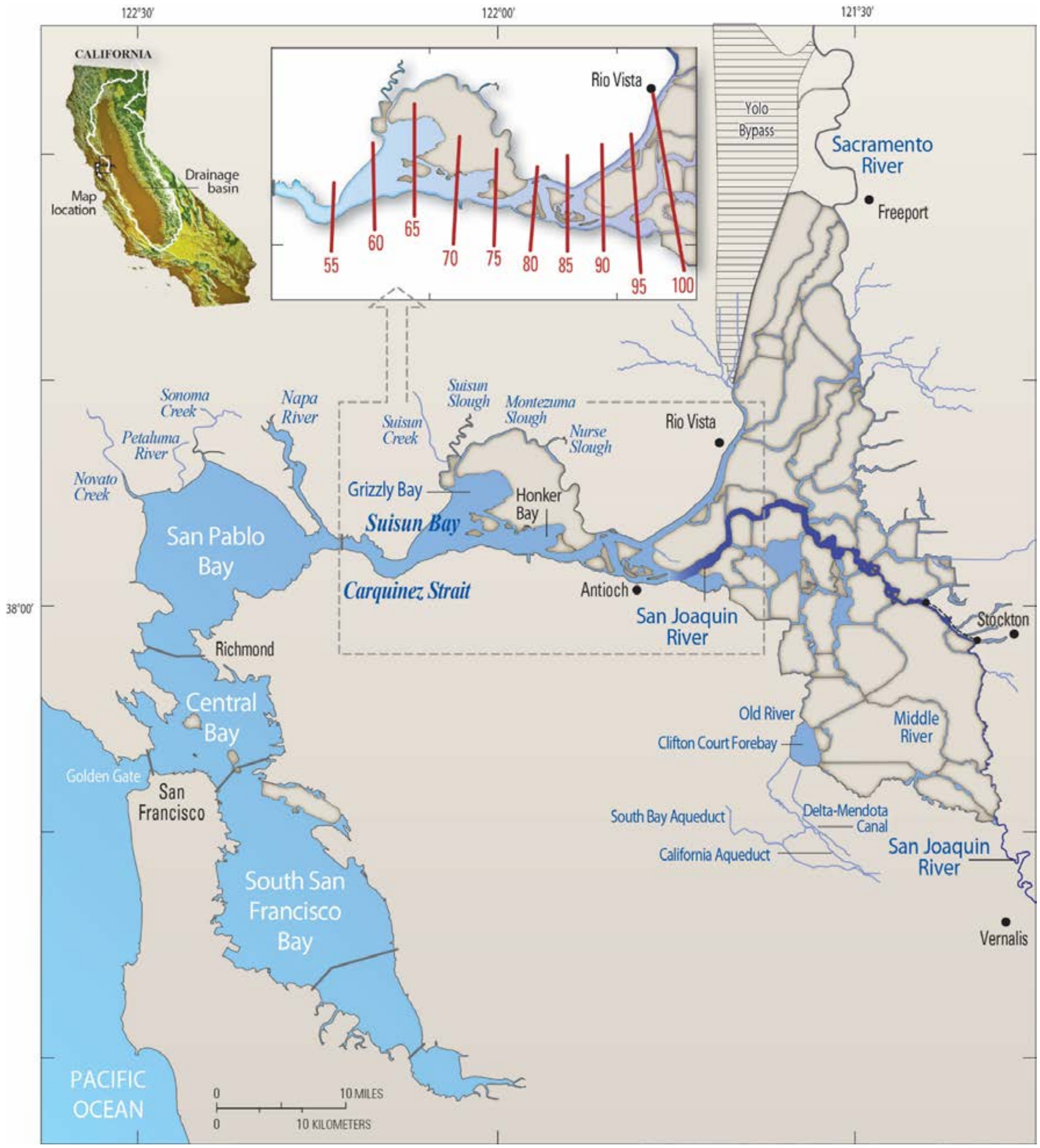


Figure 1. San Francisco Bay Estuary. Also shown are locations corresponding to different values of X2, which is the horizontal distance in kilometers from the Golden Gate up the axis of the estuary to where tidally averaged near-bottom salinity is 2 (adapted from Jassby and others, 1995).

Purpose and Scope

For this work plan we focus on a management action in which SMSCG are operated in summer to improve salinity and habitat conditions for Delta Smelt in the Bay-Delta . This action is conceptually related to the companion North Delta Food Web Project, where dry season flows will be increased through the Yolo Bypass for the purposes of improving food web conditions for Delta Smelt. The SMSCG project also has linkages to Action 4 of the BiOp, which also seeks to improve Delta Smelt habitat during the drier fall months (USFWS 2008). As will be described later in this document, the SMSCG and the other actions noted above area all considered as part of the Collaborative Adaptive Management Team (CAMT's) efforts to provide guidance for flow and habitat actions under the BiOp and the DSRS. Since all the actions listed above are related to flow manipulations, the monitoring and evaluation covered in this plan will be included as part of the Interagency Ecological Program's Flow Evaluation Project Work Team (IEP FLoAT), an open forum to coordinate many of the proposed actions. Hence, there is substantial overlap between the current work plan for SMSCG and the monitoring and evaluation reports prepared by IEP FLoAT for other actions such as Fall X2 (e.g. Brown *et al*. 2017).

This work plan has 3 major objectives. The first major objective is to develop a set of hypotheses to assess regarding the expected effects of altered SMSCG operations on ecological conditions and Delta Smelt in the upper SFE. The second major objective is to provide an integrated work plan for monitoring and assessment studies that provide the data needed for evaluation of the hypotheses, including testing of corresponding predictions. The third major objective is to begin to put the expected results of the action into context within the larger body of knowledge regarding the SFE (Figure 1) and in particular the upper SFE, including the Sacramento-San Joaquin Delta (Delta) and Suisun Bay and associated embayments (Suisun Bay) (Figure 2).

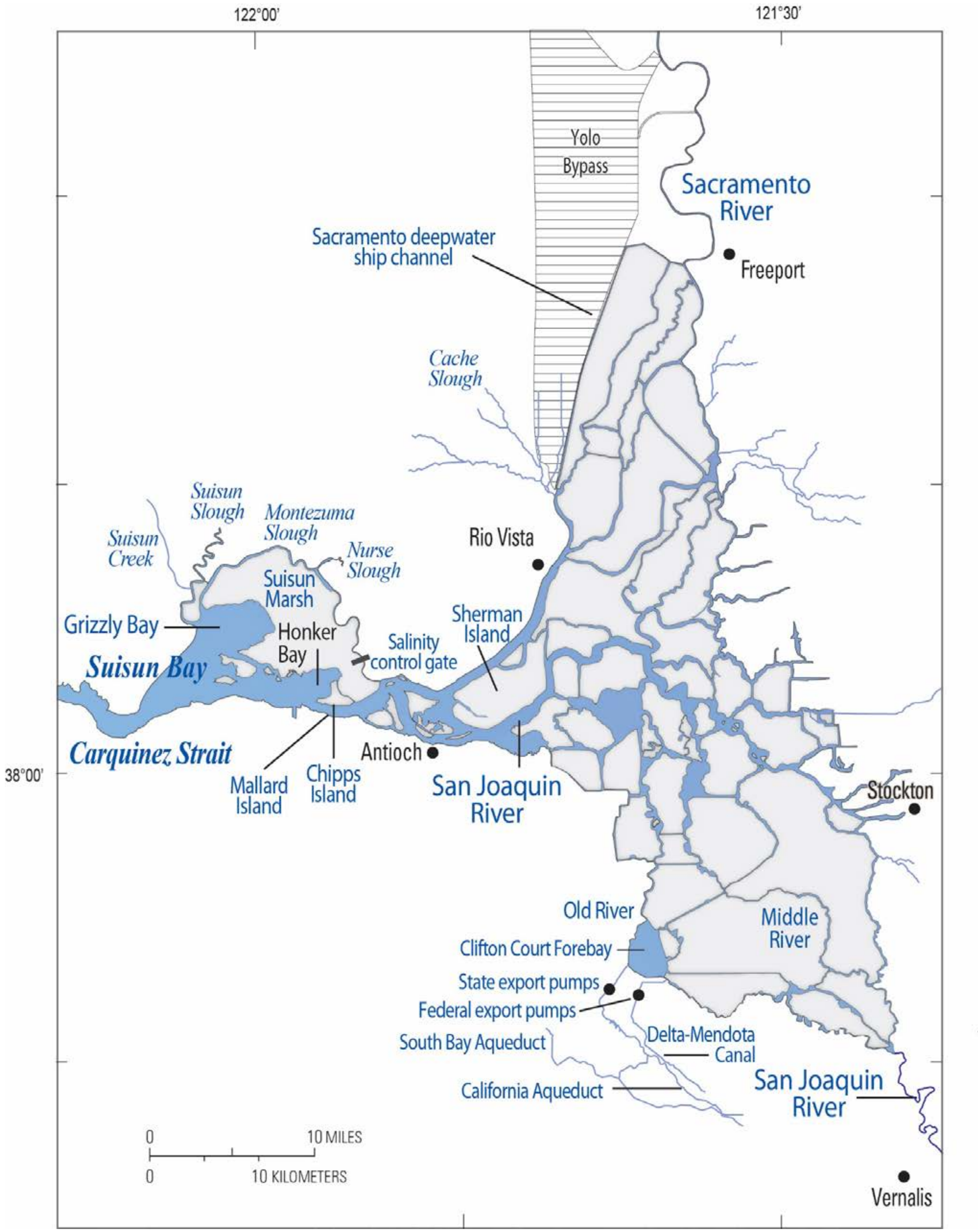


Figure 2. Sacramento-San Joaquin Delta, Suisun Bay, and associated areas (from IEP-MAST 2015).

The overall focus this work plan is on Suisun Marsh and Suisun Bay: however, we also include the freshwaters upstream of the low salinity zone (LSZ – see below) in the North Delta, and the LSZ to put the habitat needs of Delta Smelt into a broader context. Note that this geographical emphasis does not mean that downstream areas are unimportant for Delta Smelt. For example, Delta Smelt can tolerate higher salinities (Komoroske et al. 2016) and it is well known that the Napa River region represents key habitat for this species (Merz et al. 2011).

The North Delta includes the Sacramento River from Freeport to the area between Rio Vista and Decker Island and various sloughs and waterways to the west of the Sacramento River. The Cache Slough Complex extends north of the confluence of Cache Slough with the Sacramento River to the upper extent of tidal influence (Figure 3). Because our effort is focused on Delta Smelt and its habitat, the LSZ is defined as the area of the upper SFE with salinity ranging from 0.5 to 6 PSU, consistent with recent reports and conceptual models (Brown et al. 2014, IEP-MAST 2015). This is generally considered a core part of the distribution of Delta Smelt (Bennett 2005), although fish also occur outside this core range (Feyrer et al. 2007, Kimmerer et al. 2009, Merz et al. 2011; Sommer et al. 2011a). The geographic boundaries of the LSZ are dynamic both seasonally and among years, because periods of high outflow push the LSZ seaward, but in drier periods the LSZ is located further inland. Therefore, we also consider fresher and more brackish waters to the extent needed to understand both Smelt responses and the role of the LSZ.

Because the current project is proposed to begin in Summer 2018, this period and months that immediately precede and follow that season are the focus of this work plan. However, IEP monitoring and other studies have been ongoing in the SFE for many years providing the opportunity to put the current work plan into a broader temporal context. In fact, this broad perspective is likely critical to understanding how flow augmentation can contribute to the protection and recovery of Delta Smelt. This report represents an initial step in addressing this broader scope.

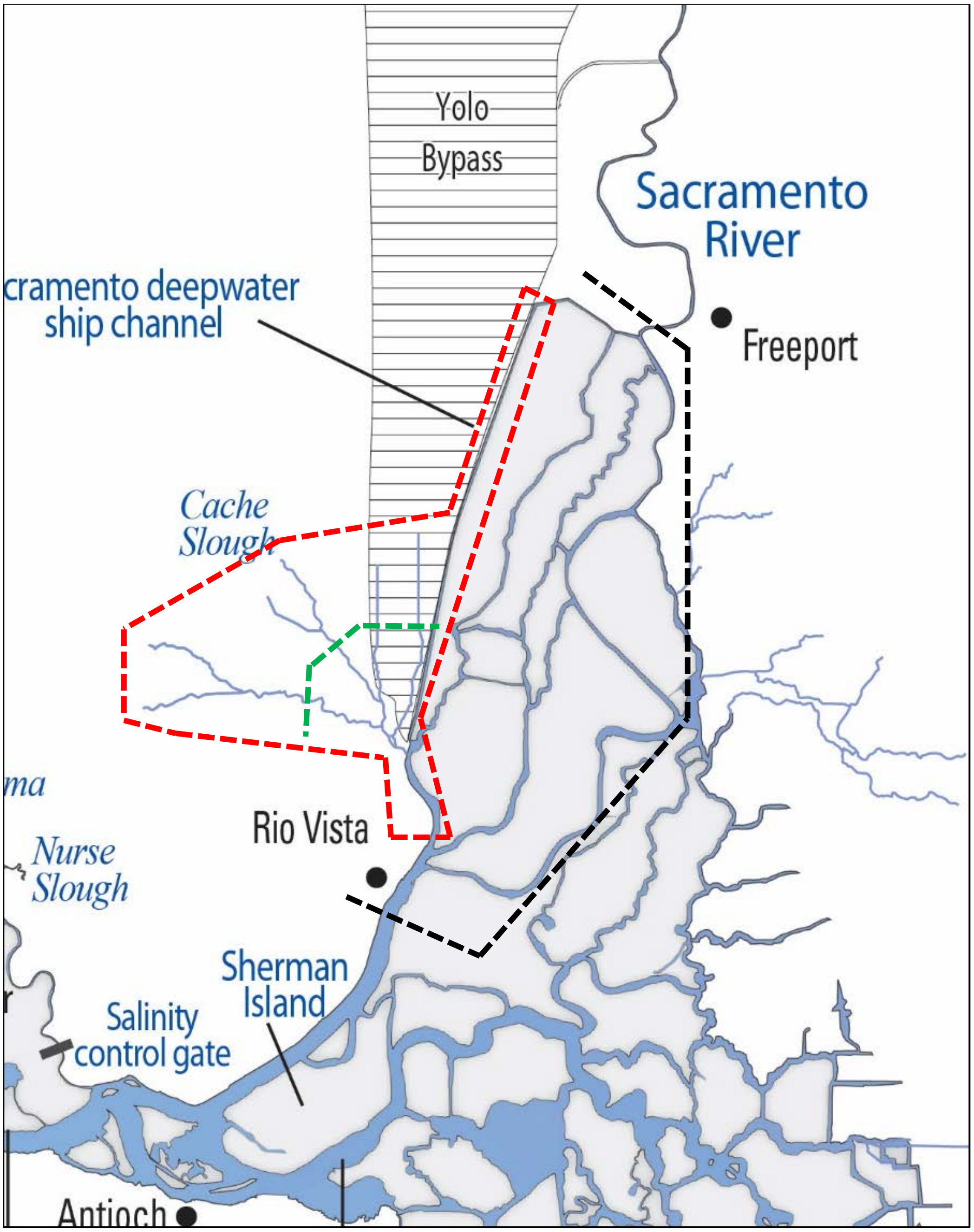


Figure 3. Regions of the North Delta. The black dotted line defines the north, south, and eastern extent of the North Delta as defined for this work plan. The red dotted line encloses the Cache Slough Complex. The green dotted line is an approximation of the division between the northern and southern Cache Slough Complex.

