# Structured Decision Making for Delta Smelt Demo Project

**Prepared for**

CSAMP/CAMT

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## Executive Summary

This report documents a demonstration project undertaken during the summer/fall of 2017 to trial an application of structured decision making (SDM) techniques to the management of delta smelt in California's Sacramento–San Joaquin Delta.

Working closely with a Technical Working Group associated with the Collaborative Science and Adaptive Management Program (CSAMP), analysts from Compass Resource Management undertook a preliminary, multi-objective analysis of the 13 actions in the California Natural Resources Agency's Delta Smelt Resiliency Strategy.

The primary purpose of the analysis was to demonstrate the steps and processes that might be followed in the future to create a robust foundation for developing and evaluating actions undertaken in the Delta for delta smelt. The authors are not delta smelt experts but served to facilitate discussions among people with a broad understanding on the ecological, social and economic dimensions of the delta smelt management context.

Over the course of several months, the group worked through the typical steps of a structured decision making process, including, clarifying the decision context; defining an objectives hierarchy and associated performance measures; developing alternatives; estimating consequences and evaluating trade-offs and preferences.

As part of this work, for each of the 13 actions, a coarse-level influence diagram was developed, and major pathways of hypothesized cause and effect relationships described. 'Full build-out' cases for each action were defined to account for the discrepancy between different scales of application of actions specified in the Resiliency Strategy. A bioenergetics model was adapted to help predict the possible consequences for delta smelt of changes in physical parameters resulting from the actions. Structured expert judgment processes were followed to estimate other ecological impacts.

A consequence table summarizing the predicted performance of each of the actions on the objectives was populated and the results used to reach tentative conclusions about the relative priority that might be shown to each of the 13 actions. While this demo project was a 'first pass' analysis of the Resiliency Strategy actions, the process was such that the TWG felt confident in providing preliminary recommendations based on what had been learned.

Finally, this document presents a summary of recommendations about possible next steps and further work.

## Introduction

Delta smelt (*Hypomesus transpacificus)* is a small fish endemic to the Sacramento–San Joaquin Delta in California that is on the verge of extinction (Moyle et al. 2018). In 2016, the California Natural Resources Agency released a Delta Smelt Resiliency Strategy that comprised 13 actions intended to improve the status of delta smelt (CNRA 2016). Although informed by the MAST Report and Conceptual Models (IEP 2015), the Resiliency Strategy does not attempt to assess the relative performance potential of the actions, aiming instead to be, "an aggressive approach to implementing any actions that can be implemented in the near term, can be implemented by the State with minimal involvement of other entities, and have the potential to benefit Delta Smelt". As such, the 13 actions address different hypotheses that, individually or collectively, could affect the current status of the species.

In general, actions for DS can be difficult to implement because of their typically high direct and indirect costs. This is partly due to the large spatial scale and associated resources required of almost any meaningful action and partly due, for those actions that require them, to the high economic value of alternative uses of water and land, as well as the large number of stakeholder groups involved.

The Collaborative Science and Adaptive Management Program (CSAMP) is a multi-stakeholder policy and science advisory body that acts as a forum for discussion between regulatory agencies, non-governmental organizations (NGOs) and Public Water Authorities (PWAs). Its stated purpose is to act as a catalyst through which contentious and urgent management relevant science issues can be discussed and to compile and disseminate information for decision makers on contentious and urgent science issues (CSAMP, 2017). CSAMP has four groups of participants: 1) a Policy Group consisting of federal and state regulatory agency directors and top-level executives from relevant NGOs and PWAs; 2) A Collaborative Adaptive Management Team (CAMT) comprising managers and staff scientists that serve at the direction of the Policy Group; 3) Scoping Teams created on an as-needed basis to scope specific science studies; and 4) Investigators contracted to conduct studies.

In early 2017, CSAMP discussed the potential use of a Structured Decision Making (SDM) process to support some of CSAMP's immediate and longer-term discussions. As used here, SDM is an approach to deconstructing complex and controversial environmental management problems using techniques that help organize and separate technical uncertainties (which are a matter of science) from value-based judgments (which are a matter of policy).

CSAMP decided to trial the use of SDM via a limited demonstration project, referred to as the SDM demo project. The purpose of the demo was to explore the potential application of SDM to issues of importance to CSAMP to better understand its potential future value to the organization.

On behalf of CSAMP, in July 2017 the State and Federal Water Contractors hired Compass Resource Management Ltd of Vancouver, Canada to lead the demo project with technical and policy support from CSAMP members. Compass specializes in using SDM techniques to facilitate multi-stakeholder group decision making in a wide range of environmental management contexts.

## Approach

Compass led initial scoping meetings (in person and via screenshare calls) with CAMT members to begin to understand the decision context and to discuss various possible frames appropriate for SDM analysis. A key decision was taken early on to focus attention on delta smelt issues (as opposed to the wider scope of ecological issues over which CSAMP takes an interest), primarily because the proposal to consider the use of SDM originated from members of the Delta Smelt Scoping Team.

It is obvious that the wider delta smelt management context is profoundly challenging, from both technical and policy perspectives. As a demo project, it was understood that this work should not be expected to in any way 'solve' the broader regulatory problem that delta smelt recovery represents. Rather, it was hoped that this demo could help illustrate how such an approach might, over time, be employed to improve the quality of delta smelt decision making. Whatever the state of technical uncertainties, management decisions nevertheless must be made. A reasonable goal for this work might therefore be to help demonstrate how decision analysis techniques might be used to aid the discussions of a collaborative and multi-stakeholder forum such as CSAMP, both to help structure short-term decision making based on the creative use of the best currently available information and, looking forward, to help organize the research and monitoring activities that might best feed an adaptive, ongoing decision-making framework into the future.

The SDM work relied on the iterative application of the SDM steps shown in Figure 1 (Gregory et al. 2012).

**Figure 1: Structured Decision Making Steps**


The steps are based on decision theory axioms originally set forth by Neumann and Morgenstern (1947) and further developed by others including, perhaps most influentially, Keeney and Raiffa (1993) and Keeney (1992).

- **Clarifying the Context.** The first step is to clearly establish the planning and decision making context: What is the problem or opportunity at hand? Why does it need to be addressed? What decision needs to be made and who will make it? Who else needs to be involved or consulted? What kind of decision is it and how can it usefully be structured? What is the scope and bounds of the process and the decision (e.g., what's in and what's out)? The initial structuring step lays out a road map for both the deliberations and the analysis that will follow.
- **Defining Objectives and Measures**. Objectives define what matters about the decision at hand – the things that people care about and could be affected by the decision. Measures define exactly what is meant by an objective for the purposes of the decision at hand. They are used to consistently estimate and report the predicted consequences of different alternatives, for the purposes of making a choice. Objectives should include all the things that matter, not just the ones that are easily quantified.
- **Developing Alternatives**. Alternatives are the various actions or strategies that are under consideration. In many environmental management contexts, the alternatives are complex sets of actions that need to be thoughtfully developed. This step therefore involves iteratively developing, comparing and refining alternatives in the search for one(s) that offers the best balance across objectives.
- **Estimating Consequences**. At this step the consequences of the alternatives against each objective are estimated or characterized. Sometimes there's a need to gather more information before the consequences can be estimated. Proposed studies are scoped to deliver information

directly relevant to the estimation or understanding of the consequences for the stated objectives and measures. Results are typically presented in a consequence table, which is a concise summary matrix illustrating the performance of each alternative with respect to each objective, as reported by the measures.

- **Evaluating Trade-offs and Preferences**. Although a good decision process typically finds a number of win-wins – alternatives that perform well on multiple objectives – trade-offs of some sort are usually required. The SDM process requires that participants make explicit choices about which alternatives are preferred, based on what is gained and lost on each objective. They are asked to do this based on their own values and their understanding about the values of others (which they've learned about through the process). A variety of methods from the decision sciences are used to facilitate constructive deliberations about values and trade-offs and to ensure that trade-off judgments are informed, thoughtful and transparent.
- **Monitoring and Learning**. A distinguishing feature of SDM is its focus on learning, both to support the decision at hand and to improve future decision making. The focus at this stage of the process is on how to implement the decision in a way that reduces uncertainty, improves the quality of information for future decisions, and provides opportunities to revise and adapt based on what is learned. Many SDM processes end with a formal transition into adaptive management and monitoring, and produce recommendations for the governance and oversight of monitoring programs, as well as triggers and mechanisms for review and amendment.

The above steps describe the generic application of SDM. In practice, modifications are made to these steps to suit a particular context.

This report is structured around the SDM steps, though it should be remembered that although presented in a linear way, actual discussions iterated through the various steps as initial decision sketches took shape. After setup meetings had occurred, the roles of the following groups were defined:

- **SDM facilitators / analysts / researchers** Graham Long, Sally Rudd and Holly Nesbitt, all with Compass Resource Management, led and facilitated the SDM process.
- **Technical Working Group** comprising Ted Sommer (DWR), Scott Hamilton (CSD), Pat Coulston (DFW), Shawn Acuña (MWD) and Will Smith (FWS) (identified at the July 18, 2017 Delta Smelt Scoping Team meeting)
- **CAMT SDM Core Team** comprising Carl Wilcox (DFW), Ted Sommer (DWR), Scott Hamilton (CSD), Erin Gleason (FWS), Kaylee Allen (FWS), Cathy Marcinkevage (NOAA), David van Rijn (USBR), Frances Brewster (PWAs), Garwin Yip (NOAA), Maria Rea (NOAA), Gregg Erickson (DFW), Jason Peltier (PWAs), Josh Israel (USBR), Dave Mooney (USBR), Ingram Campbell (DC) and Leo Winternitz (NGOs).
- **Other Technical Contacts** including Louise Conrad (DWR), Eddie Hard (DBW), Brad Cavallo (Cramer), Erik Loboschefsky (DWR), John Durand (UCD), Rosemary Hartman (DFW), April Hennessey (PWAs), Jim Hobbs (UCD), Brett Harvey (DWR), and others.

Initial scoping and decision-structuring meetings primarily relied on the input of the CAMT SDM Core Team, with regular updates given to the full CAMT group and the Policy Group. Once initial scoping decisions had been made, the Technical Working Group (TWG) met once weekly via phone and screen-share software with Compass. The TWG provided content expertise and offered technical judgments on issues as requested by Compass. Often individual TWG members would provide an offline analysis that would subsequently be reviewed by the wider group and amended as required. Compass' consultants are not fish specialists, but have substantial experience with implementing SDM in similar contexts. Between TWG meetings, Compass researched issues, interviewed other experts, sketched analytical approaches using spreadsheets and influence diagrams and generally prepared analyses for the TWG's review.

Findings of this work were presented to the CSAMP Policy Group in Sacramento on 31 January 2018.

## Problem Definition

There are many ways of framing and scoping the management decision to be examined. After discussion, CAMT, with subsequent approval from the Policy Group, decided on the following:

"Conduct a coarse-level evaluation of the thirteen actions in the Delta Smelt Resiliency Strategy to inform CSAMP discussion on which Delta Smelt Resiliency Strategy actions should be prioritized over the next few years."

CAMT further noted that:

- there are no specific decisions that need to be made regarding the prioritization of the Resiliency Strategy actions over the course of this work (i.e. fall 2017), but the work will primarily be of help with selecting between options over the coming 1-3 years;
- the analysis should not look beyond the 13 actions, but ideas for promising modifications of the 13 actions and new actions should be noted for future evaluation;
- whilst acknowledging that this should be an important aspect of future work, the analysis should not focus on exploring the underlying foundational science of delta smelt – instead the focus should be on structuring the decision as a multi-objective trade-off analysis problem for which scientific models could later provide the required data;
- various initiatives are underway, and data is being collected that could inform future choices. Therefore, the analytical framework to evaluate the 13 RS actions should be sufficiently flexible to continue to be developed and elaborated upon for an evaluation of any modified or new actions;
- assessments should be made on best available information, but should be updateable as information becomes available;
- the various actions often have different agency decision-makers and responsible actors. For the purposes of simplicity and for the purposes of this exercise, actions should be evaluated as if CSAMP were the decision-making body;
- an important emphasis was the process through which work occurs towards seeking areas of consensus based on a transparent rationale;
- the process should be documented so as to allow future updates to build on advances made on specific issues.

An early observation was that the 13 Resiliency Strategy actions are at different levels of development and scale, and so decisions needed to be made around how to compare like with like. For example, the aquatic weed control action is a small-scale pilot application to learn about the feasibility of application, with a view to potentially scaling up this work should initial results prove successful; by contrast, the summer outflow augmentation action could immediately occur at a large scale of implementation. How can these two actions fairly be compared? A decision was made to consider the actions at a hypothetical 'full build out scale' – i.e. a scale that might reasonably be foreseeable if the underlying premise of the alternative's mechanism of effect prove to be validated. The details of how this was achieved are detailed in the Alternatives section below.

In part due to this focus on the 'bigger picture' of the potential for success of the actions, implementation issues such as permitting concerns or other practical considerations were put aside for the initial SDM evaluation. If an action appears to be relatively ineffective even if its basic technical premise is assumed to be correct and without practical constraints considered, then this may imply that the action should be deprioritized. A second, more qualitative discussion about implementation and portfolio (i.e. action combinations) issues should occur as part of a more comprehensive SDM process.

## Objectives

In the decision sciences, objectives are the 'things that matter' in a decision. They are typically presented in verb-noun format with a clearly understood preferred directionality ('increase survival', 'decrease costs' etc.) (Keeney 1992). In the context of this SDM demo project, the objectives cover the full range of ecological, social and economic factors that could be affected by implementation of the Resiliency Strategy actions. In practical settings, objectives are often inferred from group exercises that yield results such as those shown in Figure 2.

**Figure 2: Initial brainstorm of relevant factors**

*From Decision sketching workshop, 5 July*
*A brainstormed list of factors that should be considered when evaluating which actions to prioritize*

- Significant contribution to recovery (formal recovery, or significant contribution to, increased DS abundance) - quantifiable
- State - resiliency is improving the ability to respond to stressors, a lower bar than recovery
- Reducing the risk of extinction
- Anything that could make things better for the smelt
- High level of certainty for contributing to recovery…
- Dollar cost and water supply cost
- Minimizing impacts to other species
- Conservation benefits to other species -
- Timeliness - time to implement
- Is there a champion
- Political support
- Time to see benefit to species
- Clarity of the result - if we try something, can we see the result
- Potential for recovery (may have low P(), but potential is there)
- Measurability
- Learning (about DS themselves)
- Duration of benefits - sustainability of the action and the result
- e.g. weed removal
- Existing regulatory requirements and context
- e.g. Take into account how section 7 would be taken into account
- Compatibility with existing statutes
- Water Quality
- Recreation
- Navigation
- Unintended consequences
- Incidental consequences
- Ability to maintain a collaborative effort (Process objective)
- Engineering feasibility
- Controversy - disagreement on science or consequence
- Agriculture
- Potential short term negative effects vs long term benefits
- Delta community - preserving the delta as 'place' - consistency with delta plan.

Post-processing of these initial inputs, in collaboration with CAMT and TWG, ultimately resulted in the development of the objective structure in Figure 3. Further information on how they were operationalized is provided in subsequent sections.

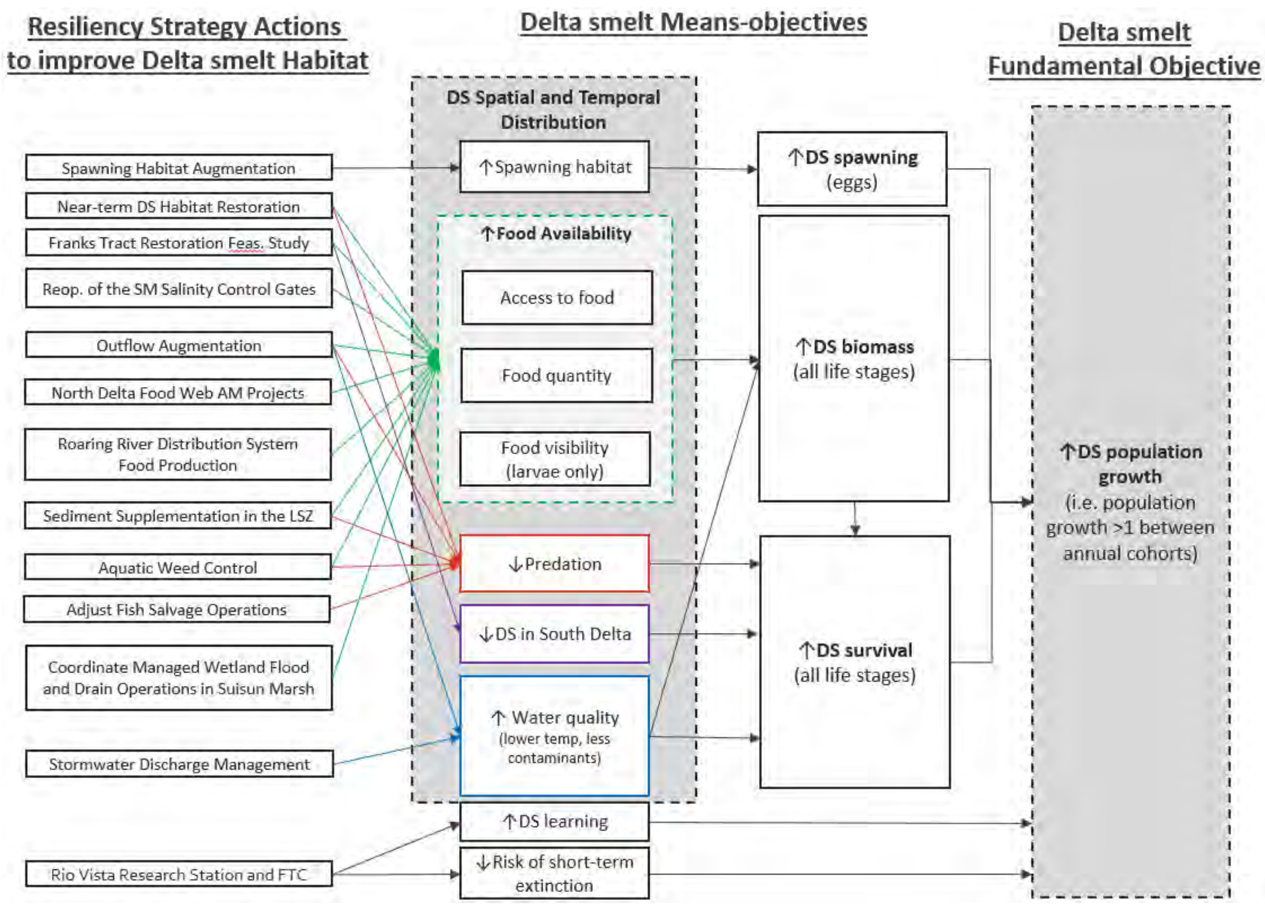
**Figure 3: Objective Structure for delta smelt demo project**

| | |
|---|---|
| **Delta Smelt Population Growth**<br>• Biomass growth<br>• Survival<br>• Spawning & recruitment<br>• Resiliency to random events<br>• Learning<br><br>**Other Ecological Considerations**<br>• Salmon<br>• Other native estuarine species<br>• Other ecological | **Socio-economic Considerations**<br>• Water quality for in-Delta diversions<br>• Navigation<br>• Recreation<br><br>**Resources Required**<br>• Financial Cost (staff time, upfront/ongoing costs, water costs) |

## Delta Smelt Objectives

A fundamental objective is to increase the population growth of delta smelt. As the MAST report (IEP, 2015) and others discuss, there are many potential cause-effect pathways that could be relevant in understanding what drives delta smelt population growth. Figure 4 is a much-simplified means-ends diagram (see, for example, Clemen and Reilly 2001) developed for this project that describes at the most generic level some of the primary assumed linkages between Resiliency Strategy actions and population growth. As the figure suggests, some actions primarily seek to increase food availability, while others seek primarily to reduce predation. One action attempts to improve spawning habitat, whilst other actions work along other pathways.

**Figure 4: Overall means-ends diagram for delta smelt**




While a fundamental objective is to increase delta smelt population growth, it is not currently possible to estimate this directly given current modeling tools. Instead, an action's effect on means-objectives or 'sub-objectives' that contribute to improved population growth were estimated. The table below summarizes the delta smelt sub-objectives used for this exercise.

The first two, increased growth (biomass) and survival, are the expected effects of most actions. As will be discussed in a later section, both were estimated using the outputs of a modified bioenergetics model. The model, however, does not capture other dimensions of benefits for delta smelt deemed important by the TWG, and so three other means-objectives are stated to account for actions that seek to address these issues: (1) spawning & recruitment, (2) resiliency to random events, and (3) learning.

| Sub-Objective | Performance Measure (PM) (Units) | Description |
|---|---|---|
| Growth (biomass) | Biomass (kg) or % change in biomass from reference | Reports the overall change in biomass predicted by the bioenergetics model for an action. Could be reported in absolute kilograms or relative to a reference case. Increased biomass is important for increasing population growth because larger fish are more likely to produce more offspring in the subsequent year and larger fish have higher rates of survival.<br><br>In the bioenergetics model used in this project, individual delta smelt biomass is a function of zooplankton biomass density, water temperature and other parameters (e.g. prey vulnerability). Total delta smelt biomass at the end of the model simulation (i.e. the total biomass of the modeled delta smelt population) is a function of both the biomass gained by individual fish and the survival rate of the modeled delta smelt population. |
| Survival (population #s) | Survival (population #s) or % change in survival from reference | Reports the overall change in delta smelt survival predicted by the bioenergetics model for an action. Is reported as the proportion of delta smelt alive at the end of the model simulation run compared to the starting population. Improved survival is important for increasing population growth as the more fish that survive to reproductive age, the more recruits.<br><br>In the bioenergetics model used in this project, survival is a function of food availability, fish size, entrainment, and a natural mortality rate that represents predation and other causes of death. This natural mortality rate varies according to turbidity. |
| Spawning & recruitment | Constructed scale (+3 to -3) | Reports expected changes in spawning and recruitment conditions from an action. This sub-objective and performance measure were used to capture any benefits of an action to the spawning and recruitment life stage that were not already captured through modeling the growth and survival benefits of an action. Because this was a demonstration project, the bioenergetics model used in this project only simulated delta smelt growth and survival from June 1 to Jan. 31 and excluded the spawning, larvae and early juvenile life stages. |
| Resiliency to random events | Constructed scale (+3 to -3) | Reports expected changes in the resiliency of delta smelt to random events, which are not included in the bioenergetics model. Delta smelt's short lifespan lends it highly vulnerable to high-impact stochastic events such as droughts or spills. Some actions increase resiliency by acting over a variety of spatial strata and lifecycle stages, reducing vulnerability to such events. |
| Learning | Constructed scale (+3 to -3) | Some actions improve our ability to learn about issues of importance to managing delta smelt, both in terms of fundamental science and in terms of understanding the effectiveness of management actions. Learning can therefore be considered an objective in its own right (McDaniels and Gregor 2004). |

## Other Objectives

The Resiliency Strategy actions have the potential to affect other important societal objectives for ecological health, efficient use of resources, and strong local economies and communities. These other objectives were grouped into three categories: (1) other ecological considerations, (2) resources required, (3) socio-economic considerations; sub-objectives of these categories were developed at a level of detail appropriate for this demonstration project (see tables below for description of the sub-objectives). A more comprehensive SDM process for delta smelt would further refine these objectives. The goal was to illustrate what a decision process might look like when potential impacts to non-delta smelt objectives are identified explicitly.

With the exception of financial costs, all other non-delta smelt objectives were evaluated qualitatively using a 7-point constructed scale from +3 to -3 to indicate whether the action is expected to have positive benefits for an objective (+1 to +3), no effect (0), or adverse effects for an objective (-1 to -3).

### Objective: Other Ecological Considerations

| Sub-Objective | Performance Measure (Units) | Description |
|---|---|---|
| Salmon | Constructed scale (+3 to -3) | Although developed with delta smelt in mind, there is the potential for Resiliency Strategy actions to have positive and negative impacts to salmon. |
| Other native species | Constructed scale (+3 to -3) | Similarly, the actions could affect other native species in a positive or negative way. |
| Other ecological impacts | Constructed scale (+3 to -3) | Actions could have an impact to broader ecological issues. |

### Objective: Resources Required

| Sub-Objective | Performance Measure (Units) | Description |
|---|---|---|
| Financial Costs | $/year | Reports the estimated financial costs of implementing the action over a 20-year period, including upfront capital costs, ongoing operating costs (e.g. staff time, annual monitoring), and water costs. |

**Objective: Socio-economic Considerations**

| Sub-Objective | Performance Measure (Units) | Description |
|---|---|---|
| Water quality for in-Delta diversions | Constructed scale (+3 to -3) | Reports any positive or negative changes that might occur to water quality from an action that would impact in-Delta diversions for municipal and agricultural uses (e.g. increasing/decreasing salinity levels). |
| Navigation | Constructed scale (+3 to -3) | Reports any positive or negative changes that might occur to navigation from an action. |
| Fishing / waterfowl hunting | Constructed scale (+3 to -3) | Reports any positive or negative changes that might occur to recreational fishing and waterfowl hunting from an action. |
| Non-consumptive recreation | Constructed scale (+3 to -3) | Reports any positive or negative changes that might occur to non-consumptive recreational activities (e.g. sightseeing) from an action. |

## Alternatives

In this process the 13 actions are treated as if they were alternatives. This is atypical in at least two ways:

1. It is unusual for an SDM process to have pre-defined alternatives. More typically, alternatives need to be creatively developed, often by considering each of the objectives in turn and exploring different ways of maximizing or minimizing them to help determine the decision space. Working with pre-defined alternatives is suitable for a demo project, but the true space of opportunity in this situation is not known and should be explored in future work.
2. Additionally, there is usually a distinction made between actions and alternatives per se. An alternative is typically defined as a complete solution to a management context, and often includes combinations of individual actions. However, in this case, CAMT and the CSAMP Policy Group were interested in developing a general sense of implementation priorities across the actions. Due to timing constraints, grouping of actions into 'portfolios' was not considered as part of this demo project, though this could be a logical next step for future work. For this reason, in this case, the terms 'action' and 'alternative' are largely treated as synonyms.

Defining the full build out case for each action was undertaken directly with the TWG with review from CAMT. Slightly different principles for doing so needed to be developed to accommodate the range of actions. These were:

- Where the action is inherently limited in scale, the largest scale of application that could reasonably be foreseen, OR
- Where the action is not inherently limited in scale, the largest scale reasonably required to have a meaningful effect

Table 1 summarizes the primary specific parameters assumed when defining the full build-out cases for each action. Detailed descriptions of these actions are included in Appendix A. Note that the full build out scenarios were based on the best professional judgement of the TWG based on what might be a reasonable larger scale. The team acknowledges that full build out alternatives could be substantially different based on information gained from initial pilot actions. As such, these scenarios are intended as examples for the current SDM demonstration effort rather than complete project descriptions for each.

**Table 1: Full Build-out Scale Scenarios for Resiliency Strategy Actions**

| **Resiliency Strategy Action** | **Full Build-out Scenario** |
|---|---|
| Aquatic Weed Control | 10,000 acres of aquatic weed control; assumes no adverse impact of herbicides (best case). |
| North Delta Food Web | 24,000 acre-feet pulse flows in Jul & Sep in Yolo Bypass. |
| Outflow Augmentation | 250 thousand acre-feet to keep X2< 80km for as long as possible in spring/summer. |
| SMSCG Reoperation | Operate gates to make Suisun Marsh as fresh in below normal and dry years as in above normal years; offset salinity increase in Delta with 60 thousand acre-feet. |
| Sediment Supplementation | Increase turbidity in LSZ by 10 NTU in below normal, dry and critical years. |
| Roaring River | Increase connectivity of Roaring River to the estuary and mange to improve food supply (zooplankton). |
| Coordinate Managed Wetlands | Flood and drain 7,500 acres of managed wetlands to improve food supply (zooplankton); assumes adverse water quality impacts (e.g. decreased dissolved oxygen from decomposition of organics) can be avoided through managing the timing of wetland draining. |
| Adjust Fish Salvage Operations | Do not return non-native fish to the Delta from Jul-Sep. |
| Stormwater Management | Reduce contaminant loading into Ulatis Creek Watershed (Cache Slough area) by 50% during winter storm events using constructed wetlands. |
| Rio Vista Research Station | Consolidate existing IEP monitoring and research activities and upgrade refuge population facilities; assumes no population augmentation. |
| Habitat Restoration | 11,000 acres of tidal marsh restoration in the north Delta arc. |
| Franks Tract Restoration | Restoration of Franks Tract to establish large areas of emergent marsh; modify flow dynamics, creating a ‘speed bump’ to reduce the number of delta smelt in less desirable habitat conditions in the S. Delta. |

Further information on the alternative definitions assumed for each alternative are presented in Appendix 1.

For the purposes of this analysis, each action is characterized in terms of several factors that are relevant for modelling and impact estimation, including, as shown in Table 2:

- Potential spatial extent of effect of the action
- Types of water years potentially affected by the action
- Life stages potentially affected by the action
- Key delta smelt sub-objectives potentially affected by the action
- Key environmental drivers affected (changes in which may be reflected in modelling input changes).

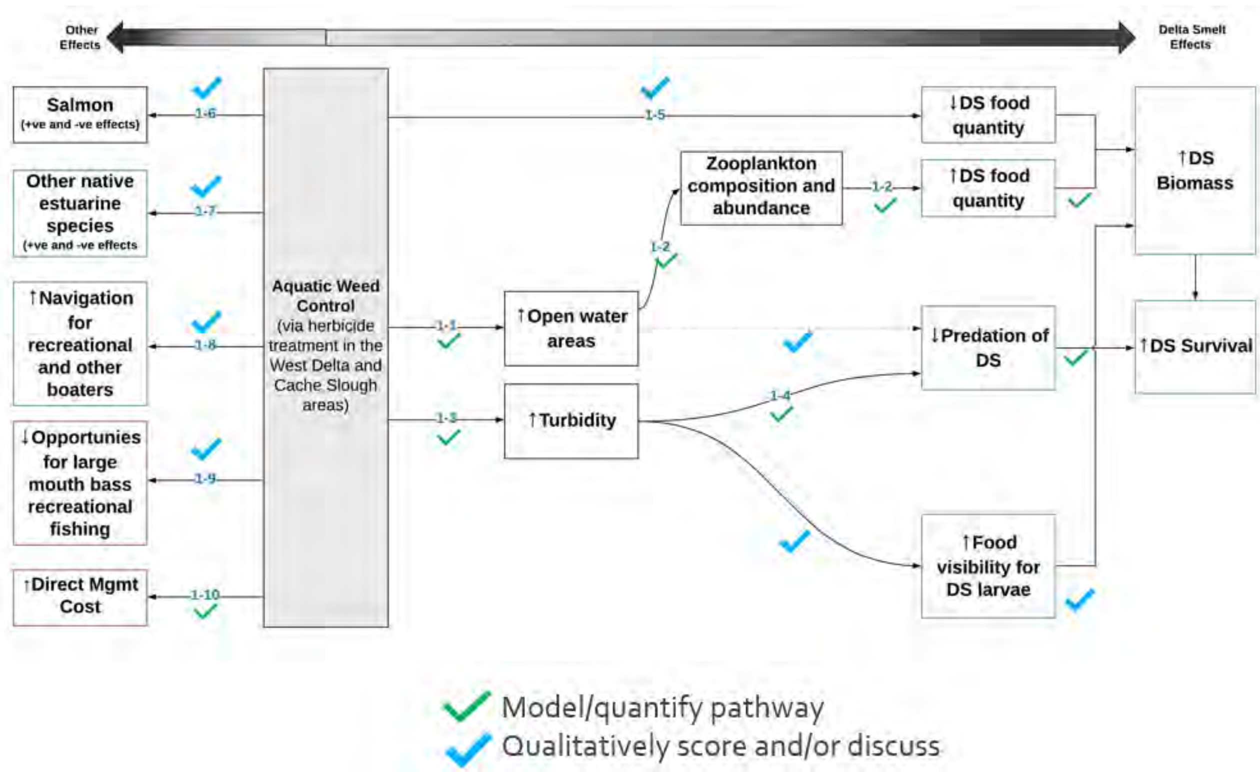
**Table 2: Detailed spatial, temporal and ecological definition of Full Build-out Scale Actions**

| Full Build-out Scale Scenario Definition | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Resiliency Strategy Actions | Spatial Scale of influence | | | | Water Years Implemented (Temporal Scale) | | | | | Life Stages Benefited (Temporal Scale) | | | | Key Means-Objectives | | | Environmental Drivers Affected | | | | | |
| | Upper Sacramento | Confluence (inc. Lower SJ) | Suisun Marsh | Suisun Bay | Wet | Above Normal | Below Normal | Dry | Critical | Eggs/Larvae Mar-Jun (Spring) | Juveniles Jun-Sept (Summer) | Sub-Adults Sept-Dec (Fall) | Adults Dec-May (Winter) | Food & Biomass Growth | Predation & Survival | DS Spatial Distribution | Productivity | Turbidity | Vegetation | Salinity | Contaminants | Predators |
| 1. Aquatic Weed Control | Y | Y | - | - | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | - | Y | Y | Y | - | - | - |
| 2. North Delta Food Web Adaptive Management Projects | - | Y | Y | Y | Y | Y | Y | Y | Y | - | Y | Y | - | Y | - | - | Y | - | | - | - | - |
| 3. Outflow Augmentation | Y | Y | Y | Y | - | Y | Y | Y | - | Y | Y | - | - | Y | Y | Y | - | - | - | Y | - | - |
| 4. Reoperation of the Suisun Marsh Salinity Control Gates | - | - | Y | - | - | - | Y | Y | - | - | Y | - | - | Y | Y | Y | - | - | - | Y | - | - |
| 5. Sediment Supplementation in the Low Salinity Zone | - | Y | Y | Y | - | - | Y | Y | Y | Y | Y | - | - | - | Y | - | - | Y | - | - | - | - |
| 7. Roaring River Distribution System Food Production | - | - | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | - | - | Y | - | - | - | - | - |
| 8. Coordinate Managed Wetland Flood and Drain Operations in | - | - | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | - | - | Y | - | - | - | - | - |
| 9. Adjust Fish Salvage Operations during Summer and Fall | - | Y | - | - | Y | Y | Y | Y | Y | - | Y | - | - | - | Y | - | - | - | - | - | - | Y |
| 10. Stormwater Discharge Management | Y | - | - | - | Y | Y | Y | Y | Y | - | - | - | Y | Y | - | - | - | - | - | - | Y | - |
| 11. Rio Vista Research Station and Fish Technology Center | N/A | | | | | | | | | | | | | | | | | | | | | |
| 12. Near-term Delta Smelt Habitat Restoration | Y | Y | Y | - | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | - | Y | Y | Y | - | - | - |
| 13. Franks Tract Restoration Feasibility Study | - | Y | - | - | Y | Y | Y | Y | Y | Y | Y | Y | Y | - | Y | Y | - | - | Y | - | - | - |

## Estimating Consequences

To estimate the consequences of each of the actions on the objectives, an influence diagram must first be developed that articulates the conceptual linkages between cause and effect. An early task was to work through each of the actions to develop such a diagram. Figure 5 illustrates the influence diagram developed for the aquatic weed control action.