Background

Delta Smelt

In this section we summarize some general information about Delta Smelt biology for readers that are unfamiliar with the species. Details of factors believed to be affecting the biology of Delta Smelt are discussed extensively in additional sections of this work plan. Early information on the Delta Smelt population was collected as part of sampling and monitoring programs related to water development and Striped Bass *Morone saxatilis* management (Erkkila et al. 1950, Radtke, 1966, Stevens and Miller 1983). Striped Bass is an exotic species but supported a popular and valuable sport fishery when development of the CVP and SWP began (Moyle 2002). These early monitoring efforts, subsequently consolidated with other activities under the auspices of the IEP, provided sufficient information on the decline of Delta Smelt (Fig. 4) (Moyle et al. 1992) to support a petition for listing under the federal Endangered Species Act, which resulted in the species being listed as threatened in 1993 (USFWS 1993). Reclassification from threatened to endangered was determined to be warranted but precluded by other higher priority listing actions in 2010 (USFWS 2010). The species status was changed from threatened to endangered under the State statute in 2009 (California Fish and Game Commission 2009). Subsequent declines in the Delta Smelt in concert with three other pelagic fishes (Figure 4) caused increased concern for avoiding jeopardy and achieving recovery of Delta Smelt. These declines are often referred to as the Pelagic Organism Decline (Sommer et al. 2007, Baxter et al. 2008, 2010).

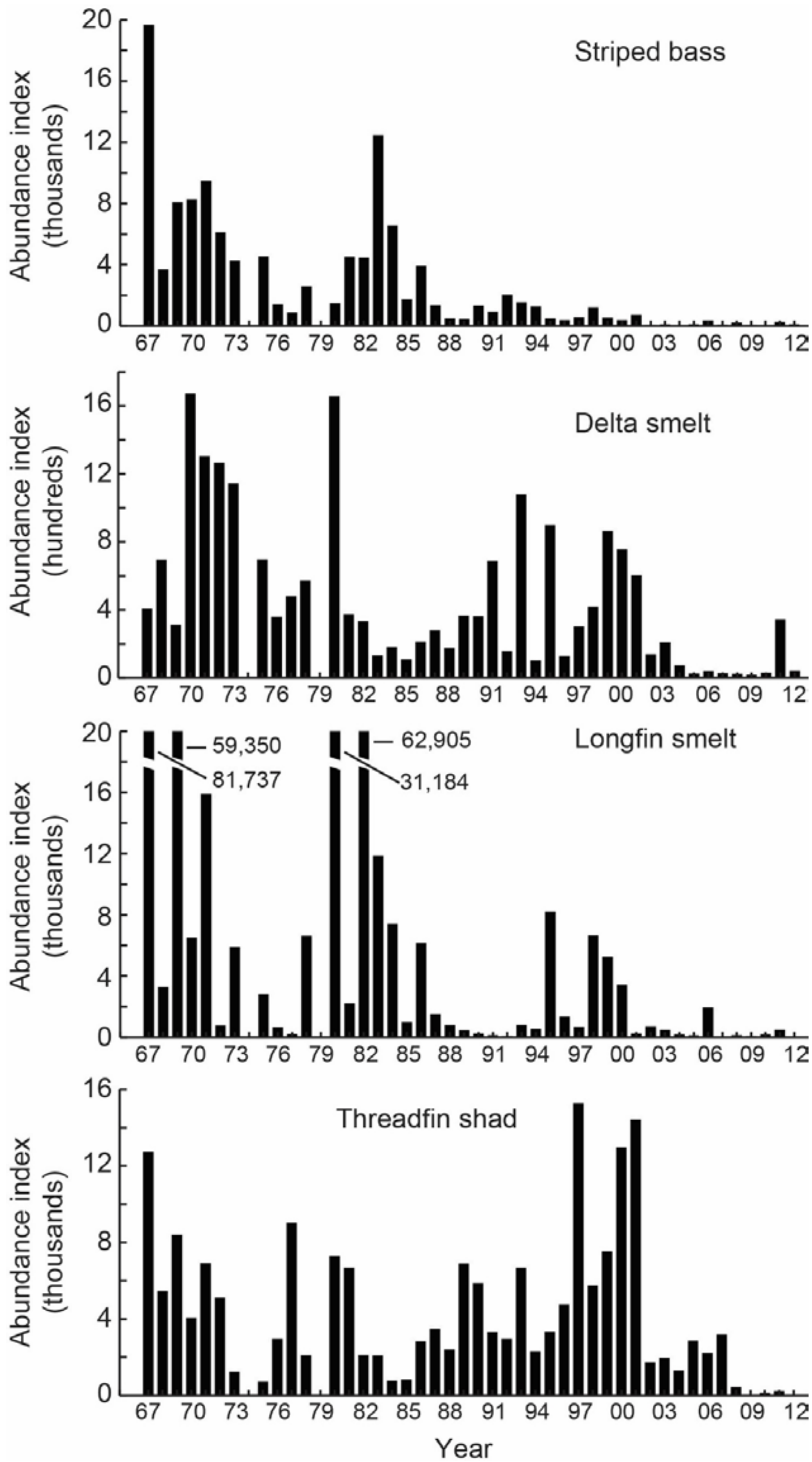


Figure 4. Trends in abundance indices for four pelagic fishes from 1967 to 2010 based on the Fall Midwater Trawl, a California Department of Fish and Game survey that samples the upper San Francisco Estuary. No sampling occurred in 1974 or 1979 and no index was calculated for 1976. Note that the y-axis for longfin smelt represents only the lower 25% of its abundance range to more clearly portray the lower abundance range (from IEP-MAST 2015).

The Delta Smelt is endemic to the upper SFE (Moyle et al. 1992, Bennett 2005). Delta Smelt is a slender-bodied fish typically reaching 60–70 mm standard length (SL) with a maximum size of about 120 mm SL. Delta Smelt feed primarily on planktonic copepods, mysids, amphipods, and cladocerans. Many Delta Smelt complete the majority of their life cycle in the Low Salinity Zone (LSZ) of the upper estuary and use the freshwater portions of the upper estuary primarily for spawning and rearing of larval and early post-larval fish (Figure 5) (Dege and Brown 2004, Bennett 2005); however, some Delta Smelt do complete their entire life cycle in freshwater and some appear to complete their entire life cycle in brackish water (Bush 2017). The continued global existence of the species is dependent upon its ability to successfully grow, develop, and survive in the SFE. The current range of juvenile and sub-adult Delta Smelt encompasses the Cache Slough Complex, and Sacramento River in the North Delta, the confluence region in the western Delta, and Suisun Bay (Figure 6). They also occur in the Napa River estuary in wetter years. Historically, juvenile and sub-adult Delta Smelt also occurred in the central and southern Delta (Erkkila et al. 1950), but they are now rare during the summer and fall months (Bennett 2005, Nobriga et al. 2008, Sommer et al. 2011a). Juvenile and sub-adult Delta Smelt occur mostly in the LSZ, with a center of distribution around salinity1-2 (Swanson et al. 2000, Bennett 2005, Sommer et al. 2011a). While some Delta Smelt complete their entire life cycle in fresh water, a large portion of the spawning population appears to rear in the LSZ (Bush 2017). Delta Smelt are generally not found at salinity above 14; however, with acclimation some can survive full seawater (Komoroske et al. 2014) for a short time. Komoroske et al. (2016) suggested that the physiological costs to Delta Smelt of living outside the low salinity zone, particularly at higher salinities, are energetically expensive and may preclude long-term occupancy of higher salinity water.

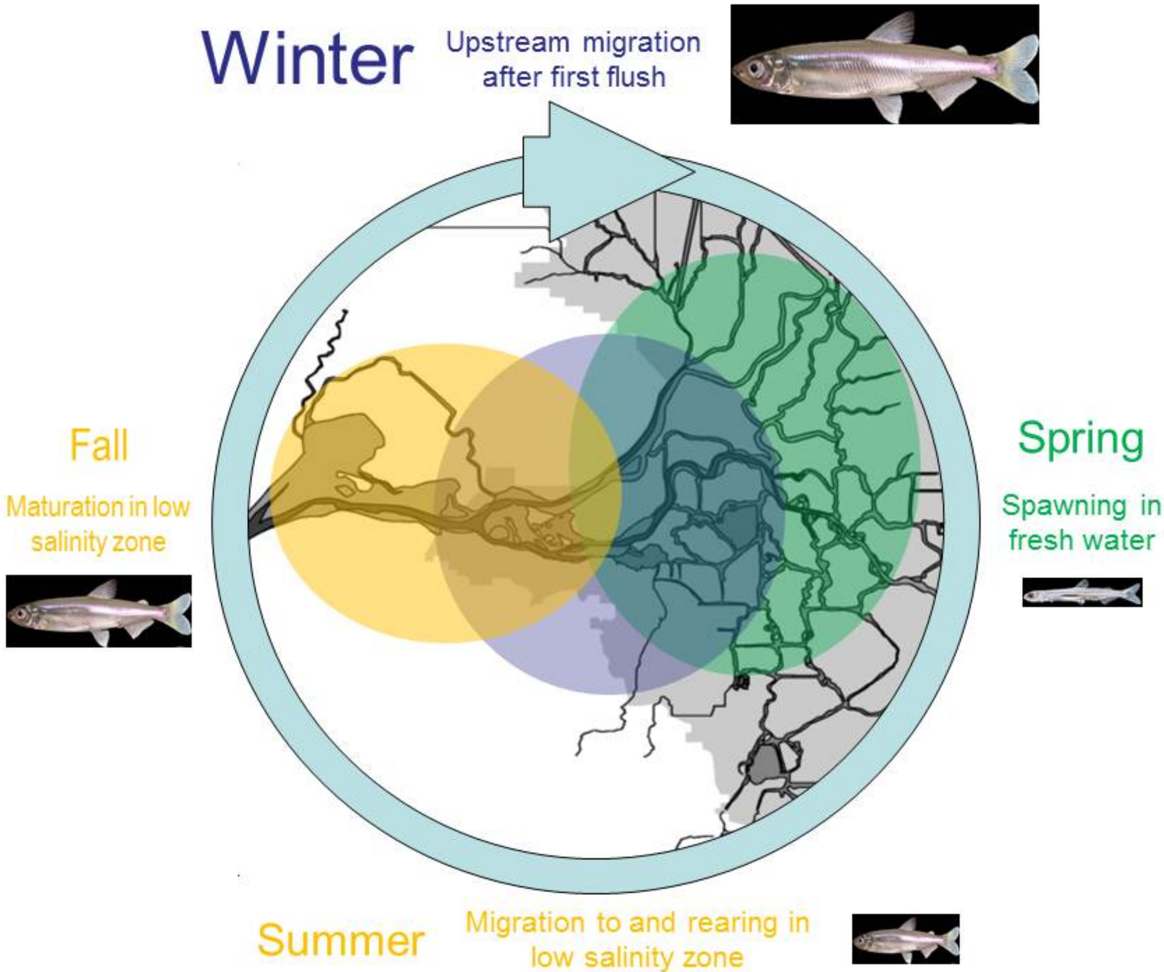


Figure 5. Simple conceptual diagram of the Delta Smelt annual life cycle for the dominant Low Salinity Zone rearing and the upper Delta spawning life history (modified from Bennett, 2005).

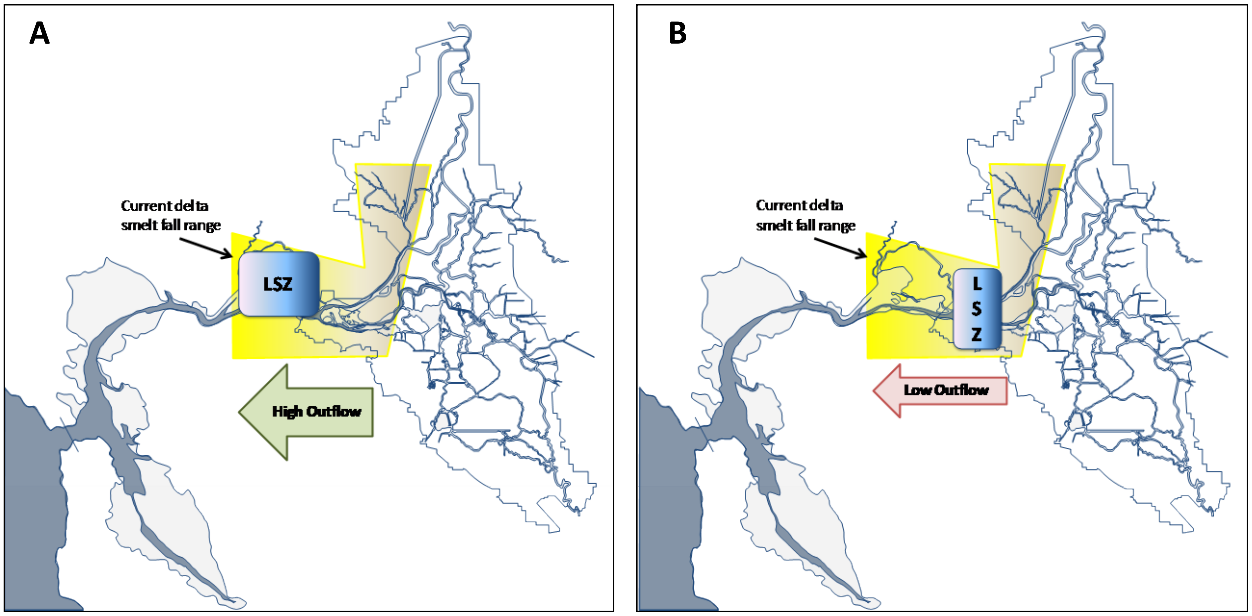


Figure 6. In the fall, Delta Smelt are currently found in a small geographic range (yellow shading) that includes the Suisun Bay, the river confluence, and the northern Delta, but most are found in or near the low salinity zone (LSZ). A: The LSZ overlaps the Suisun Bay under high outflow conditions. B: The LSZ overlaps the river confluence under low outflow conditions (from Reclamation, 2012).

Upstream movement of maturing adults generally begins in the late fall or early winter with most spawning taking place from early April through mid-May (Bennett, 2005; Sommer et al. 2011a). Not all maturing fish move up into the Delta to spawn and the movements to maturation and spawning areas can be thought of as a more general movement into freshwater areas (Murphy and Hamilton 2013). Many larval Delta Smelt move downstream with tidal or riverine flow until they reach favorable rearing habitat in the Low Salinity Zone (Dege and Brown, 2004). As noted earlier, some fish remain in freshwater, upstream areas including the Cache Slough complex and the lower Sacramento River year-round (Sommer et al. 2011a, Bush 2017). A very small percentage of Delta Smelt survive into a second year and may spawn in one or both years (Bennett 2005)

Summer physical habitat has been described by Nobriga et al. (2008) with summer (June-July) distribution of Delta Smelt determined by areas of appropriate salinity but also with appropriate turbidity and temperatures. Similarly, Feyrer and others (2007, 2010) found the distribution of Delta Smelt to be associated with salinity and turbidity during fall months (September-December). Kimmerer et al. (2009), Sommer et al. (2011a), and Merz et al. (2011) expanded on these studies by examining the habitat associations and geographic distribution patterns of Delta Smelt for each of the major IEP fish monitoring surveys. Manly et al. (2015) found that Delta Smelt were associated with some specific geographic regions in the fall, and Bever et al. (2016) found Delta Smelt associated with metrics of hydrodynamics (e.g., average water column velocity) in Suisun Bay during the fall. Overall, these studies demonstrated that most Delta Smelt have a center of distribution near the 2 isohaline, but may shift during winter and spring months when spawning and early development occur over a broader region including upstream freshwater sloughs, as well as the downstream Napa River in wet years.

Fisch (2011) determined that individuals inhabiting freshwater areas were not genetically unique relative to Delta Smelt captured from other regions of the system; rather, there is a single, panmictic Delta Smelt population in the estuary. Although not conclusive, this finding suggests that freshwater resident Delta Smelt do not form a separate, self-sustaining population. Rather, it seems likely that the life history of Delta Smelt includes the ability to rear in fresh water if other factors are favorable; however, the absence of Delta Smelt from riverine non-tidal habitats upstream of the Delta suggests that there are limits on freshwater residence.

Although abundance of Delta Smelt has been highly variable, there is a demonstrable long-term decline in abundance (Figure 4; Manly and Chotkowski 2006, USFWS 2008, Sommer et al. 2007, Thomson et al. 2010). The decline spans the entire period of survey records from the completion of the major reservoirs in the Central Valley through the POD (pelagic organism decline) (IEP-MAST 2015). Statistical analyses confirm that a step decline in pelagic fish abundance marks the transition to the POD period (Manly and Chotkowski, 2006, Moyle and Bennett 2008, Mac Nally et al. 2010, Thomson et al. 2010, Moyle et al. 2010) and may signal a rapid ecological regime shift in the upper estuary (Moyle et al. 2010, Baxter et al. 2010). The decline of Delta Smelt has been intensively studied as part of an IEP effort to understand the POD decline (Sommer et al. 2007, Baxter et al. 2010). The POD investigators have concluded that the decline has likely been caused by the interactive effects of several causes, including both changes in physical habitat (e.g., salinity and turbidity fields) and the biotic habitat (i.e., food web). This conclusion was generally supported by a recent independent review panel (NRC, 2012) and recent literature reviews (IEP-MAST 2015, Moyle et al. 2016, Brown et al. 2016).

A wide variety of statistical approaches have been applied to studies of Delta Smelt in the SFE. Various forms of regression and multiple regression models have been widely applied (e.g., Manly and Chotkowski 2006, Feyrer et al. 2010, Miller et al. 2012). General additive models have been used to identify important abiotic habitat factors (Feyrer et al. 2007, Nobriga et al. 2008). Additional models include Bayesian change point models (Thomson et al. 2010) and a Bayesian-based multivariate autoregressive model of Delta Smelt fall abundance (Mac Nally et al. 2010). Adaptive management calls for the use of quantitative models when available. Importantly, these studies differed widely in methodology and objectives and rarely evaluated the same environmental factors. As a result, they often reached alternative conclusions about the direct or indirect importance of the same environmental factor on the species.

Life cycle models that quantify and integrate many aspects of Delta Smelt biology are expected to provide results that will help guide outflow management and other management actions in the coming years. Maunder and Deriso (2011) developed a statistical state–space multistage life cycle model to evaluate the importance of various factors on different life stages of Delta Smelt. Another life cycle model developed by Newman et al, currently under development, has a state-space structure similar to Maunder and Deriso (2011). It differs from the Maunder and Deriso model in three critical ways: (1) the model is spatially explicit, so that management actions can be assessed at a local level, (2) the temporal resolution is finer, a monthly time step, and (3) data from more fish surveys are being used to fit the model (Ken Newman, written communication, 2012). A numerical simulation model has also been developed (Rose et al. 2013a,b). The life cycle models and numerical simulation model could be used to evaluate hypothesized associations in conceptual models as the SMSCG project develops.

Conceptual Model

As a follow-up to the fall low-salinity habitat studies (Brown et al. 2014), the IEP established the Management, Analysis and Synthesis Team to develop a new conceptual model for Delta Smelt Biology (IEP-MAST 2015). In this workplan, we use the original framework of the FLaSH conceptual model, which includes stationary abiotic habitat components, dynamic abiotic habitat components, dynamic biotic habitat components, and Delta Smelt responses (i.e., pelagic recruitment; Figure 7). We use the IEP-MAST conceptual model (IEP-MAST 2015) and subsequent literature (e.g., Moyle et al. 2016) to identify habitat components that likely are important to Delta Smelt in the summer (Figure 8) and fall (Figure 9) and to identify likely Delta Smelt biological responses. In contrast to the FLaSH approach, which focused on the characteristics of the Low Salinity Zone as it moved through the estuary in response to flow, we put our FLOAT conceptual model in the context of the fixed geography of the region because the SMSCG project is expected to affect only the Marsh and nearby areas. The idea that specific locations may be preferred by Delta Smelt has also received recent support in the literature (Merz et al. 2011, Bever et al. 2016, Manly et al. 2015).

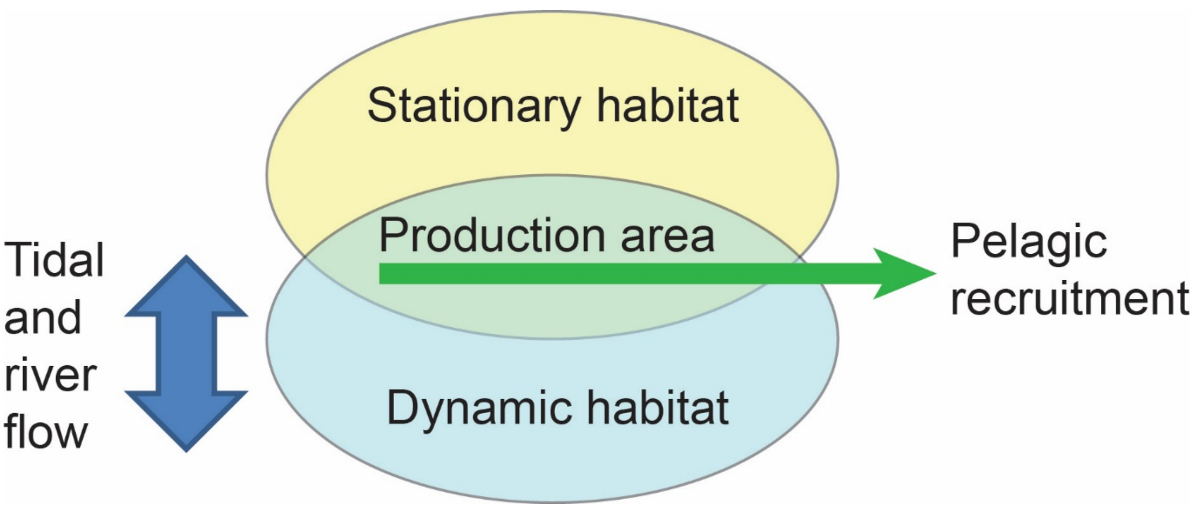


Figure 7. Illustration showing estuarine habitat conceptual model (modified from Peterson 2003).

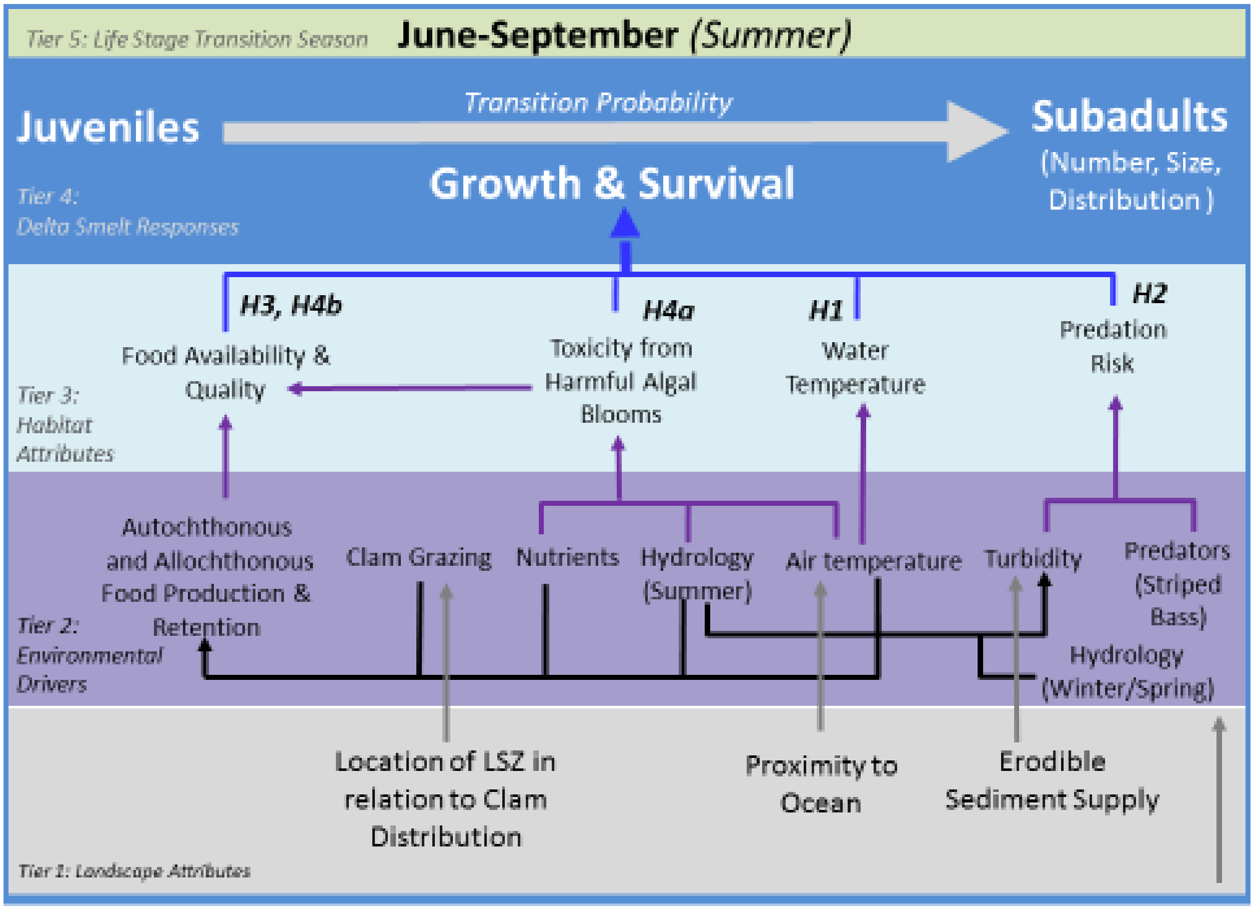


Figure 8. Summer conceptual model for Delta Smelt (from IEP-MAST 2015).

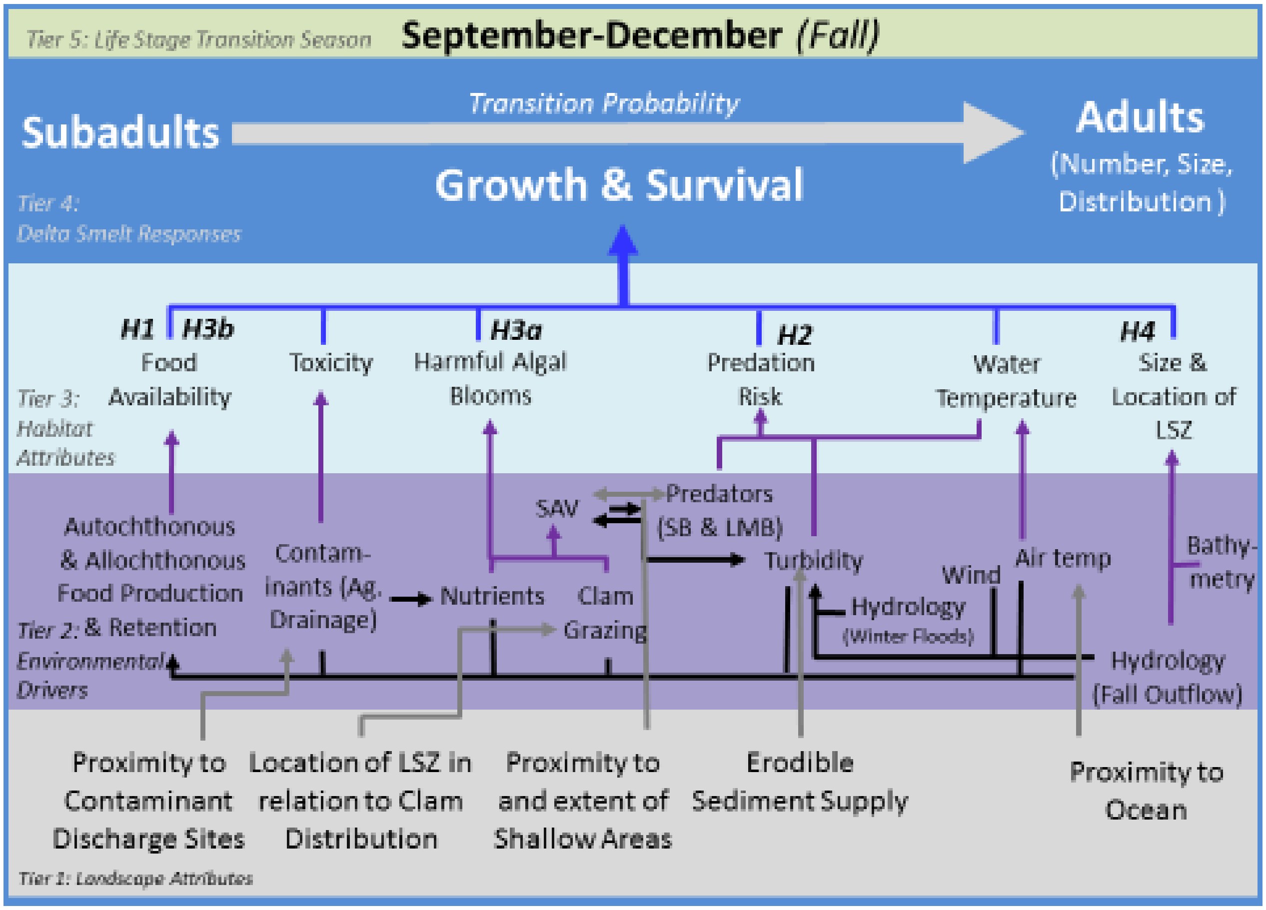


Figure 9. Fall conceptual model for Delta Smelt (from IEP-MAST 2015).

For a detailed description of the DS-MAST conceptual model, readers should refer to the original report (IEP-MAST 2015). For the purposes of this workplan we use the seasonal conceptual models for summer (Figure 8) and fall (Figure 9). Note that the DS-MAST conceptual models only show the processes considered most important to Delta Smelt in each particular season, as determined by the authors at that time. This determination also included operational considerations, such as the likelihood that flow augmentations or pumping restrictions would be considered. For the current work plan, we first considered the processes included in the DS-MAST conceptual models but also considered other processes that might be affected by SMSCG action. The DS-MAST conceptual models do include a tier of Landscape Attributes which was meant to capture the effects of fixed geographic characteristics on the dynamic abiotic and biotic attributes of the system summarized in the Environmental Drivers tier. Because the actions being considered in the work plan are very geographically specific, a more specific geographic conceptual model was developed for the FLoAT actions than was used for the DS-MAST conceptual model (Figure 10).