**Figure 5: Influence diagram illustrating hypothesized links between Action 1 and objectives**

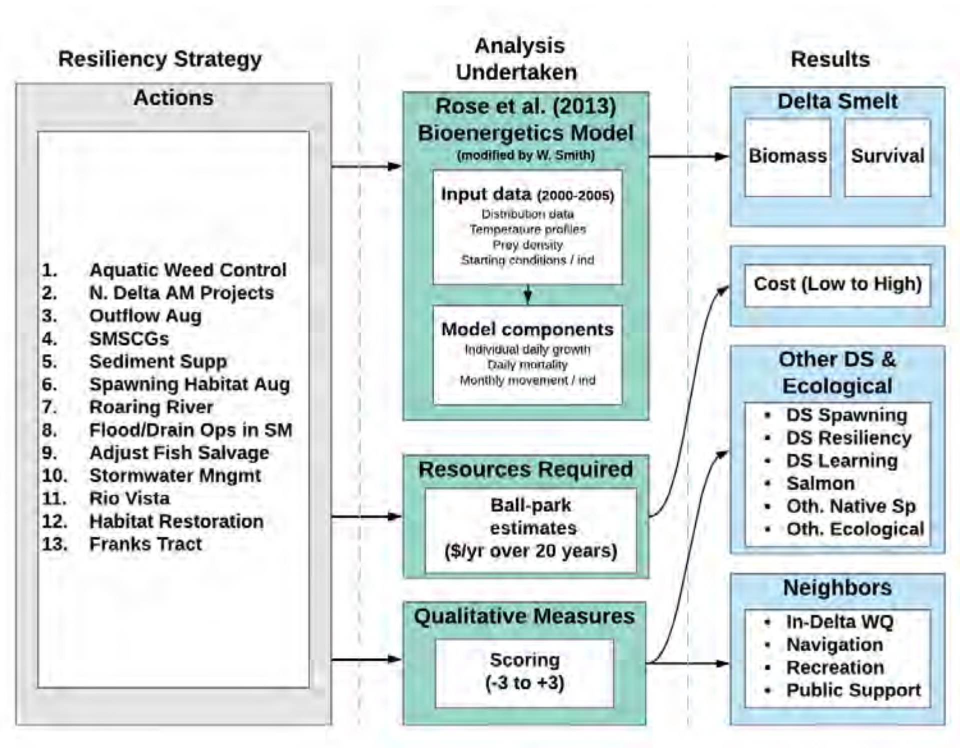



As with similar diagrams developed for the other actions, in this figure, the action is depicted in a grey box. Boxes to the left of this box represent potential links to non-delta smelt objectives. To the right, potential pathways of effect on delta smelt are developed in slightly more detail. The small arrows inside each box represent the expected directional change of each step in the influence diagram, where one is known. For example, aquatic weed control is assumed (1-1) to increase the areas of open water, which leads to (1-2) a change (positive and/or negative of various species) in zooplankton composition and abundance, which in turn is expected to increase delta smelt food quantity and quality.

For the purposes of this limited demo project, the diagram is not fully developed, but is instead intended only to capture the primary impact mechanisms identified by the TWG.

Once developed, Compass and the TWG then considered potential methods for estimating the consequences of each action on each of the links in the diagram. The main focus of the demo project was on estimating impacts on delta smelt biomass and survival. Coarser methods were developed for estimating impacts on other delta smelt objectives (spawning, resiliency to random events), and other ecological and social objectives. The methods used for estimating impacts are described in the following sections and summarized in Figure 6.

**Figure 6: Summary of methods used to estimate consequences**




## Estimation of impacts on delta smelt biomass and survival

The original bioenergetics model presented in Rose et al. (2013) was modified to simulate interannual variation in delta smelt growth and survival conditions across different actions. Will Smith's (FWS) detailed methods for modifying the Rose et al. (2013) bioenergetics model for the purposes of this project are documented in Appendix 2 and a brief summary is provided below.

The modified bioenergetics model (Figure 7) simulated the biomass and survival of individual delta smelt from June 1 to January 31. The model started with a population of 100,000 individuals randomly attributed to 11 strata within the Delta based on the June 20 mm Survey. Based on growth, mortality, and movement simulations, the model simulated changes in the number of individuals/day and their daily weight and fork length. Growth rates of each individual were considered to be dependent on water temperature in each strata, prey (zooplankton) density and composition in each strata, prey vulnerability, and stage specific consumption rates. Mortality included starvation, predation and entrainment. Movement was simulated on a monthly time step using monthly survey distributions (smoothed) and specific rules for individual movement. Input data were based on the selected year (2000 to 2005). The model then gave an estimate of biomass (sum of all growth) and abundance (total number alive) by January 31.[1] The purpose of the model was to determine the relative performance of each of the management actions on within-year delta smelt biomass and survival as proxies for evaluating an action's benefits for overall delta smelt population growth.

Different management actions could be simulated by changing elements of the model to reflect changes expected from those actions. Each action was first defined in terms of expected changes to prey density,

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[1] The model assumes that fish do not spawn before Jan. 31 (i.e. no loss of biomass occurs due to spawning in the model). This is a simplification of reality as some delta smelt will spawn prior to Jan. 31.

secchi depth, and population distribution, and then compared to a baseline scenario with no changes to any model elements. For example, for actions that were expected to affect prey density, prey parameters in the model were altered and results were compared to the baseline (unaltered simulation). For actions that were expected to affect delta smelt distribution by improving access to suitable habitat, movement probabilities were modified, and the results compared to the baseline. Decisions on how to alter input data and model parameters for the purposes of simulating an action were made collaboratively by the TWG based on information that was readily available for this analysis. This included making estimates based on existing studies, performing coarse spreadsheet analyses, and from consulting third party experts. The details of the methods used are described for each action in Appendix 1.

**Figure 7: Bioenergetics Model – modified Rose et al. (2013) model by Will Smith (FWS)**

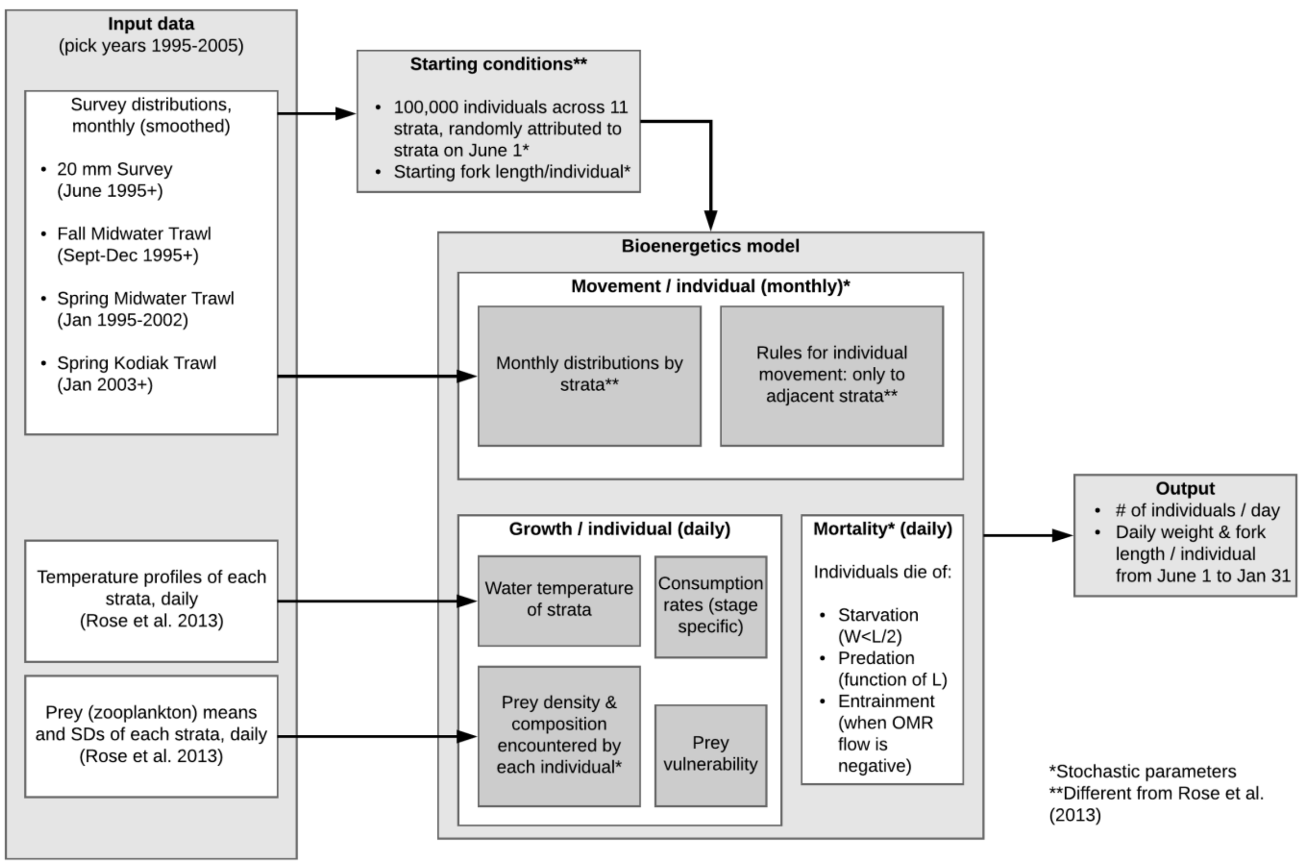
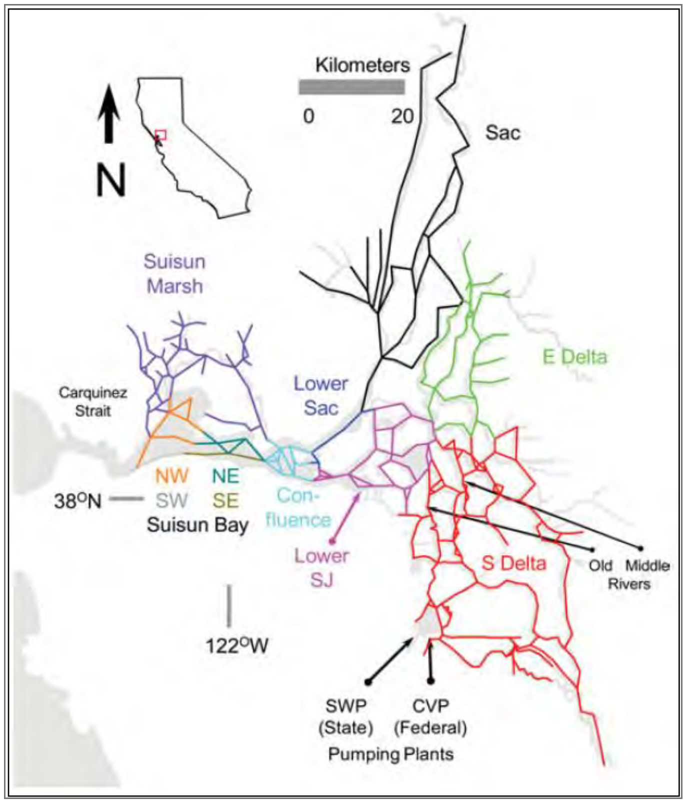


**Figure 8: Spatial grid and boxes used in the Rose et al. (2013) Delta Smelt Simulation Model. Gray represents the outline of the estuary. The 11 boxes are color coded and refer to (in numerical order): (1) Sacramento River region (Sac) of the Sacramento-San Joaquin Delta; (2) eastern Delta (E Delta); (3) southern Delta (S Delta); (4) lower Sacramento River region (Lower Sac); (5) lower San Joaquin River region (Lower SJ); (6) confluence (westernmost box in the Delta); (7) southeast Suisun Bay (SE); (8) northeast Suisun Bay (NE); (9) Suisun Marsh; (10) southwest Suisun Bay (SW); and (11) northwest Suisun Bay (NW).**




*Model limitations and uncertainty*

The main limitation of the bioenergetics model used in this project is that the model did not include delta smelt life stages from February 1 to May 30, which include the spawning, egg, larvae and early juvenile stages. This time period also includes the potentially large entrainment events for larval and juvenile delta smelt. This time period was excluded for practical reasons; the original Rose et al. (2013) model includes this period and so a complete life cycle could be built as required for future work.

The approach used in Rose et al. (2013) was the foundation for this work and much of the uncertainty is consistent between both approaches. Most parameters were not stochastic in Rose et al. (2013) and thus did not have standard errors associated with them.

The intent of the model was to examine the relative performance of each of the full build out scale action scenarios. Thus, for the purposes of this approach, the interest was in examining relative general differences in performance across actions rather than focusing on model precision.

The TWG reported that they were satisfied with the Rose et al. (2013) model for comparing the relative delta smelt growth and survival changes for different management scenarios and would recommend it for similar applications.

## Estimation of financial costs (including water costs)

Coarse estimates of the 20-year annual undiscounted costs of the actions were made. Cost levelization was necessary since some actions have a large initial capital investment, whereas others have annual costs. In some cases, relatively detailed cost estimates were developed, based on reasonable assumptions. A detailed breakdown of cost estimates is presented in Appendix 3.

For actions that required water, it was assumed that this water would need to be purchased through voluntary purchase agreements. This assumption is consistent with the intent of the Resiliency Strategy, which does not intend to mandate non-voluntary provision of water. High-, moderate- and low-cost assumptions for water purchases were provided by the CAMT SDM Core Team (August 2017 meeting).

At the January 31, 2018 CSAMP meeting where this work was presented, it was suggested by one CSAMP member that water costs should be reported separately from other financial costs as the monetization of water might not be appropriate in all contexts and deserves explicit consideration rather than being bundled with other costs.

## Estimation of other delta smelt and ecological objectives

A qualitative scoring technique was used to obtain values for the remaining delta smelt and ecological objectives. The scoring was undertaken by TWG members according to their areas of knowledge and two additional guest experts participated to score the salmon objective.

The precise methods used varied for each objective and are thus too complex to document fully here. By way of example, Figure 9 shows a stage in the development of scoring for the first qualitatively-scored objective, 'spawning and recruitment'. (Note in this figure, Action 6 was no longer considered for reasons discussed in a later section). In this case, experts were first independently asked to consider how each of the actions might affect the ability of delta smelt to spawn / recruit. They were asked to rate each of the actions on a +3 to -3 scale, where +3 indicated a strong expected net benefit to this objective. Participants were asked to consider relevant factors including:

- Consider growth and survival only for the life stages during the period that were not modelled (Feb. 1 to May 30), i.e. spawning, egg (survival) and larvae. Juveniles were excluded as their growth and survival is considered in the biogenetics modelling from June 1 onwards.
- Consider the geographic extent that the action could influence and consider the overlap between the spatial influence of the action and the spatial distribution of delta smelt during this time period.

**Figure 9: Compiled expert judgments on the impacts of actions on delta smelt spawning and recruitment**

| Resiliency Strategy Action - Full Build-out Scale Scenario | Max Minus Min | Expert 1 | Expert 2 | Expert 3 | Expert 4 | Expert 5 | Ave |
|---|---|---|---|---|---|---|---|
| 1. Aquatic Weed Control | 1 | 3 | 2 | 2 | 3 | 2 | 2.4 |
| 2. North Delta Food Web Adaptive Management Projects | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3. Outflow Augmentation | 1 | 1 | 1 | 0 | 1 | 0 | 0.6 |
| 4. Reoperation of the Suisun Marsh Salinity Control Gates | 1 | 0 | 0 | 1 | 0 | 1 | 0.4 |
| 5. Sediment Supplementation in the Low Salinity Zone | 1 | 1 | 1 | 1 | 0 | 1 | 0.8 |
| ~~6. Spawning Habitat Augmentation~~ | 0 | | | | | | |
| 7. Roaring River Distribution System Food Production | 1 | 1 | 0 | 1 | 1 | 1 | 0.8 |
| 8. Coordinate Managed Wetland Flood and Drain Operations in Suisun Marsh | 1 | 2 | 1 | 2 | 1 | 2 | 1.6 |
| 9. Adjust Fish Salvage Operations during Summer and Fall | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 10. Stormwater Discharge Management | 1.5 | 1 | 2 | 2 | 2 | 0.5 | 1.5 |
| 11. Rio Vista Research Station and Fish Technology Center | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 12. Near-term Delta Smelt Habitat Restoration | 1 | 2 | 3 | 2 | 3 | 2 | 2.4 |
| 13. Franks Tract Restoration Feasibility Study | 1 | 1 | 1 | 1 | 2 | 1 | 1.2 |

Scoring results were received from each expert, along with written comments from each on why a particular score was given. During a series of screenshare sessions, the results from each TWG member /

expert were compared, and a 'max minus min' column calculated the largest net difference between any one participant and another. Where the difference was one or less across all participants, no discussion occurred. Where there was a wider difference, the TWG discussed why such a difference may have occurred, in order to clarify whether this was a result of a difference in technical opinion or in assumptions made about the action or the scoring methodology. Through such debates, some experts modified their own scores, but no pressure was exerted to minimize the differences.

After these discussions, no notable differences in judgments between the participants remained. At the end of this process, all agreed that the discussions were valuable in helping to build mutual understanding and trust. Finally, given the ultimate relative consensus on the outcomes, an average score across the participants was used in the consequence table.

Documentation of scores and rationales is included in Appendix 4.

### Estimation of impacts for socio-economic objectives

Due to time constraints, the scores for the socioeconomic objectives were estimates made by Compass staff based on interviews undertaken as part of the general research undertaken on each of the actions. In a real SDM process, considerably more effort would be required to make these judgments. The scores are included here for demonstration purposes and to document the information gathered from this demo project. Future efforts using the SDM approach would likely include much more emphasis on estimation of socioeconomic effects. For instance, a socio-economic working group could be established to inform the estimated performance of actions on the socio-economic objectives.

## Results and Trade-offs

As a demo project, the findings of this approach should be taken for what they are – the 'first-pass' outputs of a limited process whose primary goal was to sketch the outlines of a process rather than find technically-defensible outputs.

### Delta Smelt Biomass Growth and Survival

Table 3 shows the delta smelt modelling findings by alternative. The color coding in the column headings are intended to communicate the relative degree of certainty in the findings, where blue indicates actions that the TWG had more certainty in the characterization of effects given the nature of the assumptions that needed to be made, and grey indicates less certainty.

**Table 3: Delta smelt modelling findings by alternative**

| | Units | 1. Aq. Wd. Control | 2. N. Delta Food | 3. Out-flow Aug. | 4. SMSCG | 5. Sed. Supp. | 7. Roar. River | 8. SM Drain Flood | 9. Fish Salv. | 10. Storm water | 11. Rio Vista | 12. Hab. Rest. | 13. Franks Tract |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DS growth | % change | 12% | 34% | 0% | 0% | 7% | 1% | 34% | 1% | 0% | n/a | 7% | 1% |
| DS survival | % change | 11% | 13% | 0% | 0% | 7% | 1% | 11% | 1% | 0% | n/a | 3% | 1% |

Table 3 shows the changes in biomass growth and survival as average percent differences over the six years modelled relative to a reference case (see Appendix 2 for description of reference case parameters). Actions 1, 2 and 8 are generally showing the most favorable results, with actions 5 and 12 having smaller positive results. The remaining actions are not showing a meaningful difference from the reference case; however, not all the identified delta smelt pathways of effect were incorporated into the analysis, so this should not be taken to suggest that the actions have no benefit for growth or survival.

## Other Delta Smelt and Ecological Objectives

Table 4 summarizes the qualitative scoring for delta smelt and other ecological objectives by action. It is first noticeable that all of the scores are positive.

**Table 4: Qualitative scoring for delta smelt and other ecological impacts by action**

| | Units | 1. Aq. Wd. Control | 2. N. Delta Food | 3. Out-flow Aug. | 4. SMSCG | 5. Sed. Supp. | 7. Roar. River | 8. SM Drain Flood | 9. Fish Salv. | 10. Storm water | 11. Rio Vista | 12. Hab. Rest. | 13. Franks Tract |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **DS spawning/recruitment** | -3 to +3 | 2.4 | 0.0 | 0.6 | 0.4 | 0.8 | 0.8 | 1.6 | 0.0 | 1.5 | n/a | 2.4 | 1.2 |
| **DS resiliency** | -3 to +3 | 2.8 | 1.6 | 1.2 | 1.4 | 2.2 | 0.8 | 1.4 | 0.2 | 0.9 | 1.3 | 2.8 | 1.2 |
| **DS learning** | -3 to +3 | 2.2 | 2.1 | 1.4 | 2.1 | 2.2 | 1.4 | 2.0 | 0.6 | 1.6 | 3.0 | 2.6 | 1.6 |
| **Salmon** | -3 to +3 | 2.3 | 0.1 | 1.0 | 0.0 | 0.3 | 0.8 | 1.0 | 0.0 | 1.8 | 0.3 | 2.3 | 1.3 |
| **Other native spp** | -3 to +3 | 2.7 | 2.0 | 1.7 | 1.3 | 1.0 | 0.7 | 1.0 | 0.3 | 1.7 | 0.3 | 3.0 | 1.3 |
| **Other ecological** | -3 to +3 | 3.0 | 1.3 | 1.7 | 1.3 | 0.7 | 1.0 | 1.7 | 0.3 | 1.7 | 0.0 | 3.0 | 1.7 |

It is important to note here that potential adverse effects of two actions (Actions 1 and 8) were assumed to be avoidable/manageable. The approach in this demo project was to characterize the best-case scenario for each action under the rationale that if the best-case scenario shows promising results for delta smelt there would be increased impetus for further investigating methods for avoiding or managing potentially adverse effects.

For Action 1, aquatic weed control, the potential adverse effect that is assumed to be manageable is the effect of applying herbicide. The Division of Boating and Waterways is currently applying herbicide under a Biological Opinion that permits its application under certain conditions to avoid and/or mitigate potentially adverse effects. These conditions would not allow for the application of herbicide as described for this action (i.e. 10,000 acres of application; Appendix A) and a new Biological Opinion would be required to set out the conditions for this scope of herbicide application. Aside from the potential adverse effects of herbicide application, this action shows strong estimated benefits across delta smelt and other ecological objectives, demonstrating a strong rationale for a comprehensive investigation into whether the risks of herbicide application can be reasonably managed.

For Action 8, coordinating flood and drain operations on managed wetlands in Suisun Marsh, the potential adverse effect that is assumed to be manageable is the effect on water quality of draining food-rich water into Suisun Marsh waterways and surrounding waterways. Specifically, the effect that this food-rich water would have on dissolved oxygen levels. Water quality standards are in place for dissolved oxygen in the estuary to protect aquatic life. To the TWG's knowledge, there has not been an assessment done on the effect to dissolved oxygen levels of draining food rich water. Discussions within the TWG identified potential ways to mitigate this issue – e.g. through slow release of food rich water and/or alternating the timing of draining managed wetlands. These ideas would need to be modeled to more fully understand if meeting water quality standards is a small or large challenge to the implementation of this action.

Estimated positive impacts to note include:

- Actions 1 and 12 have strong performance across all delta smelt and other ecological objectives;
- Action 5 (sediment supplementation) is estimated to have moderate to strong performance for improving delta smelt resiliency to random events – this is based on the hypothesis that expanding the range of turbid water also expands the range of where delta smelt are distributed.
- Action 13 (Frank's Tract) is estimated to have small to moderate positive effects across all delta smelt and other ecological objectives.
- The Rio Vista Research Station is estimated to have the highest potential for delta smelt learning. An important consideration behind this score is that it is becoming harder and harder to collect

delta smelt in the wild for research purposes, which means that laboratory research becomes even more important for understanding the conditions by which delta smelt grow and thrive. Similarly, hatchery fish produced at the proposed Fish Technology Center at Rio Vista are likely to be an increasingly important tool for evaluation of Smelt management actions in the field.

- The Stormwater management action was intentionally focused to just one watershed as it was considered the most relevant and likely to have the largest (but not the only) impact on contaminant loading. The action could have been broader and less focused but that would introduced complexities in understanding the linkages to Delta smelt and so was omitted and left for later evaluation.

### Financial Costs

Table 5 shows estimates of average cost impacts by action. High and low-cost ranges were also developed and these are presented in Appendix 3. Actions 3, 12 and 13 show the highest anticipated annual average costs. Note that late in the process the $9.7m per year impact for Action 4 was subsequently revised down as the result of new information. The water offset cost associated with the operation of the Suisun Salinity Gate operations is now considered to be quite low, which could reduce the annual cost of this action to million dollars per year or less (T. Sommer, pers. comm., Jan 2018).

**Table 5: Estimates of cost impacts by action**

| | Units | 1. Aq. Wd. Control | 2. N. Delta Food | 3. Out-flow Aug. | 4. SMSCG | 5. Sed. Supp. | 7. Roar. River | 8. SM Drain Flood | 9. Fish Salv. | 10. Storm water | 11. Rio Vista | 12. Hab. Rest. | 13. Franks Tract |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Cost/year** | $ million | $2.3 | $4.2 | $46.5 | $9.7 | $3.8 | $0.2 | $2.5 | $0.9 | $7.0 | $6.5 | $17.9 | $17.5 |

### Socio-economic Objectives

Table 6 shows qualitative scoring for the socioeconomic impacts. Concern over the reasonableness of some of these judgments was raised at the 31 January CSAMP Policy Group meeting. In a real application of SDM, much greater attention would need to be given to the methods used to derive estimates of impacts to these issues; stakeholder input would be welcome and very valuable in this regard.

**Table 6: Qualitative scoring for socioeconomic impacts by action**

| | Units | 1. Aq. Wd. Control | 2. N. Delta Food | 3. Out-flow Aug. | 4. SMSCG | 5. Sed. Supp. | 7. Roar. River | 8. SM Drain Flood | 9. Fish Salv. | 10. Storm water | 11. Rio Vista | 12. Hab. Rest. | 13. Franks Tract |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **WQ for in-Delta diversions** | -3 to +3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| **Navigation** | -3 to +3 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -1 |
| **Fishing / waterfowl hunting** | -3 to +3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -2 |
| **Non-consumptive recreation** | -3 to +3 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 3 |

### Full Consequence Table

Table 7 shows the full consequence table. There are various ways in which this table could be used. Primarily, it may be of value as a standalone prop for Policy Group discussions about the relative value of each action. In a more rigorous process, it may be desirable to explore the use of weighting the different objectives. Insights into preferred actions can be gleaned by allowing *each individual participant* in a discussion to weight the relative importance of each of the objectives. Often when doing so, participants with very different values may discover they prefer the same action for different reasons.

**Table 7: Full consequence table for all actions**

| | Units | 1. Aq. Wd. Control | 2. N. Delta Food | 3. Out-flow Aug. | 4. SMSCG | 5. Sed. Supp. | 7. Roar. River | 8. SM Drain Flood | 9. Fish Salv. | 10. Storm water | 11. Rio Vista | 12. Hab. Rest. | 13. Franks Tract |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **DS growth** | % change | 12% | 34% | 0% | 0% | 7% | 1% | 34% | 1% | 0% | n/a | 7% | 1% |
| **DS survival** | % change | 11% | 13% | 0% | 0% | 7% | 1% | 11% | 1% | 0% | n/a | 3% | 1% |
| **DS spawning/recruitment** | -3 to +3 | 2.4 | 0.0 | 0.6 | 0.4 | 0.8 | 0.8 | 1.6 | 0.0 | 1.5 | n/a | 2.4 | 1.2 |
| **DS resiliency** | -3 to +3 | 2.8 | 1.6 | 1.2 | 1.4 | 2.2 | 0.8 | 1.4 | 0.2 | 0.9 | 1.3 | 2.8 | 1.2 |
| **DS learning** | -3 to +3 | 2.2 | 2.1 | 1.4 | 2.1 | 2.2 | 1.4 | 2.0 | 0.6 | 1.6 | 3.0 | 2.6 | 1.6 |
| **Salmon** | -3 to +3 | 2.3 | 0.1 | 1.0 | 0.0 | 0.3 | 0.8 | 1.0 | 0.0 | 1.8 | n/a | 2.3 | 1.3 |
| **Other native spp** | -3 to +3 | 2.7 | 2.0 | 1.7 | 1.3 | 1.0 | 0.7 | 1.0 | 0.3 | 1.7 | n/a | 3.0 | 1.3 |
| **Other ecological** | -3 to +3 | 3.0 | 1.3 | 1.7 | 1.3 | 0.7 | 1.0 | 1.7 | 0.3 | 1.7 | n/a | 3.0 | 1.7 |
| **Cost/year** | $ million | $2.3 | $4.2 | $46.5 | $9.7 | $3.8 | $0.2 | $2.5 | $0.9 | $7.0 | $6.5 | $17.9 | $17.5 |
| **WQ for in-Delta diversions** | -3 to +3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| **Navigation** | -3 to +3 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -1 |
| **Fishing / waterfowl hunting** | -3 to +3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -2 |
| **Non-consumptive recreation** | -3 to +3 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 3 |

The results reported in the consequence table are either initial model results based on model inputs from coarse-level analyses using readily available information, or the result of structured expert judgement. Not all the delta smelt pathways of effect were modelled. Sensitivity analysis was not undertaken due to time constraints. The reader is encouraged to consult with the TWG members involved for their guidance on the appropriate interpretation of the meaning and significance of these results.

## Consideration of uncertainty

The findings so far presented for change in delta smelt biomass growth and survival are averages over the six years modeled. It can often be important also to communicate to decision makers the range of uncertainty that exists in such estimates. Figure 10 and Figure 11 show examples of figures that may be developed to help do so. In both figures, the x-axis shows the range of uncertainty for the ball-park cost estimates.

In Figure 10, the y-axis shows the range in variation of total biomass predicted by the model relative to the natural range of variation for the reference case shown in the grey area. With further time and resources, a sensitivity analysis of various inputs to the bioenergetic model modifications would have been undertaken. This would have further increased the bands of uncertainty for the biomass and survival measures.

In Figure 11, the y-axis reports the learning score for each action compared to cost.

**Figure 10: Delta smelt biomass versus costs including uncertainty ranges**

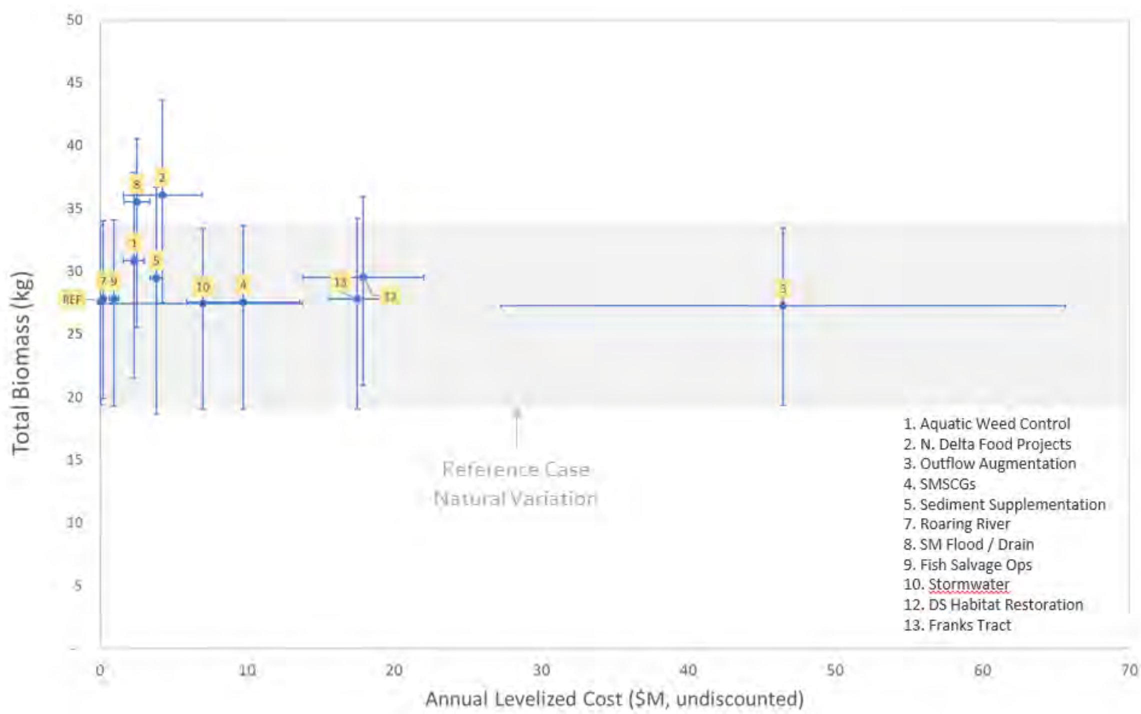
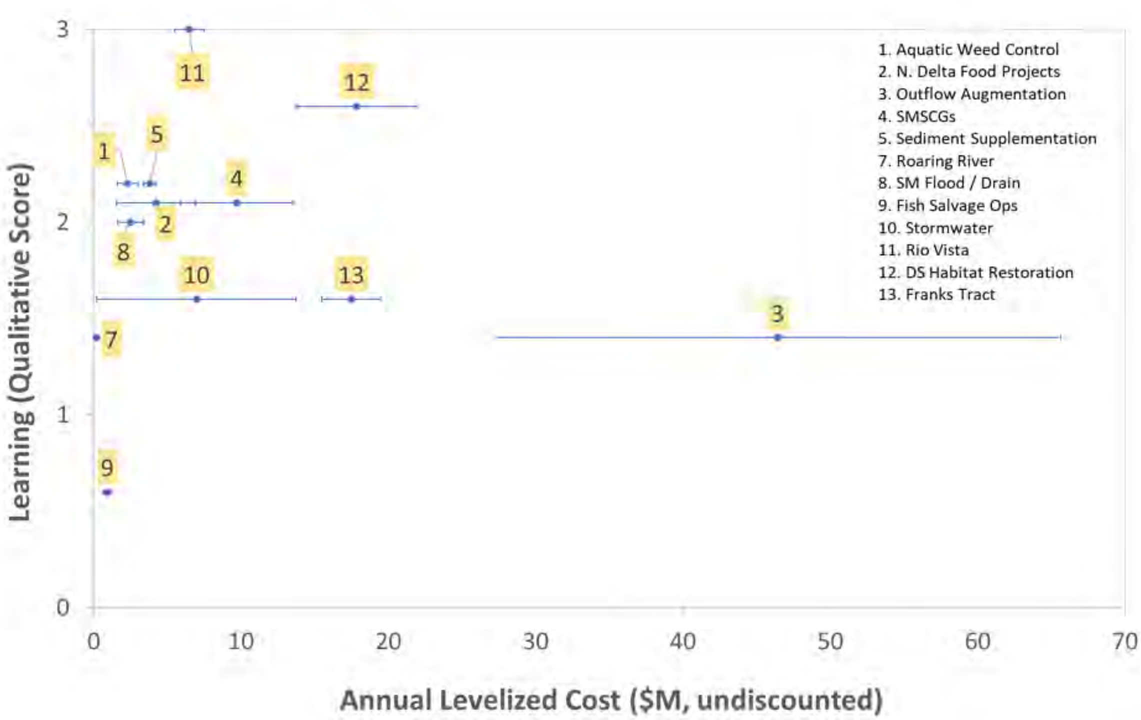



**Figure 11: Delta smelt learning versus costs including uncertainty ranges**




## Discussion and Recommendations

While this demo project was a ‘first pass’ analysis of the Resiliency Strategy actions, the process was such that the TWG felt confident in providing preliminary recommendations based on what had been learned.