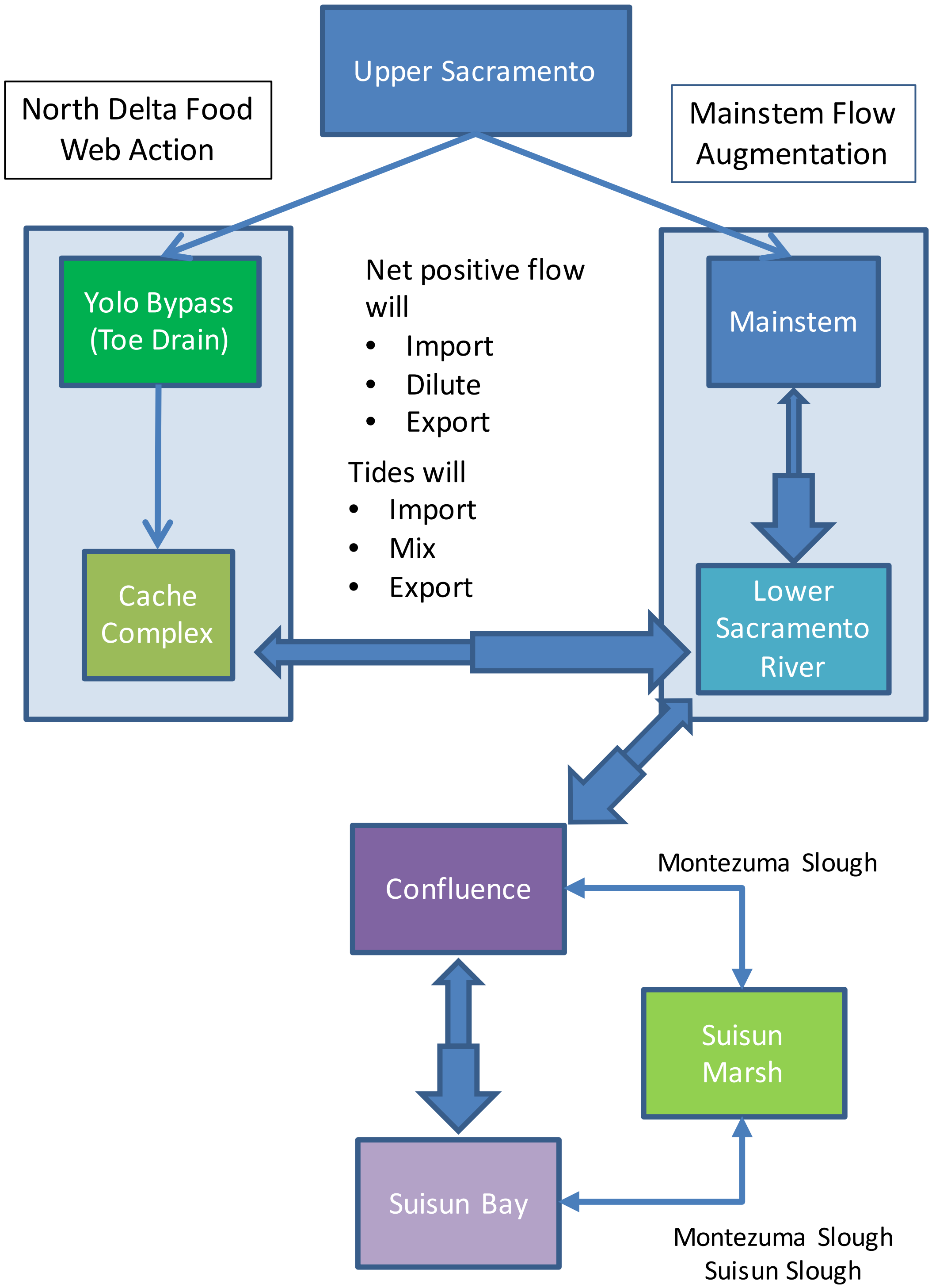


Figure 10. Box model for the geographic area of interest, and key upstream reaches.

The FLoAT geographic conceptual model (Figure 10) focuses on the specific routes for additional flow being considered under a the SMSCG and North Delta food web actions, and other potential Flow Augmentation Actions.

The water flow in Suisun Marsh exhibits several patterns affected by tidal action and net river flow. At the eastern end of the marsh water can enter through the eastern end of Montezuma Slough which connects to the confluence region (Figure 2), or from the west through Suisun Slough or the western end of Montezuma Slough at Grizzly Bay (Figure 2). Daily tidal cycles cause water in Montezuma Slough to travel a significant fraction of the slough length. When river discharge is high, net flow is westward through Montezuma Slough. During low river flow, tidal energy tends to create a small net eastward flow in Montezuma Slough, drawing in relatively saline water from the west (Fischer et al. 1979). As described in the BiOp (USFWS 2008), the SMSCG are currently operated in fall to freshen marsh channels. The general approach during operational periods is to open gates during ebb tide and close gates during flood tides. These operations essentially tidally pump water into Suisun Marsh from the confluence region by allowing freshwater into the marsh during ebb tides, then closing the gates to keep the water from getting “pushed out” by more saline high tides.

Hypotheses/Predictions

A key to the adaptive approach is to develop a suite of expected responses from dynamic habitat drivers and biological responses at multiple levels of the ecosystem during the target summer and fall period for SMSCG operations. Those expectations about dynamic habitat drivers and biological responses are presented below for each type of action. In the current work plan, we use data from past and present monitoring and research programs to help formulate predictions.

Our general approach in formulating the predictions was to review the processes and interactions depicted in the conceptual model, evaluate the available information, and in light of these conceptual models make a judgment about whether each prediction was reasonable. For the purposes of this work plan, we consider summer as being defined by June–August and Fall as only September-October due to the specific timing of a relevant and related action, Action 4 in the USFWS Biological Opinion (FWS 2008--fall outflow action). The summer and fall periods in the conceptual models overlap (Figures 8 and 9) because they are partially defined on the basis of Delta Smelt life stages, which are continuous and can vary from year to year based on environmental conditions and fish vital rates, such as growth rates. We fully recognize that there may be interactions between the SMSCG action and other manipulations such as the North Delta Food Web Action. However, for the purposes of this effort we focus on expected changes from the SMSCG project. The effects of multiple concurrent or serial actions will require a more complex approach, making it harder to evaluate the individual contribution of SMSCG operations.

Suisun Marsh Salinity Control Gate Action

The general hypothesis is that reducing salinity in Suisun Marsh is beneficial for the Delta Smelt population for reasons discussed earlier (e.g. increased distribution, increased foraging opportunities and habitat complexity). Here we describe the expected responses in two types of habitat components (Stationary, Dynamic) and for Delta Smelt. For each of the individual habitat components and fish responses, we describe Predictions (Table 1), which are essentially the same as hypotheses. For example, we predict that the average nitrate concentration will not increase either regionally or in the Low Salinity Zone (LSZ) under the proposed SMSCG Action relative to the base case (No Action). The implied hypothesis is therefore: “We hypothesize that the average nitrate concentration will not increase either regionally or in the LSZ under the proposed SMSCG Action relative to the base case”. To avoid redundancy, we do not restate each prediction as a hypothesis.

Note that each of the predictions in Table 1 are provided for two defined geographical areas that might be affected by the SMSCG Action: 1) Suisun Region – Marsh, Montezma Slough Grizzly Bay, Honker Bay; and 2) Delta Region – Confluence to Rio Vista. In addition, we provide predictions for the Low Salinity Zone, the dynamic habitat which tidally and seasonally shifts across different fixed geographic regions.

Stationary abiotic habitat components

There are four key stationary habitat components that differ between the Sacramento River, the river confluence region and Suisun Bay and may affect habitat quality and availability for Delta Smelt. In addition, they all vary within each region, and change over time in response to dynamic drivers, albeit much more slowly than the dynamic habitat components. For example, bathymetry and erodible sediment supply can change as more sediment is transported into the region and deposited or eroded and flushed out to the ocean. Contaminant sources and entrainment sites are added or eliminated with changes in land and water use. Although we make predictions for several abiotic habitat components, we note that most would not change either regionally or in the Low Salinity Zone under the action (Table 1).

Table 1. Predicted responses relative to base conditions (i.e. similar periods without SMSCG operations). Predicted outcomes for the SMSCG Action assuming a change in gate operations during summer of dry-below normal years. Extreme wet and very dry years are excluded from the predictions because the SMSCG action is unlikely under those conditions.

Variable (Aug-Oct)	Predictions Relative to Base		
Habitat Conditions	**Full Low Salinity Zone (Dynamic Location)**	**Suisun Marsh Region (Montezuma Sl, Grizzly Bay, Honker Bay)**	**River Region (Confluence area to Rio Vista)**
Average Daily Net Delta Outflow	Higher	Higher	Higher
San Joaquin River Contribution Outflow	Neutral	Neutral	Neutral
Surface area of the fall LSZ	Higher	Higher	Neutral
Hydrodynamic Complexity	Higher	Neutral	Neutral
Salinity	Neutral	Lower	Neutral
Temperature	Neutral	Neutral	Neutral
Average Wind Speed	Neutral	Neutral	Neutral
Average Turbidity	Neutral	Neutral	Neutral
Average Ammonium Concentration	Neutral	Neutral	Neutral
Average Nitrate Concentration	Neutral	Neutral	Neutral
Non-Smelt Food Web Responses			
Average Phytoplankton Biomass (excluding *Microcystis*)	Higher	Neutral	Neutral
Diatoms Biomass	Neutral	Neutral	Neutral
Average *Microcystis* Biomass	Neutral	Neutral	Neutral
Calanoid copepod biomass in the LSZ	Higher	Neutral	Neutral
Cyclopoid copepod biomass in the LSZ	Higher	Neutral	Neutral
Bivalve biomass	Neutral	Neutral	Neutral
Bivalve survival	Neutral	Neutral	Neutral
Bivalve growth	Neutral	Neutral	Neutral
Fish assemblage	Different	Different	Neutral
Delta Smelt (DS) Responses			
DS caught at Suisun power plants	0	0	0
DS in SWP & CVP salvage	0	0	0
DS distribution	Westward	Westward	Westward
DS growth, survival, and fecundity in fall [a]	Higher	Higher	Neutral
DS health and condition in fall	Better	Better	Neutral
DS Recruitment the next year	Better	Better	Better
DS Population life history variability	Better	Better	Better

Bathymetric complexity: Differences in bathymetry and spatial configuration between the three regions affect nearly all other habitat features and interact strongly with the prevailing dynamic tidal and river flows to produce regionally distinct hydrodynamics. Overall, the Suisun Bay and the Marsh region targeted in the SMSCG action are more bathymetrically complex than the river. Hence, these differences are reflected in our regional predictions. Extensive shallow, shoal areas in the Suisun Bay are considered particularly important. The river confluence area is more constrained and channelized but is still influenced by areas with some complexity, such as the shallow waters and tidal wetlands around Sherman Island and Decker Island. The upper Sacramento River upstream of Decker Island is deep and highly constrained and changes character above the confluence of Cache Slough where it becomes narrower and more riverine; although it is still highly constrained.

Erodible Sediment Supply: The amount and composition of the erodible sediment supply is an important factor in the regulation of dynamic suspended sediment concentrations and turbidity levels in the water column. Suisun Bay features extensive shallow water areas such as Grizzly and Honker Bays that are subject to wind waves that resuspend bottom sediment and increase turbidity relative to the confluence (Ruhl and Schoellhamer, 2004). The contribution of organic material to the erodible sediment supply in Suisun Bay and the river confluence and its role is uncertain, so we don’t make specific regional predictions. The upper Sacramento River likely functions more as a conduit for suspended sediment since it is leveed and maintained, at least partially, to convey flood flows during winter storms.

Contaminant Sources: The large urban areas surrounding the estuary and the intensive agricultural land use in the Central Valley watershed and the Delta have resulted in pollution of the estuary with many chemical contaminants (Brooks et al. 2012, Johnson et al. 2010). Many of these pollutants (e.g. heavy metals, pesticides) can be toxic to aquatic organisms (Fong et al 2016). Sources of contaminants in these broad regions are quite extensive, including but not limited to the mothball fleet, duck pond management, refineries, waste water treatment plants, integrative pest management, industrial and agricultural chemicals, and storm drains. The largest wastewater treatment plant in the Delta, the Sacramento Regional Wastewater Treatment Plant (SRWTP), discharges effluent with high ammonium concentrations into the Sacramento River near the northern border of the Delta. Pyrethroid pesticides and other chemicals are also present in SRWTP's effluent. The Contra Costa wastewater treatment plant also discharges effluent with high concentrations of ammonium, along with potential for other chemicals, into the western Suisun Bay near Carquinez Strait. Ammonium has been found to suppress nitrate uptake and growth of phytoplankton in the Delta and Suisun Bay (Dugdale et al. 2007), but recent Delta research has also indicated that phytoplankton growth is minimally affected by ammonium at environmental concentrations (Berg et al. 2017, Krause et al. 2017) and should be researched in parallel with other Delta features potentially influencing phytoplankton growth (Ward and Paerl 2017). Stormwater runoff is a significant and seasonal problem with invertebrate toxicity detected in Delta Smelt critical habitat (Weston et al 2014). Aquatic weed and vector control programs directly apply pesticides to the Suisun/Delta. Intermittent accidental spills also occur, for example the Kinder Morgan Diesel Fuel Oil Spill in Suisun Marsh in 2004. In addition to chemical pollution, blooms of the toxic cyanobacteria like *Microcystis aeruginosa* have become a common summer occurrence in the central and southern parts of the Delta, including the river confluence and the eastern edge of the Suisun Bay (Lehman et al. 2008, 2010). Because *Microcystis* and other cyanobacteria can produce cyanotoxins (e.g., microcystins, saxitoxins, and anatoxins) and are considered poor food for secondary consumers, it is considered a biological contaminant. <u>Overall, we predict that contaminants and toxic blooms will be more of an issue in regions upstream of Suisun Bay</u>. This prediction is consistent with work from Hammock et al. (2015), in which histopathological examinations of Delta Smelt tissue from fish collected from Suisun Marsh, Suisun Bay, and the Cache Slough Complex showed the greatest evidence of contaminant exposure in the Cache Slough Complex. Note that there might be slight differences in contaminant levels during higher Delta Outflow (and associated dilution) under the proposed action, but we do not expect that these changes will be detectable.

Entrainment sites: Entrainment sites include agricultural water diversions and urban water intakes throughout the Delta and Suisun Bay, the state and federal water project pumps in the southern Delta (Figure. 3), and two intermittently-operated power plant cooling water intakes in the Suisun Bay (in Pittsburg and Antioch). Entrainment can cause direct mortality in fish screens, pumps, or pipes (Grimaldo et al. 2009; Castillo et al. 2012), and it can cause indirect mortality due to enhanced predation or unsuitable water quality associated with diversion structures and operations (Arthur et al. 1996; Feyrer et al. 2007; Moyle et al. 2010). Direct entrainment of Delta Smelt in the summer-early fall months covered by the SMSCG action are most likely to occur at local agricultural diversions and perhaps at the North Bay Aqueduct. Hence, we predict that entrainment will be modest overall, but with potential for greater effects upstream of Suisun Bay given the larger number of diversions.

Predictions for dynamic abiotic habitat components

There are a number of dynamic components that change in magnitude and spatial configuration at daily, tidal, seasonal, and interannual time scales. Their interactions with each other and with stationary habitat components determine the extent and location of production areas for estuarine species. There are eight major dynamic abiotic habitat components to consider. Predictions are summarized in Table 1.

Total Delta outflow and San Joaquin River contribution in the summer-fall The interaction of ocean tides with inflows from tributary rivers is the main dynamic driving force in estuaries and determines outflow to the ocean. The estuary is located in a Mediterranean climate zone with highly variable precipitation and river flow patterns (Dettinger, 2011). Winters are generally wet and summers are dry, but there is large interannual variability. Only a small amount of San Joaquin River water is actually discharged to the ocean in all but the wettest years. This is especially true in the summer and fall months, when only a very small fraction of Delta outflow is contributed by water from the San Joaquin River. Thus, the prediction is that the proposed action will not change the contribution of San Joaquin River flows in summer. However, the Proposed Project would result in a modest overall increase in Total Delta Outflow. Operations of the SMSCG in fall is known to result in a slight upstream shift in the salt field as indexed by X2 (USFWS 2008). The reason is that operation of the SMSCG essentially directs more freshwater inflow into the marsh rather than along the main open water region of the estuary, i.e. the Deep Water Ship Channel. Less flow along the main open water region of the estuary (Deep Water Ship Channel) therefore results in a slight upstream shift in the salt field (X2). For this reason, the Proposed Project includes additional Delta Outflow to offset a similar expected upstream encroachment of salinity (X2) for August operations of the SMSCG. As reflected in the current Project Description, there would be a modest increase in Total Delta Outflow (27 TAF) during August and part of September. We do not expect that this additional outflow would come from the San Joaquin River.

Location and extent of the fall Low Salinity Zone. Under the static summer-fall outflow regime that has been typical for the POD period (Brown et al. 2014), outflows throughout much of the fall are always low and salinity intrudes far to the east (X2 > 80 km), causing the LSZ to be constricted to the confluence of the deep Sacramento and San Joaquin river channels (Figure 12). When X2 is more seaward, the LSZ includes more of Suisun Bay (Figures 13 and 14). As will be described in detail below, the extent and location of the LSZ may affect fish distribution and habitat attributes.