In particular, the process involved significant levels of review, analysis, and deliberation on the potential effects of actions on delta smelt and the potential costs of these actions.

The TWG's following recommendations take into account the results as represented in the consequence table along with their experience and learnings from participating in the generation of these results. The recommendations take the form of 'binning' the actions into three different categories, as discussed below. Again, shading is used to show the level of certainty the TWG had in the characterization of effects for each action as represented in the consequence table – blue indicates more certainty and grey indicates less certainty.

**Category 1: Higher priority actions**

These actions are considered relatively higher priority because they appear to offer a good benefit to cost ratio. In all cases, there appears either to be good or some prospect of expected benefits to delta smelt and other ecological objectives, while negative impacts to socio-economic interests are smaller or commensurate with the degree of benefit.

| Action | Rationale for being in this category |
|---|---|
| 2.North Delta Food Web | High food and survival benefit, low cost |
| 8. Suisun Marsh Flood and Drain Ops | High food and survival benefit, low cost |
| 12.Tidal Wetland Habitat Restoration | Higher cost, but long term habitat benefits |
| 11.Rio Vista Research Station / FTC | Higher costs, but high learning benefits;<br>Also potential for population augmentation (not evaluated in this exercise) |
| 4. SMSCG | Uncertain benefit but low cost and good learning potential |
| 7. Roaring River Food Production | Lower benefit but low cost, synergy with managed wetlands |

**Category 2: Actions to Investigate Further**

Actions that warrant further analysis before benefit / cost ratio can more confidently be judged include:

| Action | Rationale for being in this category |
|---|---|
| 5. Sediment Supplementation | • Moderate DS survival and resiliency benefits and moderate costs<br>• Hurdles include permitting and sourcing sediment |
| 1. Aquatic Weed Control | • Many ecological benefits at moderate cost<br>• Questions about: feasibility at large scale and managing risks of herbicide application |
| 3. Spring/Summer Outflow Augmentation | • Action cost is relatively high<br>• Initial bioenergetics modeling shows no benefit, however other potentially important pathways remain unexplored, and substantial uncertainties exist regarding the fish distribution response to the action |

| Action | Rationale for being in this category |
|---|---|
| 10. Stormwater Mgmt | • Specific benefits poorly understood, high cost if land is purchased<br>• Only considered a discrete area of the distribution of Delta smelt. |
| 13. Franks Tract | • Modest benefits / high cost and negatives to stakeholders<br>• May be other pathways to explore |

**Category 3: Actions to reconsider**

Over the course of this evaluation, the TWG expressed considerable doubt that these actions could result in any meaningful benefit to delta smelt.

| Action | Rationale for being in this category |
|---|---|
| 6. Spawning Habitat Augmentation | Adding sand unlikely to make effective spawning habitat |
| 9. Adjust Fish Salvage Operations in Summer and Fall | Likely minimal benefit |

## Process Reflections and Proposed Next Steps

This demo project sought to explore whether and how SDM techniques might be used to help structure management decisions regarding delta smelt. Based on feedback received by participants and the Policy Group, it does appear that there is support for moving forward with a more comprehensive application of these techniques.

Having worked through the process over several months, some of the benefits of an SDM process have been made apparent. These include:

**Separation of facts and values** – in this process, subjective values were used to frame the decision and to develop objectives. The subsequent process of evaluating actions was largely a technical task; disagreements that were encountered focused on resolvable issues of technical fact or prediction and not on questions of preference. Questions around preferences or priorities were postponed until late in the process, after a thorough and collaborative process of technical investigation had taken place. Building a consequence table is the collaborative goal for much of the process, and once constructed, this serves as a key prop through which to discuss value-based trade-offs. As such, the analysis has helped to untangle the otherwise often conflated discussions about facts and values.

**Value of considering all decision relevant objectives** – SDM promotes the rigorous evaluation of the consequences of proposed alternatives and emphasizes the development of a strong decision-relevant information base including economic, environmental and socio-economic analyses. Structuring this investigative process using clear steps and clearly defined roles for stakeholders, decision makers and technical experts helps people understand issues in depth without losing track of the overall big picture. Directly addressing what matters, even when what matters is hard to quantify, ensures that the analysis reflects the decisions faced by managers.

**Value of coordinating experts from different backgrounds -** This demo has shown the value of co-ordinating many specialists with deep expertise across a wide variety of disciplines. The delta smelt context is far too large for any individual to independently grasp in its entirety. A collaboratively-built structure for understanding actions and their possible consequences is necessary for harnessing scientific expertise to serve the decision-makers who must ultimately make tough, value-based decisions that affect scientific and socio-economic objectives. Linking analysis and consultation by deconstructing cause and effect relationships makes the decision process more efficient and improves the relevance of technical and stakeholder inputs to decision making.

**Value of exposing trade-offs** - Trade-offs are at the core of difficult decisions and SDM addresses them directly. Making trade-offs explicit and well understood spurs creative energy to develop better management actions. SDM provides an explicit values-basis for decisions, and does not purport to be objective or value-free. It explicitly incorporates the values of stakeholders and decision makers in a structured and transparent way. By exploring creative solutions by emphasizing the search for joint gains and exposing the nature and magnitude of residual trade-offs, the quality of the solutions is improved.

**Value of structuring for understanding uncertainties and reducing uncertainties over time** - Structuring judgments by decomposing and simplifying complex judgments helps experts, stakeholders and decision makers think clearly about complex problems and make better and more transparent judgments. SDM provides a foundation upon which to clearly and consistently consider uncertainty, explore risk tolerance, make judgments about acceptable levels of risk and precaution, and find creative ways to manage residual risks.

**Possible next steps**

The Delta Smelt Resiliency Strategy identified a set of actions that might be implemented in the near term to benefit delta smelt. The Resiliency Strategy has set in motion the implementation of a range of actions on various fronts on behalf of delta smelt. While this occurs, there is time to reflect on these actions and also to step back from them to consider other actions, some of which might perform more effectively. Very likely, there are other actions that may benefit delta smelt but did not meet the criteria needed for inclusion in the Resiliency Strategy, or that might emerge from a comprehensive review of the factors limiting recovery.

CAMT is considering the initiation of a new structured decision-making (SDM) process focused on delta smelt. This new SDM process would build on this SDM demo project, which focused the relatively modest range of projects that were included in the DSRS rather than the full suite of potential management actions that could be applied for delta smelt. Hence, a preliminary purpose statement suggested by CAMT for an SDM process is "to identify and evaluate a comprehensive set of strategic actions to significantly benefit delta smelt".

The new process would build on this work and broaden the scope of evaluation beyond the Resiliency Strategy actions. Among the key limitations of this demo SDM project are:

- the focus of the study was limited to the specific actions in the Resiliency Strategy;
- because the role of limiting factors in delta smelt life history are not sufficiently understood, the demo SDM project explored the implications of each action assuming all the hypothesized mechanisms each action sought to address were indeed factors limiting delta smelt;
- the demo SDM project leaned heavily on an adapted bioenergetics model to help estimate the degree of impact from each action on growth and survival. However, there is not unanimous agreement on the validity of this model, nor the assumptions used by Compass and the TWG.

A next phase in the delta smelt SDM work would take a step back from these actions and work through the steps of SDM with an integrated effects analysis in a more comprehensive manner. There are many different ways that this work could be scoped, and different methods and modes of delivery that could be employed to meet time and resources constraints. Further, CAMT also wishes to specifically integrate the new activities with these ongoing efforts:

- Developing a long-term science plan that identifies specific monitoring, research, modeling, and evaluation activities designed to assess the effect of ambient conditions and management actions on delta smelt habitat quality and vital rates;
- Delta Science Program Structured Decision Making for Scientific Management in the Bay Delta;
- USBR Directed Outflow Project;
- IEP FLoAT PWT and FLoAT MAST;
- 10-year Review of the Fall X2 action; and
- Jim Peterson's ongoing SDM work into salmonid issues.

As a demo project, this work proceeded without consideration of the many important governance realities in the area. More work needs to be undertaken by the Compass SDM analysts to better understand the complex governance context in which decisions about delta smelt are made. Not only are there a variety of agencies, NGOs and PWAs, each with their own perspectives, relationships, interdependencies and stakeholders, but each also participate in other initiatives and programs that overlap in scope and implementation. More meaningful applications of SDM need to fit into this governance context. A first step of SDM is to define and clarify the problem to be analyzed and to identify the range of issues and objectives that decision makers consider to be most relevant: What is the problem to be solved? What are the program objectives and measures of success? What outcomes are desired, and what level of technical analysis and engagement is needed to achieve those desired outcomes?

Given this context, the next phase in the delta smelt SDM process would ideally involve a face-to-face session with senior agency administrators / decision makers to help determine the specific nature and scope of issues that are of most concern to resource managers with responsibility to conserve delta smelt. As well, integration of the various separate initiatives listed above should, ideally, be in service of the same direction given by this foundational conversation. Each of those project components should have clear objectives and explicit roles in meeting the overall vision articulated by leadership. There should be coordination in design and execution from the beginning.

<u>Proposal</u>

Our proposal has two main phases. A first phase over the summer of 2018 involves Compass engagement with the broader community of practice in the delta smelt management field to become better attuned to the various initiatives, parties and participants to better understand potential roles for SDM moving forward. Specifically, it is proposed that Compass initiate and maintain regular communications with relevant other organizations to become better acquainted with broader activities in the region. Further, in close collaboration with the facilitator for CSAMP/CAMT, Compass would undertake phone interviews with a variety of CSAMP/CAMT members to better understand the potential scope of future SDM activities.

The second phase would be to use what is learned over the summer of 2018 to design a 2-day workshop in September that broadly follows the following structure:

- A morning session with senior agency leadership to clarify the scope, objectives, and desired outcomes that they wish to see

- One and a half days in which managers and scientists develop an SDM-based proposed approach to work through the technical issues that must be engaged to deliver on the leadership's requests.

Following this session, work would take place offline to develop a more detailed SDM process proposal for 2018-2019.

## References


CNRA (California Natural Resources Agency). 2016. Delta Smelt resiliency strategy, July 2016. Available: http://resources.ca.gov/docs/Delta-Smelt-Resiliency-Strategy-FINAL070816.pdf. Accessed: 5 March 2018.

CSAMP (Collaborative Science and Adaptive Management Program). 2017. Purpose, Approach and Scope. February 13, 2017.

IEP (Interagency Ecological Program). 2015. An updated conceptual model of Delta Smelt biology: our evolving understanding of an estuarine fish. Available: http://www.water.ca.gov/iep/docs/Delta_Smelt_MAST_Synthesis_Report_January%202015.pdf Accessed: 5 March, 2018.

Keeney (1992) Value-Focused Thinking - A Path to Creative Decisionmaking. A Path to Creative Decision Making. Harvard University Press, Cambridge, MA.

Keeney, R.L., Raiffa, H (1993) Decisions with multiple objectives–preferences and value tradeoffs, Cambridge University Press, Cambridge & New York/

McDaniels, T., R. Gregory, 2004, "Learning as an objective within structured decision processes for managing environmental risks," Environmental Science and Technology, 38, 7, 1921-1926.

Moyle, P. B., Hobbs, J. A. and Durand, J. R. 2018, Delta Smelt and Water Politics in California. Fisheries, 43: 42–50. doi:10.1002/fsh.10014

Neumann and Morgenstern (1947) von Neumann, J., & Morgenstern, O. (1947). Theory of games and economic behavior, 2nd ed. Princeton, NJ: Princeton University Press.

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

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

## Appendix 1 – Action Definitions

This appendix provides background information and methods used to estimate the effects of each Delta Smelt Resiliency Strategy action under a coarse-level Structured Decision Making (SDM) analysis. This document was developed with input from a technical working group (Shawn Acuña, Scott Hamilton, Pat Coulston, Ted Sommer and Will Smith) and through interviews and email correspondence with other experts.

The following is described for each action:

- **Action scales:**
  - **Resiliency Strategy scale –** in some cases the Resiliency Strategy described the geographic and temporal scale of the action.
  - **Full build out scale** – the scales of the actions described in the Resiliency Strategy were often inconsistent among actions. Sometimes the Resiliency Strategy described an action in detail and with high certainty while other times the scale was described at a very cursory level, (e.g., requiring pilot programs to inform the future full scope of the action). To be consistent among actions, we describe here a "full build out scale" which is the assumed upper boundary of the action if it were to be implemented. Actions under the full build out scale were evaluated under the SDM analysis.
- **Influence diagrams** describe the key effect pathways by which each action influences the objectives that were evaluated in the SDM analysis.
- **Effect hypotheses tables** provide a concise summary of the effect hypotheses identified in the influence diagram and identify the method by which the effect pathway was estimated in the SDM analysis. Note that the effect hypotheses are typically referenced by personal communication with an expert rather than a literature-based reference. As this was a demo project, the quickest way for Compass to identify the relevant effect hypotheses was through phone interviews with recognized experts as identified by the TWG.
- **Resiliency Strategy's original content** describes the action and linkages to the conceptual models in the original report from July 2016, as well as the update for each action from the June 2017 Resiliency Strategy Progress Report.
- **Key references** used for estimating the consequences of an action.
- Any other contextual background information required to understand the action.

# 1 Aquatic Weed Control

## 1.1 Action Summary

Submerged and floating species of invasive aquatic vegetation have expanded in the Delta, particularly during the recent drought, and now occupy the majority of shallow-water and littoral areas of the system. Between 2008 and 2014, submerged aquatic vegetation (SAV) increased its cover by 50% (estimated coverage of 6,070 acres in 2014), while floating aquatic vegetation (FAV) saw a multi-fold increase, reaching 6,460 acres (Conrad, 2017). Invasive weeds encroach on open water habitat that delta smelt depend upon, and often harbor non-native predators. The plants reduce phytoplankton and slow water movement, removing suspended particles that help hide delta smelt from predators. The Resiliency Strategy calls for increased treatment of aquatic weeds in the Delta.

**Table 8: Scale of action under the Resiliency Strategy and full build out scale scenario**

| Resiliency Strategy Scale | Full Build Out Scale | Scaling Criteria and Reference for Full Build Out |
|---|---|---|
| • Herbicide treatment for invasive weeds of about 150 acres of delta smelt habitat at Decker Island (Western Delta) and Little Hastings Tract (Cache Slough complex in the north Delta) in 2017 (Conrad, 2017). Need to determine location and scope for 2018 treatment.<br>• The above actions are being treated as a pilot project to evaluate the effects of herbicide treatment on delta smelt habitat, including effects on water quality and delta smelt's food web (Conrad, 2017). | • **Removal of 10,000 acres of aquatic weeds** distributed in the following way:<br>o 50% in the Upper Sacramento strata (e.g. Cache Slough)<br>o 25% in the Confluence strata<br>o 25% in the Lower San Joaquin strata<br>• **Key assumption: We assume this action can be implemented in way that avoids negative effects to delta smelt altogether, or in a way that has short-term/temporary negative effects that are offset by larger and long-term benefits.**<br>• The 10,000 acres of weed control would be in addition to the ~3,000 acres that the Division of Boating and Waterways (DBW) currently focuses weed control efforts. DBW's current weed control program focuses on important navigation channels and areas where weeds cause problems for water intakes.<br>• **Frequency and duration:** It takes approximately 3 years to get an area infested with weeds 'under control' using herbicide. This area then needs ongoing maintenance to prevent the weeds from returning which would involve applying less herbicide than during the 3-year control phase; hard to say by how much less at this point (pers. Comm., E. Hard, Aug 1, 2017). | • 10,000 acre target provided by C. Wilcox (DFW, July 18, 2017), which was his judgement on an amount of weed control that would make a significant difference to delta smelt.<br>• Distribution of effort among areas provided by L. Conrad (pers. comm., Aug. 11, 2017) as a preliminary guess at where efforts would be best placed considering importance of the area to delta smelt and current coverage trends of aquatic weeds. |

L. Conrad (pers. comm., Aug. 11, 2017) stated that a strategy needs to be developed to determine where best to do aquatic weed control to benefit Delta Smelt. The distribution suggested above for the full build-out scale was suggested as a reasonable definition for the full build out scale in this SDM demo project, recognizing that no actual decisions on how to distribute effort will be made from this SDM analysis. L. Conrad stated that if aquatic weed control for delta smelt increases in the future, a strategy will be needed to determine best locations for weed control to maximize benefits to delta smelt. This strategy would need to address the following types of questions:

- Where will weed control be most beneficial to delta smelt?
- Where will application of the herbicide be most effective at removing aquatic weeds?
- Which types of aquatic weeds should be targeted, FAV or SAV? L. Conrad stated that there is currently no reason to target one type of aquatic weed over another from the perspective of what would be most beneficial to delta smelt. However, there may be reasons to target one over another from an efficiency perspective – e.g. it is easier to get rid of FAV than SAV, however, when FAV is treated, this opens up habitat for SAV to establish itself. FAV shades an area, preventing SAV from establishing itself underneath. If FAV is removed and there is an adjacent area with SAV, then removal of FAV opens up an area for the expansion of SAV.
- How should habitat connectivity be considered in selecting areas for aquatic weed treatment?

## 1.2 Influence Diagram

**Figure 12: Influence diagram for aquatic weed control action.**

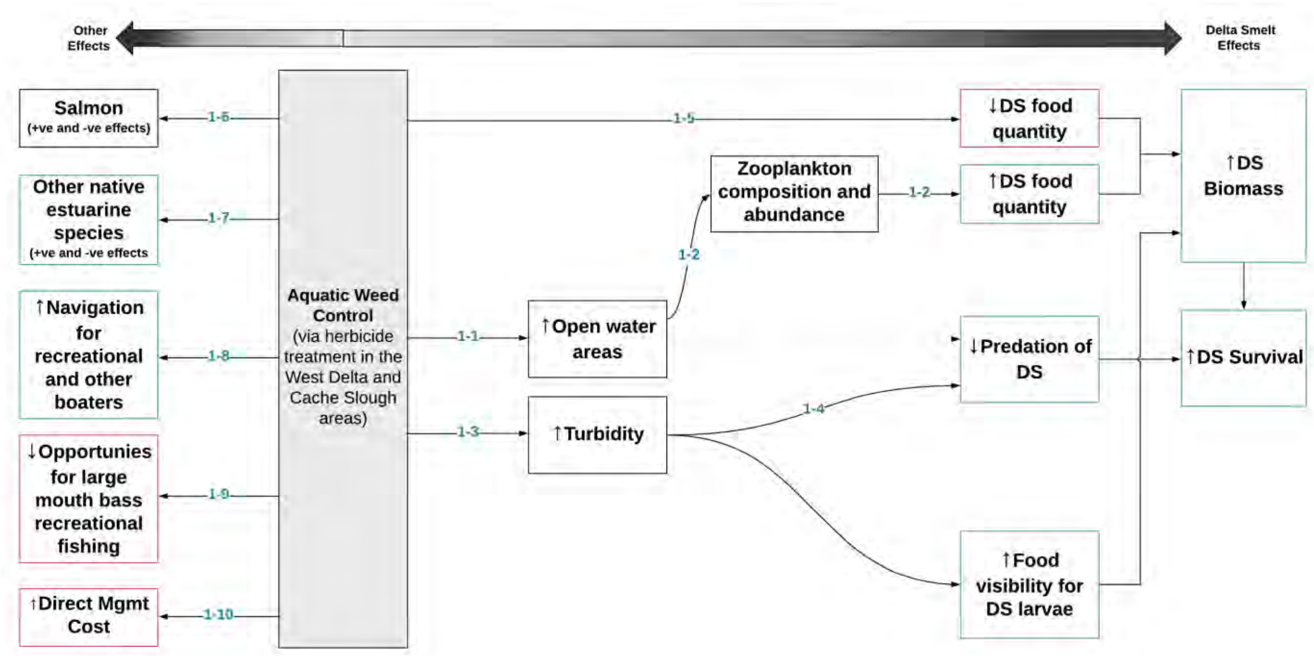



**Table 9: Effect hypotheses for aquatic weed control action to be assessed in SDM analysis.**

| # | Effect Hypothesis | Estimation Method |
|---|---|---|
| ***Delta Smelt*** | | |
| 1-1 | **Aquatic weed removal → Decreased density of aquatic weeds and increased open water areas** Depending on the specific characteristics of a site, herbicides can vary in their effectiveness of | For the purposes of the SDM demo project, an assumption will be made that herbicide |

| # | Effect Hypothesis | Estimation Method |
|---|---|---|
| | removing aquatic weeds. For example, treatment of SAV by fluridone is limited to slow moving and stagnant waters because fluridone works by being taken up through leaves, stems and root systems and needs to be in contact with the plant for a certain length of time for this to occur (USFWS, 2013; E. Hard, pers. comm., Aug. 1, 2017). | treatments effectively remove aquatic weeds from 10,000 acres.<br>If this action is advanced, site specific characteristics would need to be considered in a comprehensive strategy to apply herbicides in areas that will be most effective at removing aquatic weeds. |
| 1-1<br>&<br>1-2 | **Aquatic weed removal → Increased open water areas → Improved zooplankton composition and abundance for Delta Smelt**<br>It is thought that macrophytes, such as aquatic weeds, compete with phytoplankton such that macrophytes decrease phytoplankton densities and this in turn reduces zooplankton densities. Moreover, it is likely that Delta Smelt will not enter aquatic weed beds to forage, so removing weed beds increases the area in which they can feed (L. Conrad, pers. comm., Aug. 11, 2017). | **Rose BEM modeling method:** Assume that total biomass of zooplankton in each strata increases linearly with the increase in open water areas (TWG agreement, Oct. 6, 2017 call) (see Table 12 below for assumed values). |
| 1-3 | **Aquatic weed removal → Increased turbidity**<br>SAV slows water and makes it clearer (i.e. less turbid) (Moyle et al., 2016). Hestir et al. (2016) isolate the effect of SAV from sediment supply on declining turbidity in the Sacramento-San Joaquin River Delta. | **Rose BEM modeling method:** Use Hestir et al. (2016) to make an estimate of how much turbidity would change in the Delta if 10,000 acres of aquatic weeds are removed. Hestir et al. (2016) provide trends for turbidity decline as a function of aquatic weeds and sediment supply. |
| 1-4 | **Increased turbidity → Decreased predation**<br>The translucent body color and small size of delta smelt may make them less visible to predators in moderately turbid water (Moyle et al., 2016). Ferrari et al. (2014) find that adult Delta Smelt predation is lower in more turbid water.<br>Note that it has also been hypothesized that removal of aquatic weeds would decrease DS predation because these weeds provide habitat to ambush type predators. However, in Ferrari et al. (2014), there was no difference in predation of DS between vegetated and unvegetated areas. There was only a difference in predation of DS between turbid and clear water. | **Rose BEM modeling method:** Use Ferrari et al. (2014) relationship to alter the natural mortality parameter in the model such that it is scaled to turbidity.<br>**Assumption for modeling:**<br>• 0 to 10 NTU, no change to natural mortality parameter;<br>• 10 NTU to 20 NTU: mortality decreases linearly where at 10 NTU, mortality is 100% of base model natural mortality parameter and at 20 NTU, mortality is 67% of the base model natural mortality parameter<br>• 20 NTU and above: mortality is 67% of base model value. |
| | **Increased turbidity → Increased food visibility for DS larvae**<br>Studies have shown that delta smelt larvae benefit from turbidity to see their prey (Baskerville-Bridges et al., 2004; Hasenbein et al., 2016; Moyle et al., | The Rose BEM used for this project is not modeling the period between Feb. 1 and May 30 and so does not model the growth of larvae. |

| # | Effect Hypothesis | Estimation Method |
|---|---|---|
| | 2016). However, no studies show this relationship for adult and juvenile DS. | The benefits for DS from this pathway will be incorporated into the score for how this action benefits the spawning/recruitment of DS. |
| 1-5 | **Aquatic weed removal (via herbicide treatment) → Reduction in food quantity**<br>Based on lab studies, environmental concentrations of fluridone (used to treat SAV) and the herbicides used to treat FAV are low risk to delta smelt and their food webprey. There is evidence that herbicides could have negative impacts on phytoplankton that would have cascading effects to zooplankton and consequently Delta smelt. There is some evidence that an additive used in conjunction with the herbicide to make it adhere to the vegetation better could have adverse effects to delta smelt and the foodweb- research is ongoing. | **Pathway excluded from analysis:** Within this project, we did not have the ability to adequately investigate this pathway. The full build-out scale analysis assumes the best-case scenario that a method will be available to effectively remove the weeds with either no effects to delta smelt or only short-term temporary effects that are offset by longer term benefits of the weed removal.<br>L. Conrad (pers. comm. Aug. 11, 2017) stated that a significant research effort would be needed to have confidence that application of herbicides in the Delta at this magnitude would not do harm to delta smelt, their food web, or any other ecological endpoints of concern.<br>Key uncertainties include:<br>• Effects of herbicides on phytoplankton;<br>• Effects of fluridone settling on sediments; and,<br>• Effects of herbicides on delta smelt and food web considering possible interaction of these herbicides and additives with other water quality constituents in the Delta. |
| ***Other Ecological Endpoints*** | | |
| 1-6 | **Aquatic weed removal → Salmon**<br>Notes from discussion with B. Cavallo (July 27, 2017):<br>• **Food and predation:** When juvenile salmon are migrating through the estuary between December and June they are looking for shoals, floodplains (grasses inundated with water), and inter-tidal mud flats. These areas have less predators and provide better access to food for juvenile salmon. At this life stage, juvenile salmon are predominantly benthic feeders and they are not effective at foraging for open water zooplankton. When aquatic weeds take over shoals, floodplains, and inter-tidal areas, they are unavailable to juvenile salmon. Juvenile | The effects of this action on this pathway are scored by the Technical Working Group, Brett Harvey and Brad Cavallo using a constructed scale to qualitatively describe their opinion on the effects of this action to salmon. |

| # | Effect Hypothesis | Estimation Method |
|---|---|---|
| | salmon then have to make more use of open water areas where they are more vulnerable to predators and have less access to food.<br>• **Herbicide effects**: Herbicide may have direct effects to juvenile salmon and/or indirect effects to their food web (primarily phytoplankton, benthic organisms: anthropoids, insect larvae). However, current weed treatment activities avoid much of the peak salmon migration season.<br>• **Decomposing weeds:** Could affect juvenile salmon during slow flows, such that fish are unable to move out of areas turning anoxic. | |
| 1-7 | **Aquatic weed removal → Other native estuarine species** | The effects of this action on this pathway are scored by the Technical Working Group using a constructed scale to qualitatively describe their consensus opinion on the effects of this action to other native estuarine species. |
| ***Socio-economic Considerations*** | | |
| 1-8 | **Aquatic weed removal → improved navigation for recreational and other boaters (water skiing, sailing, etc.)**<br>The presence of aquatic weeds inhibits the use of an area by boats. The specific benefits of aquatic weed removal for boaters would depend on the specific sites that are treated and the extent to which those areas are valued use areas for boaters. | |
| 1-9 | **Aquatic weed removal → Large mouth bass recreational fishing.**<br>The main benefit of aquatic vegetation to large mouth bass is at the juvenile life stage, where the fish find food and shelter from predators in the weeds. Juveniles will have higher survival in the weeds than without. Older large mouth bass are less reliant on the weeds – they will use tules and woody debris. Significant efforts at weed control would be needed in central, south and east Delta to decrease the population of large mouth bass (L. Conrad, pers. comm., Aug. 11, 2017). | Large mouth bass fishery is more prominent in the central (e.g. parts of Lower SJ strata), east, and south Delta. Striped bass fishing is more prominent in the North Delta (Upper Sacramento strata). The areas where aquatic weed control would be targeted for delta smelt (as defined by the full build out scale) are expected to have low to no overlap with areas that are important for large mouth bass fishing, therefore, a healthy large mouth bass fishery can be expected to remain if this action is implemented (L. Conrad, pers. comm., Aug. 11, 2017). |
| ***Resources Required*** | | |
| 1-10 | **Aquatic weed removal (via herbicide) → Direct management costs** | Compass spoke with Eddie Hard, manager of the Aquatic Weed Control Program at the DBW on Aug.1, 2017. E. Hard provided a ball-park $/acre cost estimate to Compass along |

| # | Effect Hypothesis | Estimation Method |
|---|---|---|
| | Direct management costs include (pers. comm., E. Hard, Aug. 1, 2017):<br>• Herbicide costs<br>• Staff for applying herbicide, environmental costs, managing the program<br>• Transportation costs (boats, trucks)<br>• Regulatory sampling analysis | with details on the challenges, limitations, and process to ramp up the Aquatic Weed Control Program to 10,000 acres for delta smelt. E. Hard's ball park estimate is $2500 - $3500 per acre of weeds for the "control phase" or the initial removal of weeds. These costs would be spread over the control phase, which can take about 3 years. E. Hard did not have an estimate for the subsequent "maintenance phase", which would be the ongoing action to prevent weeds from re-establishing themselves in the area. |

**Table 10: Assumed % increases in zooplankton compared to baseline years for aquatic weed control action**

| Strata | Area of strata (acres) | Percent of 10,000 acres targeted | Acres targeted | Proportion of strata targeted | % Increase in zooplankton relative to baseline |
|---|---|---|---|---|---|
| Upper Sacramento | 14,145 | 50% | 5,000 | 35% | 35% |
| Confluence | 7,957 | 25% | 2,500 | 31% | 31% |
| Lower San Joaquin | 14,011 | 25% | 2,500 | 18% | 18% |

## 1.3 Implementation

Permitting for 10,000 acres for delta smelt would likely pose many implementation challenges to overcome (pers. comm. E. Hard., Aug. 1, 2017).

Each treatment site requires a treatment protocol that follows specific requirements to account for wind, dissolved oxygen, pH, drinking water intakes, and agricultural intakes (USFWS, 2013, pg. 5).

DBW's SAV and FAV control programs are highly regulated to ensure avoidance or minimization of significant impacts to beneficial uses of waters of the U.S., and threatened and endangered species protected by the *Endangered Species Act* (ESA).

DBW obtained a multi-year (2013-2017) authorization from USFWS and NMFS to operate the SAV Control Program pursuant to Section 7 of the ESA. Consultations with Federal Fishery Agencies are underway for a new BO and Letter of Concurrence past 2017:

- USFWS Biological Opinion (08FBDT00-2013-F-0015), effective May 3, 2013
- NMFS Letter of Concurrence (2013/9391), effective March 26, 2014

DBW obtained multi-year (2013-2017) authorizations from USFWS and NMFS to operate the FAV Control Program pursuant to Section 7 of the ESA.

- USFWS Biological Opinion (81410-2013-F-0005), effective March 13, 2013
- USFWS Biological Opinion (08FBDT00-2014-F-0029), effective August 11, 2014
- NMFS Letter of Concurrence (2013/9443), effective February 27, 2013
- NMFS Letter of Concurrence (2014-394), effective May 28, 2014

DBW is currently in consultation with USFWS and NMFS for a new BO and Letter of Concurrence beyond 2017.

A National Pollutant Discharge Elimination System (NPDES) permit is required by the State Water Resources Control Board (SWRCB). Coverage under this permit was obtained in December 2013 and expires in 2018, and is referenced as the Statewide General NPDES Permit for the Discharge of Aquatic Pesticides for Aquatic Weed Control in Waters of the United States (Permit No. CAG990005, Water Quality Order 2013-0002-DWQ).

In addition, a Streambed Alteration Agreement (or Routine Maintenance Agreement) was entered into between DBW and CDFW for the mechanical removal/harvesting of FAV (Notification No. 1600-2015-0132-R3). The Agreement became effective October 23, 2015 and shall expire on December 31, 2019.

## 1.4 Original Action in Resiliency Strategy and Updates

**Linkage to Conceptual Models:** This management action would benefit all life stages and the Environmental Drivers affected would include Turbidity and Predators.

**Summary of Action:** DWR will coordinate with DBW to increase the treatment of aquatic weeds in the Delta to ensure the Strategy would provide maximum benefits to Delta Smelt habitat. The action will take place during 2017–2018 in locations permitted by U.S. Fish and Wildlife Service (USFWS) and determined to be beneficial to Delta Smelt. In addition to Franks Tract, likely treatment areas would include Sherman Lake, Decker Island, and Cache Slough Complex.

**Update:** DWR, DFW and DBW built on the state's existing herbicide treatment program for invasive weeds to target nearly 200 acres of Delta smelt habitat at Decker Island in the western Delta and in the Cache Slough complex in the north Delta. Field studies have begun to evaluate the effect of herbicide treatment on the habitat, including the Delta smelt's food web.

## 1.5 Additional Background

SAV species in the Delta include: Brazilian waterweed (Egeria densa), curlyleaf pondweed (Potamogeton crispus), Eurasian watermilfoil, coontail, fanwort.

FAV species in the Delta include: water hyacinth, South American spongeplant, Uruguay water primrose.

In 2013, Assembly Bill 763 was passed designating the Division of Boating and Waterways (DBW) as the lead agency in cooperating with other agencies in identifying, detecting, controlling, and administering programs to manage invasive aquatic plants in the Sacramento-San Joaquin Delta, its tributaries, and the Suisun marsh.

## 1.6 References


Baskerville, B., & Lindberg, C. (2004). The effect of light intensity, alga concentration, and prey density on the feeding behavior of delta smelt larvae. In *American Fisheries Society Symposium* (Vol. 39, pp. 219-227). (Cited in USFWS, "Why Flow is a Necessary Element of Delta Smelt Habitat", June 29, 2016)

Clemen, R. T., & Reilly, T., (2001). Making hard decisions with Decision Tools. Pacific Grove, CA: Duxbury/Thomson Learning.Conrad, L. (2017). 2017-2018 Study Plan: Action for Enhanced Control of Aquatic Weeds & Understanding Effects of Herbicide Treatment on Habitat. Document available from Louise Conrad, Department of Water Resources, Louise.Conrad@water.ca.gov .