Based on initial modeling studies, it appears that operations of the SMSCG in August will increase the amount of habitat conducive to Delta Smelt in the Suisun Marsh and Bay, specifically Grizzly Bay. The degree to which this will change depends substantially on water year types. In general, the degree of effect is greatest in drier water years and modest in above normal years. The same is true for the predicted effect of the SMSCG operations on LSZ. Specifically, SMSCG operations are expected to result in a modest increase the area of the LSZ in drier years and a very slight increase in above normal years. Moreover, the action would substantially increase the proportion of the LSZ that it located in Suisun Marsh.

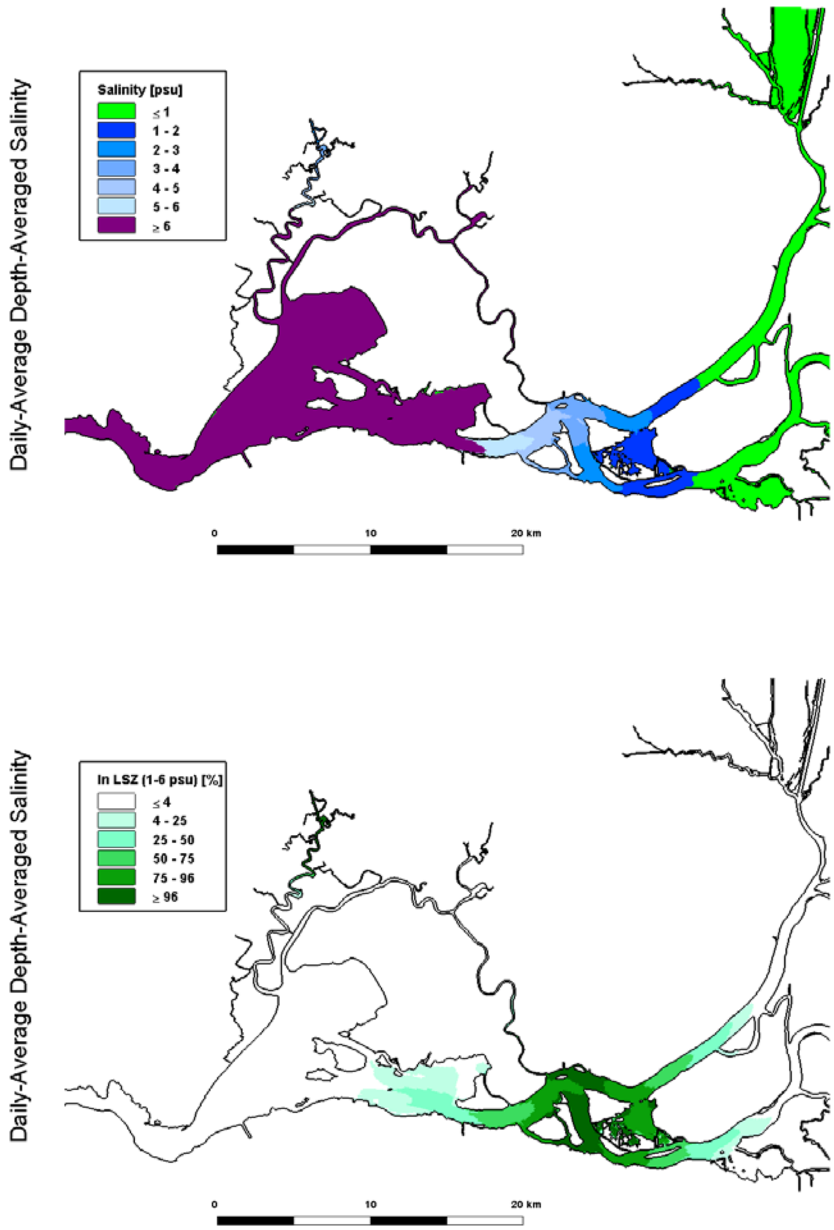
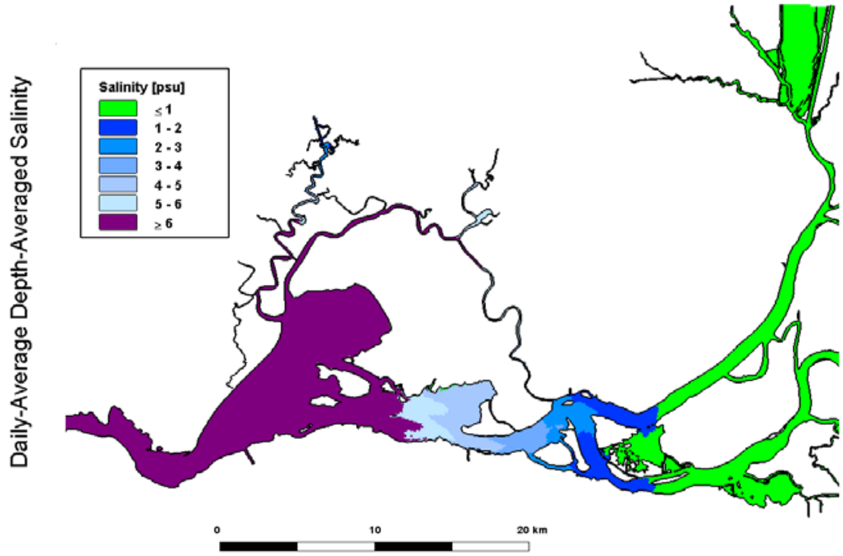


Figure 11. Location and extent of the fall Low Salinity Zone.



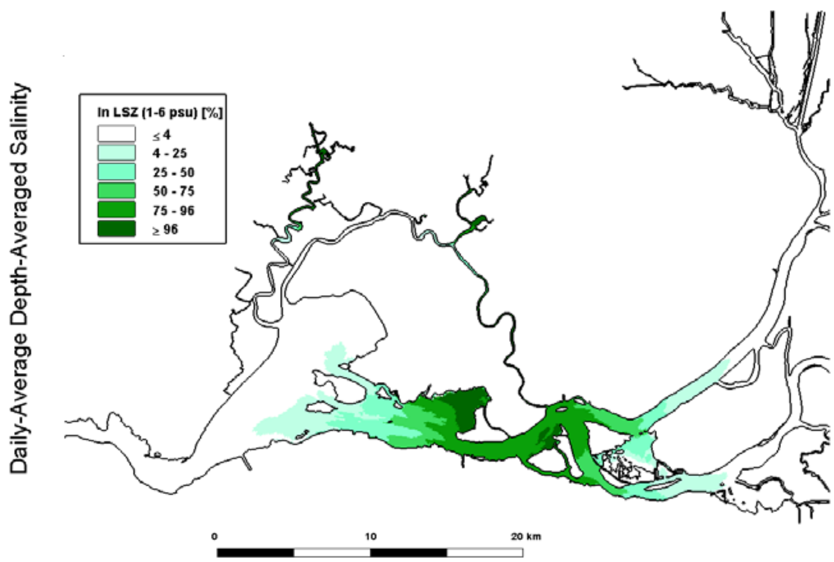
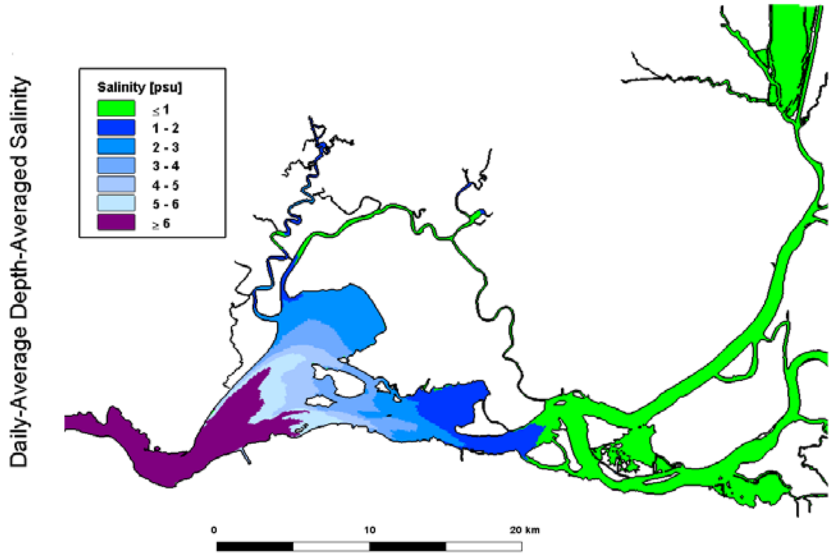


Figure 12. Low Salinity Zone located further west.



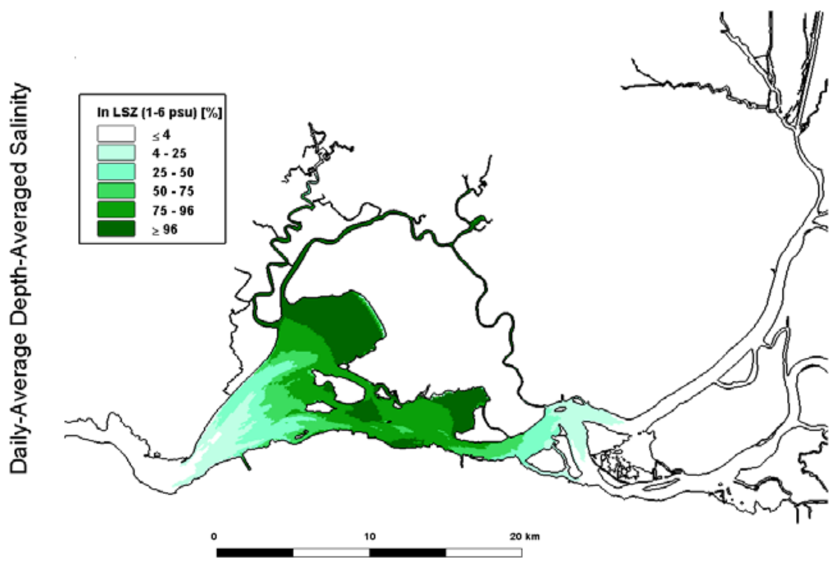


Figure 13. Location and extent of the Low Salinity Zone under very fresh high flow conditions.

Hydrodynamic complexity in the LSZ. The basic idea behind the idea of hydrodynamic complexity is habitat heterogeneity within the LSZ (Brown et al. 2014, Bever et al. 2016). It is hypothesized that when the LSZ is located in Suisun Bay, there is more shoal habitat available, connections with Suisun Marsh are possible, and there is greater likelihood of gyres and eddies forming. Conceptually, this provides a greater array of habitat types for Delta Smelt to utilize for resting, feeding, and other activities. Hydrodynamics are primarily driven by the interaction of dynamic river flows, and ocean tides with stationary bathymetry and spatial configuration of channels. With respect to the movement of water masses through the estuary, hydrodynamics in the estuary are generally understood and have been modeled with a variety of tools (MacWilliams et al. 2016). There remains much uncertainty, however, about the interaction of hydrodynamics with the stationary habitat components in Suisun Bay, the river confluence region, and the Sacramento Rivers and their combined effect on other dynamic habitat components including turbidity, contaminants, and biota. The diverse configurations of shoals and channels and connections to Suisun Marsh produce complex hydrodynamic features such as floodtide pulses in Grizzly Bay (Warner et al. 2004), tidal asymmetry (Stacey et al. 2010), lateral density fronts in Suisun cutoff (Lacy et al. 2003), and multiple null zones and turbidity maxima (Schoellhamer and Burau, 1998, Schoellhamer, 2001). In contrast, the river confluence area has simpler bathymetry that lacks extensive adjacent shallow embayments. Large, shallow freshwater embayments (flooded islands) exist in the central and northern Delta, but are outside of the region overlain by the LSZ. The hydrodynamics of the Sacramento River are less well known but Delta Smelt are commonly captured around Decker Island which provides some habitat complexity. <u>We predict that the proposed SMSCG action will increase hydrodynamic complexity because more of the LSZ will be located in Suisun Marsh and Bay.</u>

Temperature: Temperature is increasingly recognized as a key habitat variable affecting Delta Smelt (Brown et al. 2014; Sommer and Mejia 2013). As noted in the Delta Smelt MAST report (IEP 2016), water temperature is fundamental to aquatic ecosystem health and function. It directly influences biological, physical, and chemical properties such as metabolic rates and life histories of aquatic organisms, dissolved oxygen levels, primary productivity, and cycling of nutrients and other chemicals.

The Delta Smelt MAST report (IEP 2016) further notes that long term temperature records from selected sites in the SFE show substantial seasonal and daily fluctuations in water temperature (Kimmerer 2004). While daily variations are evident and likely important to organisms, seasonal variations are much greater (Wagner et al. 2011). Median water surface temperatures across all stations monitored by the IEP Environmental Monitoring Program (EMP) (Fig. 15) from 1975-2012 range from 9 °C in January (minimum: 6 °C) to 22 °C in July (maximum: 28 °C). There are also clear regional variations in water temperature, with a general trend towards cooler temperatures in the lower estuary. In July and August, the hottest summer months, water temperatures are usually highest at monitoring stations in the south Delta (average 23-26 °C, maximum 28 °C), lower at stations in the northern and western Delta (average 21-23 °C, maximum 25 °C) and lowest at stations in Suisun and San Pablo Bays (average 19-21 °C, maximum 24 °C). In January, the coldest winter month, average water temperatures are uniformly below 10 °C in the entire Delta, but above 10 °C in San Pablo Bay.

There is currently little evidence for increasing water temperatures in the Delta, although with climate change such increases are expected over the course of the century (Cloern et al. 2011,Wagner et al. 2011, Brown et al. 2014). However, there is increasing concern that recent record warm years may be related to climate change. For example, Delta Smelt appear to have done relatively poorly despite wet conditions in 2017—record high summer temperatures are thought to have been a key factor.

Our prediction is that the proposed SMSCG action will not have any effect on water temperatures in the Delta or Suisun Regions, or in the LSZ. However, a key objective of the proposed action is to provide Delta Smelt with access to potentially cooler downstream habitat. As noted above, more seaward locations such as Suisun Bay tend to have lower temperatures, so a more downstream distribution of Smelt (see below) could provide some access to somewhat cooler habitat. Moreover, high habitat complexity in Suisun Marsh could provide unique temperature refuges based on interactions between its tidal channels and the marsh plain (Enright et al. 2013). This is unlikely to be detectable based on average LSZ temperature, but could nonetheless be a project benefit.

Wind speed Strong winds from the north and west are characteristic of Suisun Bay and the Delta. On average, wind speeds are high throughout most of the year including summer-early fall, but lower in mid to late fall. The interaction of wind with river and tidal flows and the erodible sediment supply drives the resuspension of erodible bed sediments. Wind-wave resuspension is substantial in the shallow bays of the Suisun Bay (Ruhl and Schoellhamer, 2004) and flooded islands in the Cache Slough Complex (Morgan-King and

Schoellhamer 2013) and helps maintain generally high suspended sediment concentration and turbidity levels in these areas. In contrast, wind likely plays a less important role in suspending sediments in the deep channels of the river confluence. We hypothesize that wind speeds would be higher over the LSZ as it is shifted into the open Suisun Bay. Operation of the SMSCG could therefore result in a very slight increase in mean wind speeds, but the change is likely to be below detection limits. <u>We therefore predict no change in wind speeds in the LSZ or other regions under the proposed SMSCG action.</u>

Turbidity: Turbidity, often measured as Secchi depth in the Delta, has been found to be an important correlate to Delta Smelt occurrence during the summer (Nobriga et al. 2008) and fall (Feyrer et al. 2007). Turbidity during the winter also appears to be important as a cue for the spawning movements (Grimaldo et al. 2009; Sommer et al. 2011a). Turbidity is assumed to reduce predation risk for Delta Smelt as it does for other fishes but no direct experiments or observations exist to support the hypothesis. In the SFE, turbidity is largely determined by the amount of suspended inorganic sediments in the water (Cloern 1987, Ganju et al. 2007, Schoellhamer et al. 2012), although organic components may also play a role (USGS 2008). Sediment particles are constantly deposited, eroded, and resuspended, and are transported into, within, and out of the estuary. The amount of sediment that is suspended in the water column depends on the available hydrodynamic energy, which determines transport capacity, and on the supply of erodible sediment. Strong turbulent hydrodynamics in Suisun Bay caused by strongly interacting tidal and riverine flows, bathymetric complexity, and high wind speeds continue to constantly resuspend large amounts of the remaining erodible sediments in large and open shallow bays of Suisun Bay. Suisun Bay thus remains one of the most turbid regions of the estuary. Turbidity dynamics in the deep channels of the river confluence and Sacramento River are driven more by riverine and tidal processes while high wind and associated sediment resuspension has little if any effect (Ruhl and Schoellhamer 2004, Schoellhamer et al. 2016). By contrast, wind wave resuspension is relatively high during summer in open water areas of Suisun Bay. This difference is also consistent with preliminary analyses by W. Kimmerer (SFSU, pers. com.) that suggest that turbidity in the LSZ is higher when fall X2 is further downstream and the LSZ overlaps Suisun Bay. <u>As discussed above with regard to wind speed, there may be slight improvements in turbidity since more of the LSZ</u>

will be located in Suisun Bay and Marsh, but we don't expect to observe a detectable change in turbidity.