Division of Boating and Waterways, website on Aquatic Invasive Species Programs: http://dbw.parks.ca.gov/?page_id=28764

DBW. (2016). "Submersed Aquatic Vegetation Control Program 2016 Annual Monitoring Report". http://dbw.parks.ca.gov/pages/28702/files/SAV%20-%202016%20Monitoring%20Report.pdf

Ferrari, M. C., Ranåker, L., Weinersmith, K. L., Young, M. J., Sih, A., & Conrad, J. L. (2014). Effects of turbidity and an invasive waterweed on predation by introduced largemouth bass. *Environmental biology of fishes*, *97*(1), 79-90. (Cited in USFWS, "Why Flow is a Necessary Element of Delta Smelt Habitat", June 29, 2016)

Hasenbein, M., Komoroske, L. M., Connon, R. E., Geist, J., & Fangue, N. A. (2013). Turbidity and salinity affect feeding performance and physiological stress in the endangered delta smelt. *Integrative and comparative biology*,*53*(4), 620-634. (Cited in USFWS, "Why Flow is a Necessary Element of Delta Smelt Habitat", June 29, 2016)

Hasenbein, M., Fangue, N. A., Geist, J., Komoroske, L. M., Truong, J., McPherson, R., & Connon, R. E. (2016). Assessments at multiple levels of biological organization allow for an integrative determination of physiological tolerances to turbidity in an endangered fish species. *Conservation Physiology*, *4*(1), cow004. (Cited in USFWS, "Why Flow is a Necessary Element of Delta Smelt Habitat", June 29, 2016)

Hestir, E. L., Schoellhamer, D. H., Greenberg, J., Morgan-King, T., & Ustin, S. L. (2016). The Effect of Submerged Aquatic Vegetation Expansion on a Declining Turbidity Trend in the Sacramento-San Joaquin River Delta. *Estuaries and Coasts*, Volume 39, pg. 1100-1112.

Moyle, Peter, L. Brown, J. Durand, J. Hobbs, (2016). "Delta Smelt: Life History and Decline of a Once-Abundant Species in the San Francisco Estuary". *San Francisco Estuary and Watershed Science,* Vol. 14(2).

# 2 North Delta Food Web Adaptive Management Projects

## 2.1 Action Summary

Historically, the slow-moving wetlands and waterways of the Delta generated prodigious amounts of the microscopic plants and animals—phytoplankton and zooplankton—that support delta smelt. In today's vastly altered, channelized Delta, smelt suffer from a shortage of food, particularly during summer and fall. The Strategy calls for augmented flows through the Yolo Bypass, one of the remaining food-rich areas, to deliver plankton to downstream areas inhabited by delta smelt. Net summer and fall flows through Yolo Bypass are often low or negative, so productivity in this region isn't transported downstream.

**Table 11: Scale of action under the Resiliency Strategy and full build-out scale scenario**

| Resiliency Strategy Scale | Full Build Out Scale | Scaling Criteria and Reference for Full Build Out |
| --- | --- | --- |
| • Flow augmented in the Yolo Bypass in July and/or September to promote food production and export into areas where delta Smelt are known to occur.<br>• In 2016, a managed flow pulse through the Yolo Bypass between 200 to 500 cubic feet/second (cfs) for about two and half weeks was undertaken with agricultural drainage water (Sommer and Frantzich, 2017).<br>• There was no interest in doing this action in July 2017 because it was a wet year. The action was not possible in the Fall of 2017 because of a construction project in the Yolo Bypass (pers. comm., T. Sommer, Aug. 4, 2017).<br>• A similar action is planned for Fall 2018, though (T. Sommer, April 5, 2018) | Defined by Ted Sommer (pers. comm., Aug. 4, 2017):<br>• Pulse flow (300 to 500 cfs) through the Yolo Bypass in July and September up to 24,000 acre-feet in water volume per pulse flow event (48,000 acre feet in total for July and September pulse flows).<br>• For estimating consequences of the full build out scenario, assume the water can be obtained for this action in July and September for 70% of water years. The action wouldn't be possible in extreme dry or extreme wet water years.<br>• In September, agencies will likely be able to obtain agricultural drainage water with no or low water cost.<br>• In July, water will likely need to be obtained through a negotiated agreement with willing sellers in the Northern valley as not much agricultural drainage water is available at this time of year. | 24,000 acre feet over ~4 weeks is the scale of pulse flow that occurred in 2011 when a large algal bloom was observed. This is the event that precipitated the idea for this action (pers. comm., T. Sommer, Aug. 4, 2017).<br>A smaller natural pulse flow also occurred in the fall of 2012. (Frantzich and Sommer, 2016) |

Figure 13: Aerial View of Liberty Island in Yolo Bypass (from Sommer and Frantzich, 2016)

## 2.2 Influence Diagram

**Figure 14: Influence diagram for North Delta food web adaptive management projects action.**

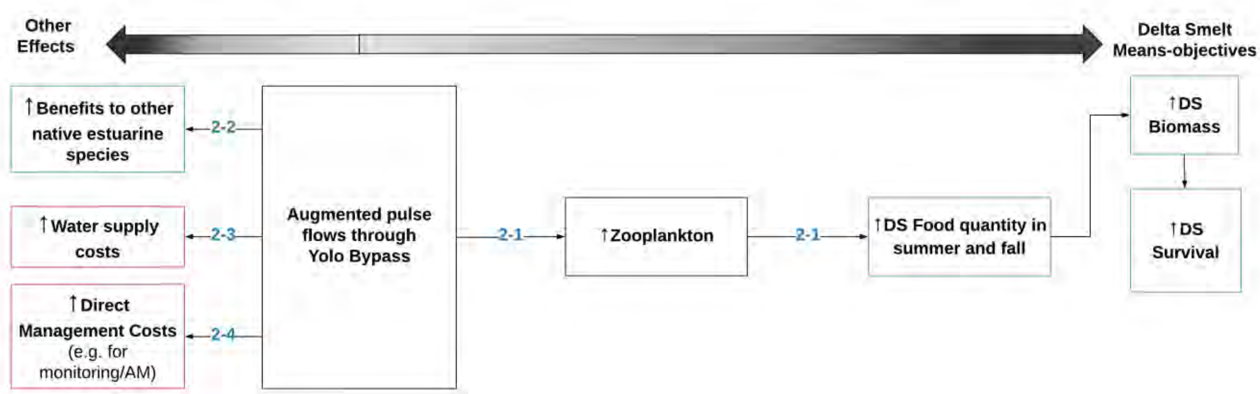



**Table 12: Effect hypotheses for North Delta food web adaptive management projects action to be assessed in SDM analysis.**

| # | Effect Hypothesis | Estimation Method |
|---|---|---|
| ***Delta Smelt*** | | |
| 2-1 | **Pulse flow through Yolo Bypass → Increase zooplankton (food) for Delta Smelt**<br><br>DWR and DFW partnered with many agencies and farmers in the summer of 2016 to direct water through a wetland and tidal slough corridor of the Sacramento River system and into the Delta. Close monitoring showed that the nutrient-rich “pulse flow” successfully | **Rose BEM modeling method:** The TWG made an assumption for the magnitude of zooplankton increase from this action based on a coarse analysis of zooplankton survey data following the pulse flows through the Yolo Bypass in 2011 and 2016 compared to average zooplankton levels (see Table 14 below for assumed values). |

| # | Effect Hypothesis | Estimation Method |
|---|---|---|
| | generated a phytoplankton bloom and enhanced zooplankton growth and egg production (Resiliency Strategy).<br><br>Sommer and Frantzich (2017) and Frantzich et al. (2018) show evidence of a big change in downstream biomass in the Lower Cache and Lower Sacramento River areas following the flow pulse through Yolo Bypass. | Sommer and Frantzich (2017, presentation) is the best available information for summarizing the phytoplankton and zooplankton changes that occurred with the July 2016 North Delta Food Web AM Project. A technical report is under development. Unusual flow conditions as observed by Frantzich et al. (2018) provide an indication of potential broad benefits under full build-out scale. |
| ***Other Ecological Endpoints*** | | |
| N/A | **No effects to salmon identified.**<br>Since this is a summer action, juvenile salmon will not be in the estuary and therefore will not be affected by this action (pers. comm. B. Cavallo, July 27, 2017) | The effects of this action on this pathway are scored by the Technical Working Group, Brett Harvey and Brad Cavallo using a constructed scale to qualitatively describe their opinion on the effects of this action to salmon. |
| 2-2 | **Effects to other native estuarine species**<br>Increasing productivity in the Delta is expected to benefit all aquatic species (pers. comm. T. Sommer, Aug. 4, 2017). | The effects of this action on this pathway are scored by the Technical Working Group using a constructed scale to qualitatively describe their consensus opinion on the effects of this action to other native estuarine species. |
| ***Resources Required*** | | |
| 2-3 | **Pulse flow through Yolo Bypass → Water costs**<br>For the July 2016 North Delta Food Web Action, some water was donated and some water was purchased by DFW. The total water cost was $230,000 for 200 to 500 cubic feet/second (cfs) for about two and half weeks. Water diverters in the Northern Valley are supportive of this action and are willing to provide water, sometimes donating water or providing the water at lower than market value (pers. comm. T. Sommer, Aug. 4, 2017). | • Water in July would likely need to be purchased from North Delta agricultural water supplies (pers. comm. T. Sommer, Aug. 4, 2017)<br>• September water may come at no cost because it would be agricultural drainage (pers. comm. T. Sommer, Aug. 4, 2017)<br><br>For July water costs, use same market water price scenarios as for the Outflow Augmentation action ($125, $250 and $500 per acre foot) for representative above normal water years, representative below water years and representative dry water years. Assume that the action is not completed in the July of a critical water year. |
| 2-4 | **Pulse flow through Yolo Bypass → Direct management costs** | For each North Delta Food Web Action, assume staff time and monitoring activity costs of $300,000. If the action was done |

| # | Effect Hypothesis | Estimation Method |
|---|---|---|
| | For the July 2016 North Delta Food Web Action, $300,000 was spent on staff time and monitoring activities (pers. comm. T. Sommer, Aug. 4, 2017).<br>Field work included the collection of: nutrients concentrations, chlorophyll-a (chl a) concentration, phytoplankton, zooplankton, benthic (clam), continuous water quality and flow data over two autumn periods. | in both July and September, the annual cost would be $600,000 (pers. comm. T. Sommer, Aug. 4, 2017). |

**Table 13: Effect pathways not included in SDM analysis.**

| Effect Hypothesis | Comments |
|---|---|
| **Risk of harmful algal blooms.**<br>A reasonable question around this action is whether it would lead to an unintended consequence of increasing the risk of harmful algal blooms. | The July 2016 flow pulse action was dominated by a "good" variety of algae, not a harmful species (DWR, 2016). |
| **Pulse flow through Yolo Bypass → Water Quality for in-Delta diversions**<br>When this action uses agricultural drainage water, it is re-routing water that would otherwise go down the Sacramento River by about 400 cfs for a month. This would improve the water quality in the Sacramento River at the point of Sacramento's water intake (pers. comm. T. Sommer, Aug. 4, 2017). | This is presumed to be a minor incremental benefit to Sacramento region municipalmunicipal water users, but the scope of this analysis does not allow for further investigation (Compass judgement). |

**Table 14: Assumed % increases in zooplankton compared to baseline years**

| | Strata | | | | | | |
|---|---|---|---|---|---|---|---|
| **Month** | **Lower Sac** | **Confluence** | **Lower SJ** | **SE Suisun** | **NE Suisun** | **NW Suisun** | **Marsh** |
| **July** | 100% | 150% | 0% | 550% | 550% | 400% | 150% |
| **August** | 0% | 100% | 25% | 75% | 75% | 100% | 25% |
| **September** | 100% | 150% | 0% | 550% | 550% | 400% | 150% |
| **October** | 0% | 100% | 25% | 75% | 75% | 100% | 25% |

## 2.3 Original Action in Resiliency Strategy and Updates

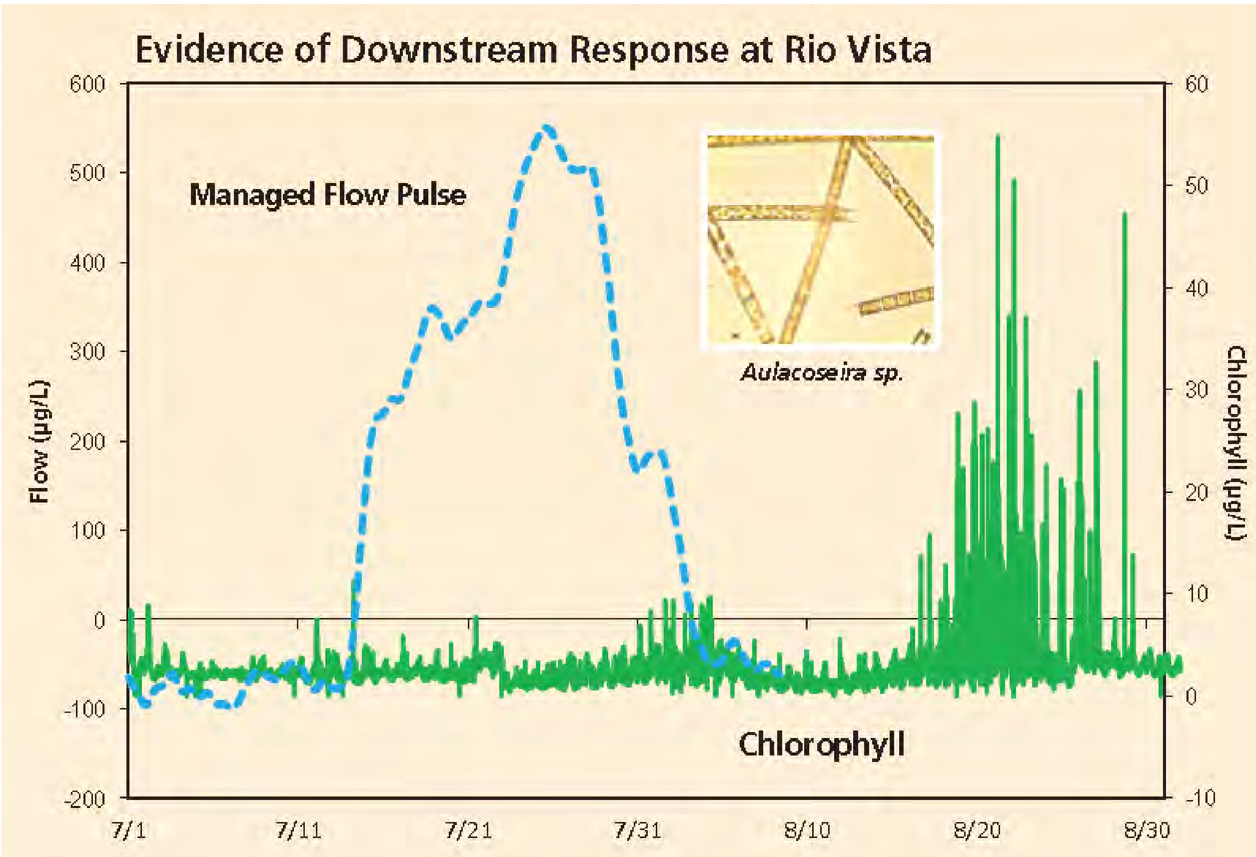
**Summary of Action:** DWR will augment flow in the Yolo Bypass by closing Knights Landing Outfall Gates and route water from Colusa Basin into Yolo Bypass in July 2016 and in July and/or September in 2017 and 2018 to promote food production and export into areas where Delta Smelt are known to occur.

Food web enhancement flows will also be considered for additional months in ways that will not conflict with agricultural and waterfowl management actions based on the availability of water to augment flows in the Yolo Bypass. DWR will also explore options for increasing outflow from the Yolo Bypass during the spring.

**Update:** DWR and DFW partnered with many agencies and farmers in the summer of 2016 to direct water through a wetland and tidal slough corridor of the Sacramento River system and into the Delta. Close monitoring showed that the nutrient-rich "pulse flow" successfully generated a phytoplankton bloom and enhanced zooplankton growth and egg production. DWR will continue to work with Sacramento Valley water districts and others to repeat such flows and enhance Delta food production. (See figure below). Based on this successful effort, DWR and partners are planning a similar action in fall 2018..

**Linkage to Conceptual Models:** This management action would benefit juvenile and sub-adult life stages and the Habitat Attributes that would be affected include Food Availability and Quality.

**Figure 15: Chlorophyll and flow time series for 2016 managed pulse flow.**




## 2.4 Background and Context

To prevent flood damage, the state of California through the Central Valley Flood Protection Board and the Army Corps of Engineers developed the Sacramento River Flood Control Project (SRFCP), which is a system of flood-relief structures and weirs that release Sacramento River and Feather River flows into a bypass system when flows exceed downstream channel capacity. The most downstream of the bypasses, the Yolo Bypass is a 59,000 acre floodway that serves as a flood relief valve and protects Sacramento and southern Sacramento Valley. At 3 miles wide and 40 miles long, the bypass is designed for a capacity of 500,000 cfs at the downstream end.

The Bypass is managed by California's Department of Water Resources. In wet times, particularly during the winter, the Yolo Bypass fills with water. Weirs are then used to drain overflow through creeks and ultimately to the Sacramento-San Joaquin Delta. During dry seasons, such as summer, the Yolo Bypass is home to agriculture. Bat colonies under the causeway between Davis and Sacramento help fertilize fields and with insect control. The Yolo Bypass is also home to the Vic Fazio Wildlife Refuge. The refuge is considered a model public/private wetland restoration effort near a large urban area. It also serves as habitat for native fish such as sturgeon and salmon and as an important stop for migratory waterfowl and birds on the Pacific Flyway. It also provides year-round wet (flooded) conditions to create habitat during the dry season (Water Education Foundation, 2017).