Contaminant Concentrations and Nutrients: Chemical contaminants from agricultural and urban sources that are present in the estuary include pyrethroid pesticides, endocrine disruptors, and many traditional contaminants of concern (Kuivila and Hladik 2008, Johnson et al. 2010, Brooks et al. 2012). Some regions of the upper estuary are also enriched with the nutrient ammonium (Johnson et al. 2010; Brooks et al. 2012). In the late summer and early fall, blooms of the cyanobacteria *Microcystis aeruginosa* can produce toxic microcystins (Lehman et al. 2010). Agricultural contaminants are delivered into the LSZ from winter to summer in storm-water run-off, rice field discharge, and irrigation return water (Kuivila and Hladik, 2008). The amount and types of agricultural contaminants that reach the LSZ vary seasonally, with more inputs from winter to summer than in the fall (Kuivila and Hladik 2008). Wastewater treatment plant and industrial discharges (including ammonium and nitrate) can occur steadily throughout the year, but the chemical load from urban storm-water run-off may increase in the winter and spring. In the fall, chemical loading from stormwater is generally negligible and lower river flows mobilize fewer sediment bound contaminants than in other seasons. Control programs for species in the Suisun/Delta directly apply pesticides in and around water. In addition, legacy contaminants due to accidental spills or land can contaminate the habitat. The factors governing nutrient and contaminant transport are extremely complex. For the purposes of this work plan our initial prediction is that the proposed action will not change contaminant or nutrient concentrations. However, given that flow could potentially be increased somewhat to offset the upstream shift in X2 (see above), we hypothesize that there may be a very slight decrease in contaminant or nutrient concentrations due to dilution.

Predictions for dynamic biotic habitat components:

Estuarine fishes seek areas with a combination of dynamic and stationary habitat components that are well suited to their particular life histories. In addition to abiotic habitat components, fish habitat also includes dynamic biological components such as food availability and quality and predator abundance.

Food availability and quality Food production in estuaries is a dynamic process that involves light, nutrients, algae, microbes, and aquatic plants at the base of the food web and trophic transfers to intermediate and higher trophic levels including invertebrates, such as zooplankton and benthic invertebrates, and vertebrates such as fishes and water birds. As in many other estuaries, higher trophic level production in the open waters of the Delta and Suisun Bay is fueled by phytoplankton production (Sobczak et al. 2002). However, there is a growing recognition that marsh carbon contributes substantially, particularly in Suisun Marsh and the North Delta (Young 2014). In contrast to many other estuaries, however, the SFE has overall low phytoplankton production and biomass (Cloern and Jassby 2008). Phytoplankton production in the estuary is highly variable on a seasonal and interannual basis (Jassby et al. 2002, Cloern and Jassby 2010). The SFE also has a large amount of spatial variability in food production and food web dynamics (Brown et al. 2016). Food webs Suisun Bay and the Delta have also been affected by species introductions (Brown et al. 2016). Estuaries and rivers often have dynamic food and biogeochemical "hot spots" (Winemiller et al. 2010) that persist in one location for some time or move with river and tidal flows. There also are usually areas with low food production and biomass. The temporal and spatial variability of food production, biomass, and quality in estuaries is the result of the interaction of dynamic drivers such as biomass and nutrient inputs from upstream, estuarine hydrodynamics, salinity, turbidity, and trophic interactions with stationary habitat components such as the bathymetric complexity and spatial configuration of a particular geographic area. Food resources for Delta Smelt in the summer-fall LSZ vary considerably on many spatial and temporal scales. *Microcystis* became abundant in the estuary starting in 2000 coincident with the POD (Lehman et al. 2005). The hepatotoxic microcystins that are often within this cyanobacterium have been found in many components of the food web (Lehman et al. 2005). Although *Microcystis* is a freshwater cyanobacterium, blooms can extend into Suisun Bay and the LSZ and the toxin microcystin associated with cyanobacteria in the SFE have been detected in the shellfish of San Francisco Bay (Gibble et al. 2016). *Microcystis* can have food web effects through impacts on calanoid copepods and cladocera, which are sensitive to *Microcystis* in the diet and microcystins dissolved in the water column (Ger et al. 2009, 2010a, b). If blooms expand in scope and duration there may be more concern regarding direct effects of toxins on fishes and other organisms. Many uncertainties remain about the dynamics of food resources at the small scales important to individual feeding Delta Smelt, which ultimately contribute to Delta Smelt survival, growth, and health in the fall. These sort of uncertainties will ultimately need to be addressed in order to fully understand how the Proposed Project affects food we processes, but are beyond the scope of the current pilot study. For example, uncertainties also remain regarding the relative importance of food subsidies from upstream regions, off-channel habitat and food produced in the LSZ. Subsidies of biomass from the San Joaquin River have been hypothesized to be important to the LSZ, when flows are sufficient to transport biomass downstream. Species invasions associated with extreme salinity intrusions during droughts have greatly altered the composition of the invertebrate community in the LSZ, with uncertain effects on Delta Smelt.

Overall, food quantity and quality may be higher for Delta Smelt if the LSZ is in Suisun Bay and Suisun Marsh than if it is in the river confluence. Like the channels of the Cache Slough Complex (Sommer et al. 2003, DWR, In review; Fred Feyrer, unpublished data), marsh channels tend to have relatively higher levels of phytoplankton and zooplankton (Rob Schroeter, UC Davis, unpublished data). We therefore predict that production of phytoplankton (including diatoms) will increase under the proposed action as the LSZ incorporates more shoals as it moves into Suisun Bay, and more long residence time habitat in Suisun Marsh. There would be slight regional (e.g. Suisun, River) change in phytoplankton as flow is increased under the proposed action, but we do not expect that the change would be detectable given the that flow will not change or only increase slightly. Similarly, the biomass of *Microcystis* might be reduced slightly in the LSZ and the target regions under the proposed action as a result of increased Delta Outflow under the Proposed Project but the change is unlikely to be detectable.

With regard to zooplankton, we predict that the increases in phytoplankton in the LSZ under the proposed action would support corresponding increases in zooplankton. Similarly, increased overlap between the LSZ and marsh channels would provide zooplankton with additional terrestrial/wetland sources of carbon (e.g. Young et la. 2017). As for phytoplankton, there would be no regional change in zooplankton levels in the Suisun or the River areas.

Clam grazing The primary bivalve grazer in the Sacramento River is *Corbicula*, and the primary bivalve grazer in Suisun Bay is *Potamocorbula* during the target study period (Greene et al. 2016; Figure 14). The confluence region has a mixture of the two. *Corbicula* is generally food limited in the Delta (Foe and Knight, 1985) suggesting grazing rates can increase in response to increased food availability.

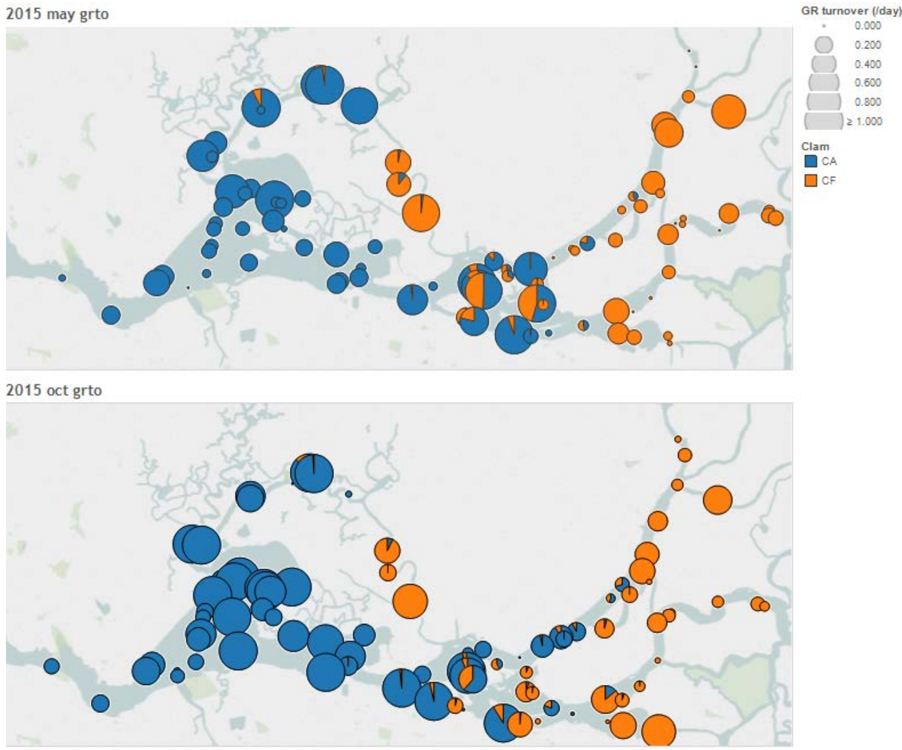


Figure 14. Distribution of *Potamocorbula* (CA) and *Corbicula* (CF) in the western Delta and Suisun Bay region.

Bivalve biomass and grazing rate vary temporally and spatially. In general, higher flows tend to limit the upstream recruitment of *Potamocorbula*. This in turn can facilitate a downstream shift in *Corbicula* (Peterson and Vaysierres 2007). Our prediction is that there will be little change in overall grazing rate, growth, survival and biomass in the LSZ and either of the two study regions. However, we also predict that there may be localized improvements survival and growth of Corbicula in marsh channels that are freshened by the SMSCG action.

Predation and competition. As for other actions being considered by IEP FLoAT (Brown et al. 2017), we chose not to make predictions about predator abundance and distribution or predation rates with respect to predation on Delta Smelt or other fishes. Data evaluation during the FLaSH study (Brown et al. 2014) and a general review of fish predation in the Delta (Grossman 2016) have found the available data to be insufficient to reach conclusions. To our knowledge, the situation has not changed sufficiently to warrant predictions. Similarly, we do not make predictions about competition since there are no data we are aware of establishing competition as a strong driver in the decline or present low abundance of Delta Smelt. Developing special studies to evaluate these processes would certainly be appropriate.

Although we make no specific predictions about the effect of the action on predation and competition, there is some expectation that the management action may result in least modest change the fish assemblage due to the shift in the distribution of the salt field and perhaps other constituents. The change is most likely to occur in the Suisun Region, but there may also be some shifts in assemblage in the LSZ.

Predictions for Delta Smelt responses

Delta Smelt will likely respond in several ways to outflow-related habitat changes such as SMSCG operations. Specifically, access to areas of greater bathymetric complexity such as those found in the Suisun Bay and Suisun Marsh (Bever et al. 2016) likely offers multiple advantages to Delta Smelt, although many uncertainties regarding the mechanisms that link Delta Smelt responses to outflow conditions and the position of the LSZ remain. Note also that the responses of Delta Smelt may be muted depending on the status of the population and conditions in other seasons. For example, severely low adult abundance is likely to generate relatively low egg production. Even with good summer and fall survival, poor conditions in winter could affect adult maturation and winter and spring conditions can affect hatching and larval survival. the increase in the 2011 Delta Smelt abundance index compared to years in the 2000s (Figure 4) suggests that the Delta Smelt population is still resilient and able to respond to favorable conditions, but low population levels in 2017 and 2018 could substantially limit the efficacy of management actions.

Distribution: Prior to their spawning movements in the winter, Delta Smelt are commonly found in the LSZ (Feyrer et al. 2007, Sommer et al. 2011a). Older life stages of Delta Smelt may not require the same high turbidity levels that larval Delta Smelt need to successfully feed, but are most likely able to discriminate level and types of turbidity (and salinity) to find waters that contain appropriate prey resources and that will provide some protection against predation. We predict that the center of distribution of the Delta Smelt population, excluding the Cache Slough Complex will move westward into Suisun Marsh with the proposed action. A more downstream distribution gives Delta Smelt access to a larger habitat area that overlaps with the more bathymetrically complex Suisun Bay with its deep channels, large shallow shoal areas, and connectivity with Suisun Marsh sloughs.

Growth, survival and fecundity Distribution across a larger area with high turbidity and more food, when the LSZ overlaps the Suisun Bay and Marsh, may help Delta Smelt avoid predators and increase survival and growth. Distance from entrainment sites and locations where predators may congregate (artificial physical structures, scour holes in river channels, *Egeria* beds) may also help increase survival. Increased growth should result in greater size of adult Delta Smelt and greater fecundity of females, since number of eggs is related to length (Bennett 2005). Our prediction is that these metrics will improve with increased access to Suisun Bay and Marsh under the proposed action.

Health and condition: The same mechanisms listed for growth, survival and fecundity, can affect health and condition. Improved health and condition at the beginning of the spawning period may increase the likelihood of spawning success and frequency. In addition, a larger habitat area may help Delta Smelt avoid areas with high concentrations of contaminants. Again, we predict that these metrics will improve with greater access to Suisun Marsh under the proposed action.

Recruitment in the next spring: Overall, our prediction is that improvements in the factors listed above will lead to increased distribution, abundance, and reproductive potential of the Delta Smelt population and greater recruitment in the following spring. However, Delta Smelt need to find suitable spawning and larval rearing habitat upstream of the LSZ for reproductive potential to result in successful recruitment in the spring. In addition to preceding summer conditions, successful spring recruitment thus requires suitable winter and spring conditions for migration, gamete maturation, spawning success, and larval rearing. These habitat conditions depend on the interplay of a different set of stationary and changing dynamic habitat features. Only if habitat conditions are met year-round will Delta Smelt be able to successfully maintain their life history and genetic diversity. For example, a large population of subadult fish present in fall 2011 did not result in a large cohort of preadults in 2012, likely because of poor survival in spring and summer (Brown et al. 2014). Our prediction is that recruitment will improve under the Proposed Project due to increased survival, growth, health and condition. However, we acknowledge that such an effect will be difficult to detect because of overall low abundance of Delta Smelt.

Adaptive Management Approach

The proposed action would be conducted in August 2018 and would be used to inform potential future actions and operations. The adaptive management planning (AMP) and activities will be led by DWR, and guided by management input from the Collaborative Science and Adaptive Management Program (CSAMP) and science input from Interagency Ecological Program (IEP). Both of these organizations already are providing leadership on flow-actions as proposed under the Delta Smelt Biop (FWS 2008) and the Delta Smelt Resiliency Strategy. CSAMP relies on a management level team, the Collaborative Adaptive Management Team (CAMT) to conduct its oversight and review activities. Because the range of hypotheses and data needs associated with an AMP was likely to be broad, CAMT in cooperation with IEP perceived the need for a science-based group to address the technical aspects of the effort. The IEP Flow Alteration Project Work Team (IEP FLoAT) was established to address those scientific needs. An additional and important source of guidance is the Suisun Marsh Preservation Agreement Environmental Coordination Advisory Team (ECAT), a multi-partner group established to provide guidance on projects with Suisun Marsh.

In 2017, much of the focus of CAMT/CSAMP and IEP FLoAT was the planning and evaluation of a fall X2 action as required under the 2008 BiOp (FWS 2008). Although no specific AMP was generated for 2017 activities, the approach relied largely on an earlier version of an AMP (USBR 2012) developed in conjunction with studies of high flow effects on low-salinity habitat of Delta Smelt in 2011 (Brown et al. 2014). That AMP was designed in accordance with the Department of Interior guidelines for design and implementation of adaptive management strategies (Williams et al. 2009). All adaptive management strategies share a cyclical design including: 1) problem assessment, including development of conceptual and quantitative models; 2) design and implementation of actions; 3) monitoring of outcomes; 4) evaluation of action outcomes; and 5) adjustment of the problem assessment and models in response to learning from the previous actions (Figure 15). This process might result in the modification of previous actions or consideration of new actions to address the identified problems.

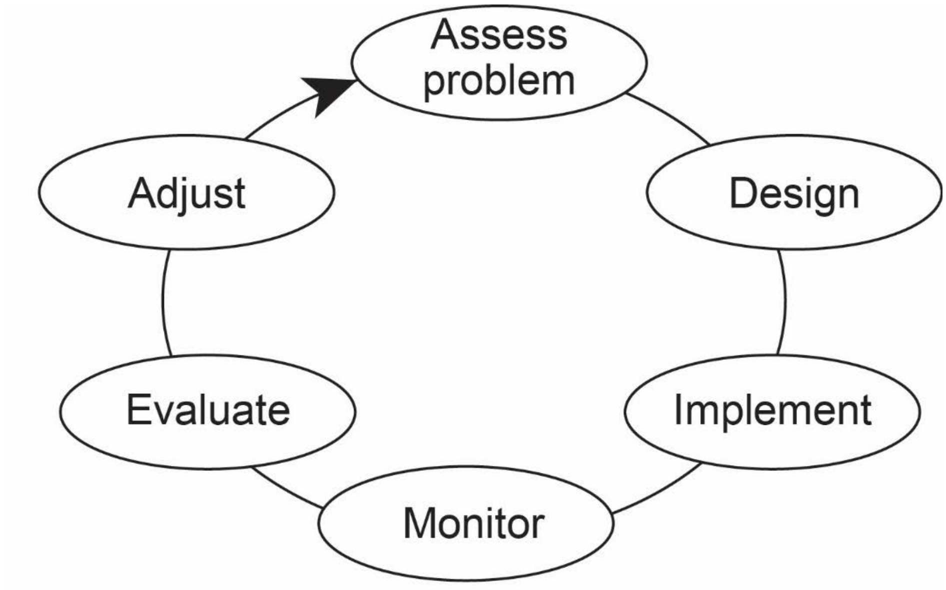


Figure 15. The adaptive management cycle (modified from Williams and others, 2009).

We propose that the SMSCG action incorporate a similar adaptive management approach, using many of the same institutions and metrics. In addition, the State Water Contractors funded the preparation of a guidance document for adaptive management focusing on many of the design and statistical considerations for the SMSCG action (SWC and SLDMWA2017). Hence, this document will be used as a resource in the design and AMP of the SMSCG work.

Coordination

A key part of the AMP will be outreach and coordination of the work. As noted above, the primary vehicle for coordination will be the CAMT and IEP FLoAT PWT. The former includes a strong complement of agencies, non-government organizations, and public water agencies, and the latter represents a public forum for all parties interested in the projects. In addition, IEP FLoAT PWT members will provide periodic briefings to the ECAT (see above), which was designed specifically to help coordinate Suisun Marsh activities. Activities through 2017 included the following:

September 2017: ECAT – overview of project.

November 2017: CSAMP – overview of project as part of DSRS briefing.

December 2017: CAMT, IEP FLoAT – overview and progress report.

February 2018: IEP Annual Meeting Presentation

Spring 2018: Presentations to IEP Estuarine Ecology Team and IEP FLoAT.

April 2018: Presentation to State Water Contractors.

Review of Draft SMSCG Monitoring Plan by IEP FLoAT

May 2018: Update to IEP Science Management Team.

This project is highly consistent with the Restoring Native Species and Communities section of the IEP Science Strategy. Specifically, it addresses Priority Questions 2-4 for Delta Smelt. 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.

As will be described below, the project relies heavily on existing data and samples collected by IEP in Suisun Marsh and the low salinity zone. Additional work requested of IEP includes: 1) Assistance with synthesis (IEP FLoAT PWT); 2) Operation of supplemental water quality sondes (DWR IEP Staff); 3) Collection and analysis of supplemental zooplankton samples (CDFW IEP Staff); and 4) Guidance from IEP EMP staff on supplemental benthic studies.

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:

UC Davis Suisun Marsh Study (Orear)

Tule Red Shallows Benthic and Pelagic Collections (De La Cruz and Hassrick)

USGS Physical and Biological Drivers Study (Feyrer et al.)

SmeltCAM Study (Feyrer et al.)

Monitoring and Evaluation

The monitoring and evaluation program for the SMSCG action will leverage existing, routine monitoring surveys, supplementing them as necessary, to evaluate the predictions detailed in Table 1. Sampling locations are shown in Figure 16, and the existing surveys that will inform the monitoring program for each of the predictions listed in Table 1 are described in Table 2. See the following section for a description of how measurements will be evaluated against "Base" conditions.

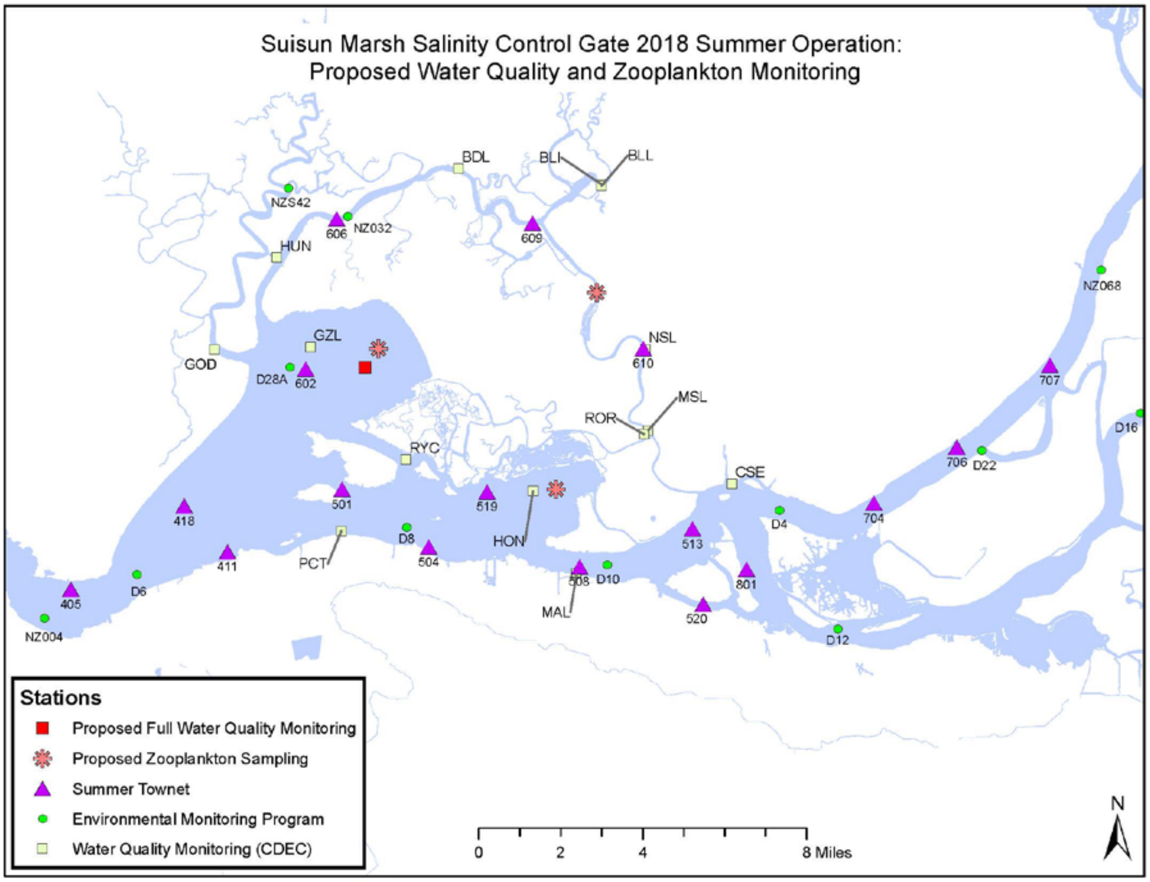


Figure 16.   Suisun Bay region existing and proposed monitoring and sampling locations.

As with the predictions, the monitoring plan is organized by regions for predicted effects of the SMSCG action (Suisun Marsh and River Regions), and by the LSZ, which has a dynamic location depending on hydrological conditions. The monitoring plan will cover the July – October period in 2018, in order to capture baseline conditions before the action occurs in August, and the full temporal range of the action's effects (through October).

A key tool in these evaluations will be the use of UnTrim 3-D model which has been used in the development of this project (see companion Project Description document). This model has been successfully used to develop indicators of hydrodynamic complexity and to estimate the area and location of the LSZ (Bever et al. 2016). The potential uses of this tool are described below in the Data Analysis section. For example, the tool allows the estimation of the velocity field, as well as other water quality attributes such as temperature and turbidity.

The LSZ, Suisun Marsh, and lower Sacramento River region are already relatively well-monitored by routine and long-standing IEP surveys such as the Environmental Monitoring Program (*http://www.water.ca.gov/iep/activities/emp.cfm*), which collects water quality, phytoplankton, zooplankton and benthic invertebrate samples on a monthly basis. Additional benthic sampling may be needed to include marsh channels, which are not regularly sampled by the EMP. The California Department of Fish and Wildlife operates the Summer Townet Survey (https://www.wildlife.ca.gov/Conservation/Delta/Townet-Survey), which collects zooplankton and fish samples at all stations shown in Figure 16, on a biweekly basis in July and August. In September, the Townet Survey is replaced by the Fall Midwater Trawl, (https://www.wildlife.ca.gov/Conservation/Delta/Fall-Midwater-Trawl), which operates on a monthly basis and also collects zooplankton samples in addition to fish sampling. Similarly, UC Davis conducts the Suisun Marsh Fish Sampling Program, a year-round monthly survey of the Suisun Marsh Region (https://watershed.ucdavis.edu/project/suisun-marsh-fish-study). Finally, the DWR Suisun Marsh group and the DWR Real-Time water quality monitoring group maintain a number of water quality gauging stations in the LSZ and Suisun region. The SMSCG monitoring plan will supplement existing surveys in order to achieve biweekly zooplankton sampling in the LSZ and the Suisun Marsh and River regions in September and October, as well as ensure sufficient spatial coverage of continuously collected variables for water quality, and chlorophyll-*a*, (chl-a) a common surrogate for phytoplankton biomass density. To examine changes in phytoplankton composition, water samples will be collected at continuous water quality stations in Montezuma Slough (Fig. 16) on a monthly basis. The samples will be used for lab validation of continuous measurements of chl-*a*. A sub-sample will be preserved in Lugol's solution and will be available (pending contractor availability) for taxonomic identification. These samples will augment existing IEP phytoplankton sampling and identification that is already carried out on a monthly basis at all EMP stations.

In addition to the EMP invertebrate surveys described above, the study will include a special UC Davis study to examine vital rates for invasive clams. The approach will test the use of caged clams to evaluate growth and survival over the course of the study in multiple locations in the Suisun Marsh region. Such cages are a common tool in ecological studies, but have not been widely used in the SFE. The species composition (e.g. *Corbicula fluminea*; *Potamocorbula amurensis*) of each cage will be adjusted based on EMP monitoring data for the ambient benthic community. Details about this evaluation are provided in Attachment 1.

In addition to long-term and supplemental data collection, other data sources may also be of use in the analysis, described below. For example, there are vegetation and bathymetry maps that may be considered as part of data interpretation.

Table 2. Data sources with current status of data collection.

Variable	**Fall Low Salinity Zone (Dynamic Location)**	**Suisun Marsh Region (Montezuma Sl, Grizzly Bay, Honker Bay)**	**River Region (Mainstem from Confluence area to Rio Vista)**
Abiotic Habitat			
Average Daily Net Delta Outflow	Dayflow	Dayflow	Dayflow
San Joaquin River Contribution Outflow	Dayflow	Dayflow	Dayflow
Surface area of the fall LSZ	Modeling (Anchor QEA)		
Hydrodynamic Complexity	Modeling (Anchor QEA)		
Average Wind Speed		Blacklock (CDEC)	
Turbidity, Salinity, Temperature	*Discrete:* Biweekly, existing STN/FMWT stations + 3 additional stations.	*Discrete:* Biweekly, existing STN/FMWT stations + 3 additional stations. (*n = 8*)	*Discrete:* Biweekly, STN/FMWT stations, from confluence up Sac River to Station 711 (*n = 5)*
	Continuous: Existing Stations + 1 new station in Grizzly Bay	*Continuous:* Existing Stations (GOD, HUN, BDL, NSL, MSL, HON, TYC, PCT) + 1 new station in Grizzly Bay	*Continuous:* Existing stations PCT, MAL, CSE, RVB
Ammonium, Nitrate + Nitrite Concentrations	All EMP Stations, monthly	EMP, monthly: D7, NZ032, NZS42	EMP, monthly: D4, D22
Biotic Habitat			
Chlorophyll-*a*	*Continuous:* Existing Stations + 1 new station in Grizzly Bay	*Continuous:* Existing Stations (GOD, HUN, BDL, NSL, MSL, HON, TYC, PCT) + 1 new station in Grizzly Bay	*Continuous:* Existing stations PCT, MAL, CSE, RVB
Average Phytoplankton Biomass (excluding cyanobacteria)	EMP Stations, monthly	EMP Stations (*n = 3)*, monthly	EMP (n = 2), monthly:
Contribution of Diatoms to Phytoplankton Biomass			
Microcystis Presence/Absence	EMP Stations, monthly; STN/FMWT stations,	EMP Stations (n = 3), monthly; STN/FMWT stations, biweekly + 3	EMP (n = 2), monthly: STN/FMWT stations, biweekly (n = 5)

	biweekly + 3 additional stations	additional stations (n = 8)	
Calanoid copepod biomass in the LSZ			
Cyclopoid copepod biomass in the LSZ			
Bivalve biomass	EMP Stations, Special Study (UCD)	EMP, monthly: D7	EMP, monthly: D4
Juvenile Bivalve survival & growth	Special Study (UCD)	Special Study (UCD)	None
Fish Community	STN/FMWT/EDSM	STN/FMWT/EDSM Suisun Marsh Survey	STN/FMWT/EDSM
Delta Smelt (DS) Responses			
DS caught at Suisun power plants	Existing Monitoring	Existing monitoring	Existing Monitoring
DS in SWP & CVP salvage	Existing Monitoring	Existing monitoring	Existing Monitoring
DS distribution	STN/FMWT/EDSM	STN/FMWT/EDSM Optional: SmeltCAM and eDNA	STN/FMWT/EDSM Optional: SmeltCAM and eDNA
DS growth, survival, and fecundity in fall [a]	STN/FMWT/EDSM (otoliths-growth)	STN/FMWT/EDSM (otoliths-growth)	STN/FMWT/EDSM (otoliths-growth)
DS health and condition in fall	STN/FMWT/EDSM	STN/FMWT/EDSM	STN/FMWT/EDSM
DS Recruitment the next year	STN/FMWT/EDSM	STN/FMWT/EDSM	STN/FMWT/EDSM
DS Population life history variability	STN/FMWT/EDSM (otoliths)	STN/FMWT/EDSM (otoliths)	STN/FMWT/EDSM (otoliths)

Data analysis and synthesis

Data analysis and synthesis will be led by the IEP FLoAT Management Analysis and Synthesis Team (FLoAT MAST), which, like the IEP FLoAT PWT, is composed of state, federal, and non-governmental scientists. Much of the synthesis will be similar to the descriptive and multivariate methods that the team has been using for similar work on the drought and high flow conditions in 2017. Many of the specific analyses used in the synthesis will be comparable to tools used by Brown et al. (2014) and IEP MAST (2015) including graphical comparisons of the study period in relation to recent (e.g. Early

Summer 2018) and historical data (e.g. 1987-Present). Many of the key statistical and design considerations are discussed in Appendix A. However, we do not expect that sample sizes for Delta Smelt Responses (Table 2) will be large enough for statistically robust analyses of several metrics because of extremely low abundance. For this reason, much of the evaluation will be based on habitat conditions. The overall assessment will rely largely on a *weight of evidence* approach that includes the responses of diverse metrics (e.g. Brown et al. 2014).

In general, we will rely on four basic approaches to evaluate the data described in the previous section: 1) Comparisons to historical data; 2) Regional Comparisons; 3) Comparisons for data Before, During, and After the SMSCG Action; and 4) Modeled simulations of habitat components with and without the SMSCG Action. Each of these approaches are described briefly, below. In addition, we provide examples of which of the four approaches will be used on data sets described above (Table 2).

1. Historical Comparisons: A primary approach will be to evaluate the predictions as compared to years when the action was not conducted during the same season (e.g. 1987-2017).
2. Regional Comparisons: A key assumption in our conceptual model is that habitat conditions with be different in the Suisun Region than in the River Region. Hence, many of the data summaries will provide comparisons of these two regions, and perhaps also the LSZ.
3. Comparisons Before-During-After: An additional part of the analysis will include looking at 2018 conditions before (early summer), during (August), and after the action (September-October). The latter approach is particularly important for selected new water quality sensors, zooplankton stations, and clam vital rates for which there is no historical record. For parameters such as temperature that have clear seasonal patterns, we will compare the difference in observed water temperature from the historical average before, during, and after gate operation, rather than absolute temperature. Some before-during-after comparisons, will also adopt a graphically approach (particularly for continuous water quality data), to visualize changes that may occur directly after the gates start operating in early August or directly after operation ends (e.g., we expect salinity to be reduced soon after gate operation begins).

4. Simulation Modeling: Interannual and seasonal variability are confounding factors that will affect our ability to interpret summaries from Approach #1 and #3 above. However, simulation modeling provides an approach to understand how conditions in 2018 might be different with and without the SMSCG Action. As described above, a key element of this work will be UnTrim modeling to provide a high- resolution evaluation of how habitat conditions changed under the action. Additional modeling (e.g. biological, life cycle) will also be considered based on guidance from team members and oversight groups. Hence, the FLoAT MAST will provide updates and presentations to the IEP FLoAT PWT, and to CAMT as appropriate.

Table 3. Example planned analyses.

Variable	Historical Comparisons	Regional Comparison	Before-During-After Comparison	Modeled With/Without Project
Abiotic Habitat				
Average Daily Net Delta Outflow	X		X	X
San Joaquin River Contribution Outflow	X		X	
Surface Area of LSZ	X	X	X	X
Hydrodynamic Complexity	X	X	X	X
Turbidity, Salinity, Temperature	X	X	X	X
Ammonium, Nitrate + Nitrite Concentrations	X	X	X	
Biotic Habitat				
Chlorophyll-*a*	X	X	*X*	
Average Phytoplankton Biomass (excluding cyanobacteria)	X	X	X	

Bivalve biomass	X	X		
Juvenile Bivalve survival & growth		X	X	
Fish Community	X		X	
Delta Smelt (DS) Responses				
DS distribution	X	X	X	
DS growth, survival, and fecundity in fall [a]	X	X	X	
DS health and condition in fall	X	X	X	
DS Recruitment the next year	X			
DS Population life history variability	X	X	X	

Deliverables

A range of deliverables will be provided to suit the needs of different audiences. For technical audiences, our products will include at least two presentations at major conferences (e.g. 2019 IEP Annual Meeting, 2020 Bay-Delta Science Conference). Written products will include a major technical report (e.g. Brown et al. 2014) and draft manuscripts for one or more publishable manuscripts, if appropriate. Our goal is to have each of these completed by Summer 2019. For broader audiences including managers, stakeholders, and the public, we will prepare short summary documents (e.g. one-page fact sheets) to support oral presentations.

Funding

The following summarizes some of the major costs for 2018 and 2019. Most of the funding comes from General Funds provided to DWR to support implementation of the Delta Smelt Resiliency Strategy (DSRS).

UCD Benthic Sampling: $107k (DSRS)

Additional water quality sondes: $30k (DSRS)

3D Modeling support: $100k (DSRS)

Synthesis: In kind contribution of time by DWR PIs and IEP synthesis staff, described in a companion IEP FLoAT MAST proposal.

All other costs included in fully-funded IEP sampling programs (EMP, TNS, FMWT, EDSM, DOP, UCD Suisun Marsh, FRP).

Sample Collection and Permitting

Since the project will rely on existing IEP fish sampling in the region (TNS, FMWT, EDSM, UCD Suisun Marsh, SmeltCAM), the take authority is covered by each respective program. The project includes some additional zooplankton, water quality sondes, and benthic sampling. No additional take for listed species is requested for any of these activities as the entities carrying out the work already have sufficient incidental take coverage.

Operation of the SMSCG in August will require additional permitting for management of the gates. DWR staff and consultants are currently working with USFWS (BO), NMFS (BO), and DFW (Longfin Smelt ITP) to secure the appropriate permits. CEQA compliance will rely on an exemption for the scientific study.

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Attachment 1: Scope of work for benthic cage studies

Suisun Marsh Salinity Control Gate Project: Proposed Studies on Benthic Vital Rates

Project Summary/Abstract

As part of the Delta Smelt Resiliency Strategy, Department of Water Resources proposes to test the use of the Suisun Marsh Salinity Control Gates to improve habitat conditions for Delta Smelt in Suisun Marsh. The purpose of the current study is to examine how changes in regional habitat conditions may influence bivalves, which can strongly affect planktonic foodwebs by reducing water column primary production with potentially serious impacts. This project will investigate factors that may limit the distribution of invasive bivalve molluscs in lower order channels in Suisun Marsh. The goal of this project is to understand how site specific environmental variables such as temperature, dissolved oxygen, and phytoplankton abundance interact with exposure to predators to potentially limit the abundance and impacts of non-native bivalves. The study will examine these processes in both open water sites and in small, low order channels. Both systematic monitoring and manipulative experimental approaches involving outplanted clams with and without predator access will be used to quantify site specific rates of growth and survival as well as size distribution and biomass of bivalves.

Although the University as authorized by the Agreement may utilize other entities to complete certain tasks identified within this Scope of Work (Exhibit A), the University is ultimately responsible for the completion of all activities set forth herein. The University's use of the Grant funds is limited to those expenditures necessary to implement the Project and that are eligible under applicable State of California law. Furthermore, the University's expenditure of Grant funds must be in accordance with the Budget (Exhibit B) and Budget Justification (Exhibit B1), and including all other Exhibits set forth or incorporated by reference within this Agreement. The University may not transfer Grant funds between or among Budget line items without written approval from the State.

Scope of Work

I. TERM OF AGREEMENT

This Agreement shall run from its effective date through July 1, 2018 ("term of agreement") unless otherwise terminated or amended as provided in this agreement. All work for which reimbursement of approved expenditures is requested shall end by June 30, 2019 ("grant end date").

II. PROJECT STATEMENT

Rationale

Delta Smelt Resiliency Strategy proposes a suite of actions to improve habitat conditions for Delta Smelt in the Bay-Delta. A key flow-related action is to use the Suisun Marsh Salinity Control Gates (SMSCG) to reduce salinities in marsh channels, which is hypothesized to allow Delta Smelt to make greater use of the more complex, food rich habitat in Suisun Marsh. Towards this goal, in summer 2018 DWR proposes to conduct an adaptive management experiment in August 2018. The tentative plan is for the SMSCG to be operated for the month of August, an action expected to reduce marsh salinities in that month and several weeks beyond.

The purpose of the current study is to examine the effects of salinity and habitat changes on bivalves in the Suisun region. In estuarine systems, benthic bivalves exert a strong influence on the planktonic food web (Cloern and Jassby 2012), including upper trophic levels such as fish (Sommer et al. 2007, Mac Nally et al. 2010). Salinity has a strong effect on the composition and density of the benthic community (Peterson and Vaysierres 2005). In small, low order channels in Suisun Marsh, bivalves, particularly invasive species occur at low levels (Young et al. 2017). However, the reason for this pattern is uncertain and may be the result of a mix of biotic and abiotic factors. Both salinity. Salinity, dissolved oxygen, and phytoplankton biomass as well as predation may contribute to the distribution of invasive bivalves.

Along with experiments that measure the effects of predation, monitoring water quality and habitat factors have been very useful for understanding the success of bivalves in benthic systems.

Systematic sampling of benthic populations will provide a description of extant bivalve abundance, size structure, biomass, and reproductive status, but not necessarily the processes that trigger specific changes in benthic ecosystem function.

Hypotheses

1. Operation of the Suisun Marsh Salinity Control Gates to reduce salinity in the marsh will alter bivalve growth and survival.
2. Other water quality variables (e.g. temperature, DO) will also have a substantial effect on benthic growth and survival.
3. Benthic growth and survival will be higher in open water areas (e.g. Honker Bay) and large channels (e.g. Montezuma Slough) than in small, shallower, low order channels of Suisun Marsh.
4. Top down predation is the major factor affecting benthic survival in Suisun Marsh and Bay.

III. PROJECT IMPLEMENTATION

Experimental Design and Monitoring Protocol

UC Davis and DWR staff will select four sites that represent both large open water areas and smaller low order channel habitats (see Project Map). The two open water sites will be in Suisun Bay and Honker Bay, and the low order channels will be within in Suisun Marsh. Locations will be selected to avoid excessive currents, high boat traffic, and similar disturbances. Placement will be selected to take advantage of nearby sondes continuously monitoring water quality variables.

At each of the four sites, UCD will conduct quarterly monitoring of bivalve populations using a benthic grab device (small Ponar) to sample size distribution and estimate biomass of bivalves at each site. On a monthly visit at each site, UCD will conduct replicate zooplankton tows to quantify zooplankton species identity and abundance.

In June 2018, at each of the four sites, UCD will install replicate experimental units that will consist of easily deployed trays that will rest on the substrate with either an open top or one covered with 7 mm mesh to exclude predators. Each tray will be approximately 0.3 x 0.3 m and approximately 0.1 m deep and filled with ambient sediment sieved to remove non-experimental clams. Trays will have side panels that angle down to meet the substrate. This will allow both access by mobile benthic predators as well as reduce flow obstruction by the side of the tray. Prior to placement in experiments, clams will be collected from the deployment site, brought into UCD (Wickson Hall lab) for 24 hours and exposed to a buffered calcein treatment to label the growing edge of the shell.

Once in the field, trays will be filled with sediment and clams will be placed in trays and allowed 30 min to orient. The species selected will be within ambient abundances of bivalve species at that site. Trays will be lowered with lines attached to corners of trays, which will be weighted to maintain placement in higher current areas. Deployment lines will also have buoys at the end for later location.

In June 2018, UCD will deploy fifteen replicates of each of the two treatments caged (no predators) vs. open (predator access) at each site. At (five) monthly intervals, UCD will retrieve three replicates of each cages and open treatments at each site and return all clams to the UCD Wickson Hall lab.

Data Analysis

UCD will analyze the growth and survival of the bivalve species used at each site in the UCD Wickson Hall lab. UCD will measure growth of marked individuals in experimental treatments as well as survival on a per cage basis. UCD will examine size structure in benthic samples collected with quarterly monitoring of ambient bivalve populations and from abundance and size distribution estimate biomass of each species at each site.

UCD will also monitor site specific environmental variables including water columns metrics such as temperature, dissolved oxygen, turbidity, and chlorophyll *a*. UCD will rely on continuous available data from moored sensors as well as data collected with hand held devices at site visits.

Data analysis will consist of comparisons of bivalve metrics (growth, survival, size distribution, biomass) among sites and among experimental treatments using both ANOVA and GLMM approaches. UCD will describe environmental variables using nMDS and Principal Components Analysis (PCA) to develop factor loadings to use with the GLMM analysis.

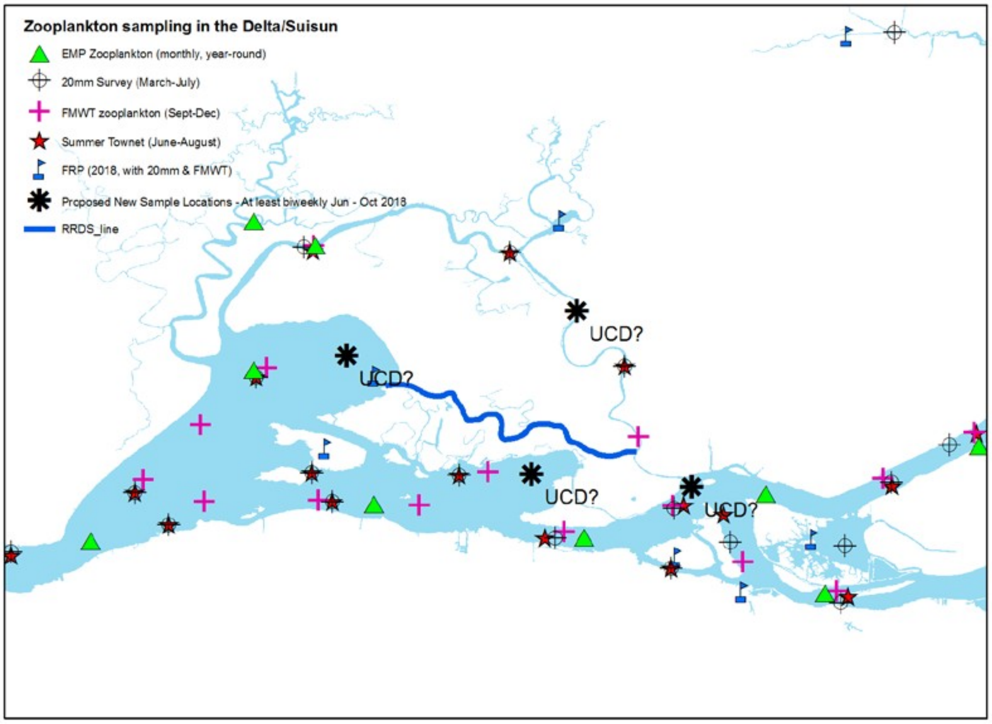
Staffing

The project with be managed and oversee by project P.I. Edwin Grosholz, UC Davis. Project co-P.I. Elizabeth Wells (DWR) will work closely with Grosholz to develop experimental and monitoring protocols and to oversee field work. Grosholz and Wells will regularly meet with project employees and oversee field work. Primary field work will be conducted by UC Davis project staff including Jr. Specialists.

Boats

Arrangements for boat access will be made through UC Davis and operators (e.g. Suisun Marsh Fish Sampling Program or other special arrangement). UCD will rely on DWR staff only for deployment and maintenance of water quality sondes.

PROJECT MAP



Zooplankton sampling in the Delta/Suisun
EMP Zooplankton (monthly, year-round)
20mm Survey (March-July)
FMWT zooplankton (Sept-Dec)
Summer Townet (June-August)
FRP (2018, with 20mm & FMWT)
Proposed New Sample Locations - At least biweekly Jun - Oct 2018
RRDS_line
UCD?
UCD?
UCD?
UCD?