## 2.5 References


DWR, 2016. “2016 North Delta Food Web Action”. Department of Water Resources Fact Sheet. File name: “IEP_Yolo Fall Phyto Study Fact Sheet 9 2016”. Obtained from Ted Sommer, August 4, 2017.

Frantzich, J. T. Sommer and B. Schreier (2018). Physical and Biological Responses to Flow in a Tidal Freshwater Slough Complex”. San Francisco Estuary and Watershed Science Volume 16, Issue 1 | Article 3. https://doi.org/10.15447/sfews.2018v16iss1art3

Nguyen, Megan (2017). “The Important Role of the Yolo Bypass: The Inland Sea of Sacramento”. *NewsDeeply,* March 10, 2017, https://www.newsdeeply.com/water/community/2017/03/10/the-important-role-of-the-yolo-bypass-the-inland-sea-of-sacramento .

Sommer and Frantzich (2017). “SWC Briefing: North Delta Food Web Study”. Presentation by Ted Sommer and Jared Frantzich with the Department of Water Resources. March 2017. File name: “SWC Briefing Sommer March 2017”. Obtained from Ted Sommer, August 4, 2017.

Water Education Foundation, http://www.watereducation.org/aquapedia/yolo-bypass, accessed on July 25, 2017.

# 3 Outflow Augmentation in the Spring and Summer

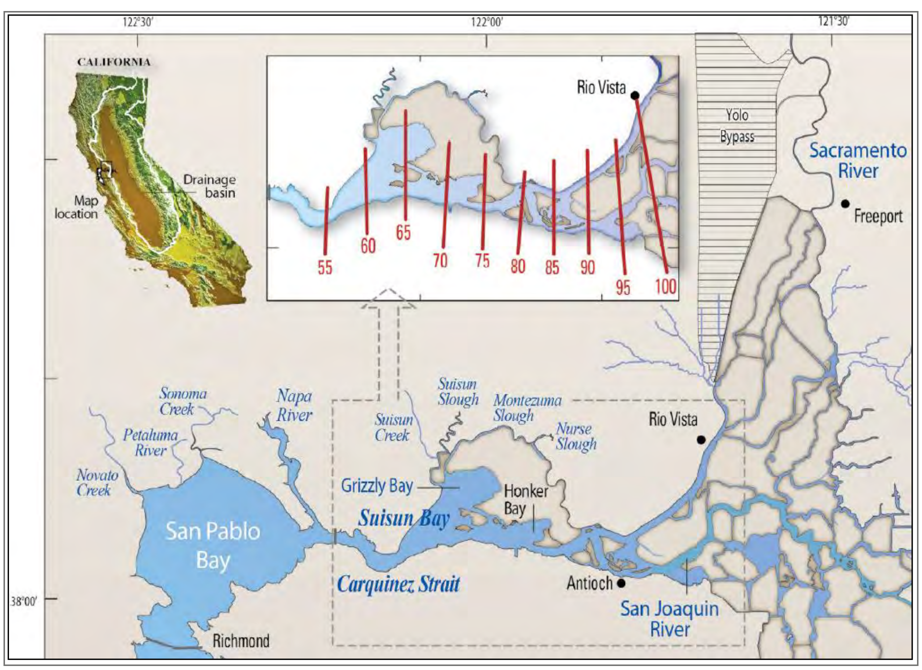
## 3.1 Action Summary

The Strategy called for spring and summer outflows of up to 250,000 acre-feet above current water quality standard requirements.

**Table 15: Scale of action under the Resiliency Strategy and full build out scale scenario**

| Resiliency Strategy Scale | Full Build Out Scale | Scaling Criteria for Full Build Out |
|---|---|---|
| Up to 250 thousand acre-feet (TAF) outflow above D-1641 requirements | • **Action objective:** Keep X2 in the spring/summer period (Mar. 1 to Aug. 31) as far westward as possible.<br>• Action definition for modeling:<br>o For an average above normal year, average below normal year, and average dry year, when X2 approaches 80, augment flow with 250 TAF in a manner that keeps X2 below 80 as long as possible (action description from Pat Coulston, DFW, Aug. 2, 2017).<br>o No action in wet or critical water years.<br>• **Implementation:** DWR and/or the Bureau of Reclamation would obtain this water from willing sellers. If a negotiated price cannot be agreed to then the full 250 TAF may not be obtained. For the purposes of evaluating the full build out scenario, assume that the 250 TAF has been obtained by willing sellers. | Same amount of water augmented as suggested in the Resiliency Strategy.<br>Full build out scale objective recommended by Pat Coulston, DFW. |

**Figure 16: Map of San Francisco Estuary. The inset shows various values of X2, the distance in kilometers from the Golden Gate to the near bottom salinity 2 isohaline (MAST, 2015)**



## 3.2 Influence Diagram

**Figure 17: Influence diagram for spring/summer outflow augmentation action.** (DS effects pathways in grey are not included in Rose BEM modeling)

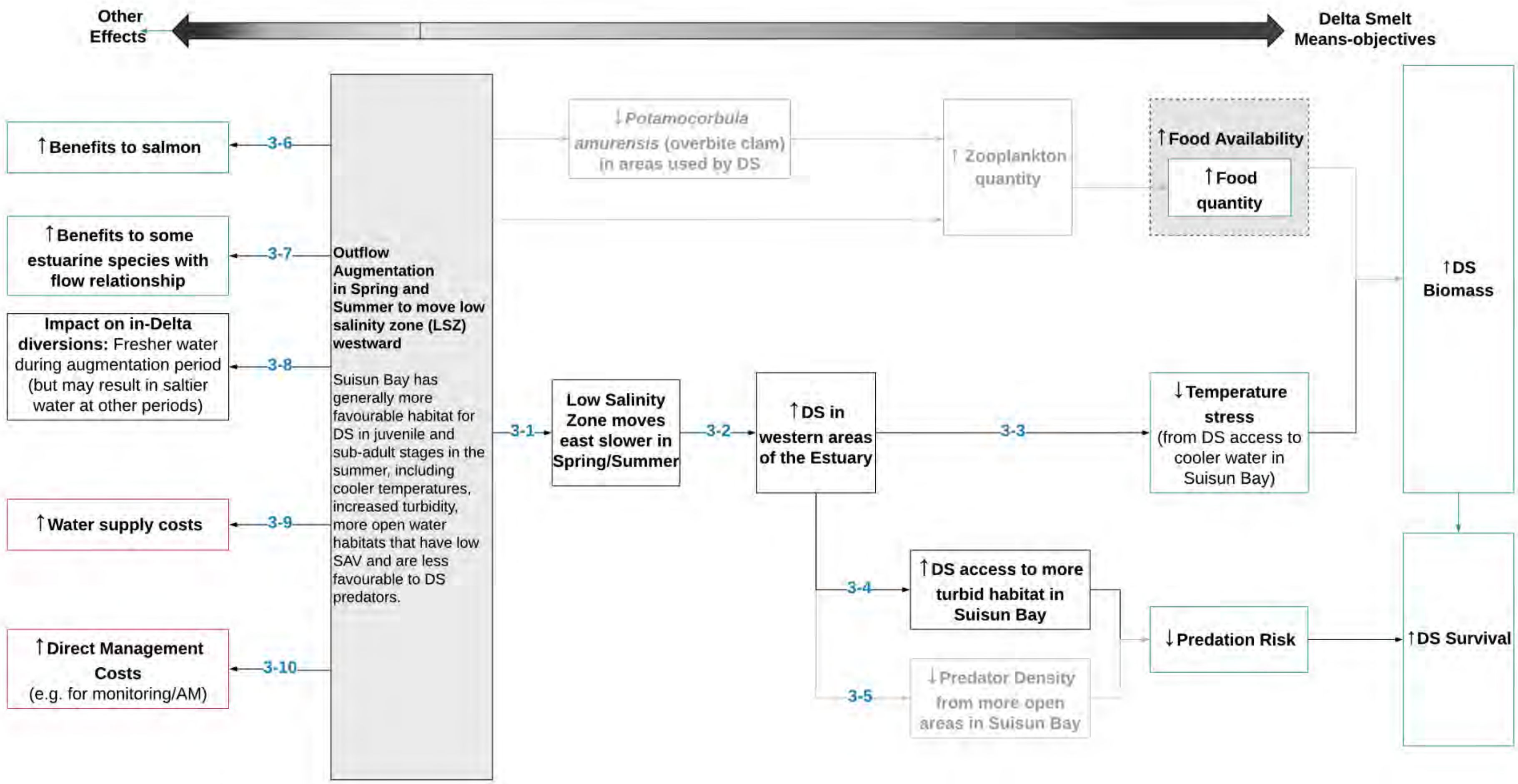


**Table 16: Effect hypotheses for outflow augmentation action to be assessed in SDM analysis.**

| # | Effect Hypothesis | Estimation Method |
|---|---|---|
| ***Delta Smelt*** | | |
| 3-1 | **Outflow Augmentation →LSZ moves east slower in Spring/Summer** | DWR has provided hydrology modeling analysis of the full build out scale scenario to show how 250 TAF of outflow augmentation in spring and summer can affect X2 positions over three different representative water years (DWR, 2017). Based on this modeling, best-case scenario assumptions for how this 250 TAF of outflow augmentation could change X2 are provided in Table 17. |
| 3-2 | **Movement of LSZ westward → More DS in western areas of estuary (Suisun Bay, Suisun Marsh)**<br>Excerpt from Sommer and Mejia (2013):<br>"Most delta smelt reside the majority of their lives in or near the low-salinity zone, typically <6 psu or <10,000 µS/cm (Feyrer et al. 2007; 2010; Kimmerer et al. 2009). Our GAM results for the 20-mm survey showed a similar pattern (Figure 4; Table 2). The distribution of delta smelt is affected by salinity at all life stages. For example, Dege and Brown (2004) found that the center of distribution of larval and post-larval delta smelt during spring was determined by the location of the salt field as indexed by X2, with a more downstream distribution during wetter years. Similarly, Sommer et al. (2011a) found that the center of distribution of older delta smelt was consistently associated with the location of the salt field (X2) during all months. This does not mean that all smelt are confined to a narrow salinity range because fish occur from fresh water to relatively high salinities (see below). The effects of salinity on habitat area vary seasonally and therefore by life stage. Kimmerer et al. (2009) found that X2 had a negative association with delta smelt habitat area (i.e. higher flow = more downstream position of X2 and more area appropriate for delta smelt) for all surveys analyzed, but the effect was strongest in spring and summer. They suggest that earlier life stages were more responsive to salinity changes because they tend to occupy fresher water than older delta smelt. Despite a clear effect of estuarine salinity on habitat area, Kimmerer et al. | **Rose BEM modeling method:** A back of the envelope analysis was done to relate DS spatial distributions with X2 positions for each Rose model strata. These relationships are used to estimate the incremental change in DS distributions as a result of the change in X2 from this outflow augmentation action. See Table 18 below for the results of this analysis and inputs into the model. |

| # | Effect Hypothesis | Estimation Method |
|---|---|---|
| | (2009) did not observe strong effects on abundance.”<br>Feyrer et al. (2011) also found a negative effect of X2 on habitat area during the fall. Feyrer et al. (2007) report a long-term decrease in habitat area based on the combined effects of salinity and turbidity (as indexed by Secchi depth), and a weak effect of fall conditions on juvenile production the following summer.” | |
| 3-3 | **More DS in western areas of estuary → Reduced temperature stress other water quality effects**<br>Moving the LSZ seaward places some delta smelt habitat under greater influence of coastal marine air providing some water-cooling effect, potentially reducing temperature stress and metabolic food demand (DFW, 2016).<br><br>Evidence from Hammock et al. 2015 suggests that fish in Suisun Bay exhibited greater signs of contaminant exposure than Lower Sacramento and Suisun Marsh. | **Rose BEM modeling method:** The model includes variation in temperature across the 11 model strata. The assumed presence of more delta smelt in Suisun Bay and Suisun Marsh as a result of this action will provide reduced temperature stress for that portion of the delta smelt population, which will be a benefit for biomass growth.<br><br>The increased contaminant exposure in Suisun Bay relative to Lower Sacramento and Suisun Marsh was not incorporated into this analysis for time/scope reasons. |
| 3-4 | **More DS in western areas of estuary → Increased turbid habitat available for DS → Reduced predation risk.**<br>A greater overlap of the LSZ with eastern Suisun Bay places more of Delta Smelt habitat in a region where wind-driven re-suspension of sediment is common and summer turbidity higher. The higher levels of turbidity are likely to protect DS from excessive predation (DFW, 2016). | **Rose BEM modeling method:** The model includes variation in turbidity across the 11 model strata and relates turbidity levels to predation based on TWG assumptions informed by the Ferrari et al. (2014) study (discussed under pathway 1-4). |
| 3-5 | **More delta smelt in western areas of estuary → Reduced Predator Density → Reduced predation risk.**<br>Predators of juvenile delta Ssmelt are likely to occur at lower densities within LSZ as it moves seaward, due to the broader, open nature of the habitat and relative absence of SAV (DFW, 2016). | **Pathway excluded from analysis:** This pathway is not directly included in the analysis. However, as a result of pathway 3-4, mortality of DS in the western areas of estuary will be lower than in other parts of the estuary. |
| N/A | **Outflow Augmentation → Reduced clams → Increased zooplankton quantity in areas used by DS at this time of year.** | **Pathway excluded from Rose BEM modeling of DS biomass:** TWG decided that this was not a critical pathway to include in the Rose BEM modeling. |

<table>
<tr><th>#</th><th>Effect Hypothesis</th><th>Estimation Method</th></tr>
<tr><td></td><td>Moving the freshwater region downstream in the Delta reduces the successful settlement of Potamocorbula amurensis[2] in freshwater regions and subsequent feeding competition. The presence of P. amurensis in waters that can be used by DS reduces the quantity of zooplankton that can be accessed by DS, reducing the overall food available to DS (DFW, 2016).</td><td>Brett Harvey recommended speaking to Janet Thompson, USGS about the possible benefit of reducing clams through outflow augmentation: https://www.usgs.gov/staff-profiles/janet-thompson , but Compass was not able to connect with J. Thompson within the timespan of this project.<br><br>Preliminary information shared with Compass is that clams can remove phytoplankton from an area very quickly. However, there are two types of invasive clams that compete with each other, one prefers more saline water (P. amurensis) and the other is okay with fresher water (Corbicula fluminea). So freshening an area might just provide a competitive advantage to one clam over another.</td></tr>
<tr><td>N/A</td><td>Outflow Augmentation → Increased zooplankton quantity in areas used by DS.<br><br>This can occur by two mechanisms:<br><br>(a) If the outflow transports copepods (a type of zooplankton eaten by DS) downstream into Suisun Bay, then this increases the food quantity available to DS present in Suisun Bay (DFW, 2016).<br><br>(b) Reservoir releases could contribute cladocerans (a type of zooplankton eaten by DS) to the Delta system (DFW, 2016). The cladocerans would have to be contributed to an area where DS are present to have an incremental increase in DS food availability.</td><td>Pathway excluded from Rose BEM modeling of DS biomass: TWG decided that this was not a critical pathway to include in the Rose BEM modeling for this project.</td></tr>
<tr><td colspan="3">Other Ecological Endpoints</td></tr>
<tr><td>3-6</td><td>Spring/Summer augmented flow → Salmon<br><br>Notes on potential effects to salmon from discussion with B. Cavallo (July 27,2017):<br><br>• Presence: Juvenile salmon are present in the estuary from December to June. Any effects</td><td>The effects of this action on this pathway are scored by the Technical Working Group, Brett Harvey and Brad Cavallo using a constructed scale to qualitatively describe their opinion on the effects of this action to salmon.</td></tr>
</table>

[2] *Potamocorbula amurensis* is a species of small saltwater clam. Common names include overbite claim, the Asian clam, the Amur River clam and the brackish-water corbula. The species is native to marine and brackish waters in the northern Pacific Ocean and has become naturalized in San Francisco Bay.

| # | Effect Hypothesis | Estimation Method |
|---|---|---|
| | of augmented flows that overlap with this time period could affect salmon.<br>• **Food:** Any foodweb effects from this action that benefit Delta Smelt could benefit juvenile salmon and at the least would not be harmful.<br>• **Turbidity:** Increasing turbidity would help juvenile salmon avoid predators.<br>• **LSZ:** There's no evidence that the location of the low salinity zone affects salmon.<br>• **Flow and speed of movement:** When flows are higher in the river sections of the channels, velocities are higher, and this helps juvenile salmon migrate through the area more quickly, which could decrease their vulnerability to predation mortality. This potential benefit only applies to the riverine sections. Flows do not assist salmon to move more quickly in tidal areas.<br>• **Flow and routing:** Higher flows can affect the routing of salmon and could route them to areas where their survival probability is higher. Coming down the Sacramento River, there are a few pathways that can take salmon into the Central and Interior Delta where survival is lower for salmon. Higher flows mean more water stays on the Sacramento River side, which means less salmon are routed into the Central and Interior Delta. Brad would need more details on the nature of the augmented flow to make a judgement on the potential magnitude of this effect, such as: where is the water coming from, duration and magnitude of the pulse.<br><br>No potential adverse effects identified. | |
| 3-7 | **Spring/Summer augmented flow → Benefits to other aquatic species.**<br><br>Several estuarine species have been shown to have a beneficial relationship with flow in San Francisco Bay (e.g. shrimp, flounder, dungeoness crab) (pers. comm. C. Wilcox, July 27, 2017). | The effects of this action on this pathway are scored by the Technical Working Group using a constructed scale to qualitatively describe their consensus opinion on the effects of this action to other native estuarine species. |
| N/A | **Outflow Augmentation → Reduced risk of harmful algal blooms.** | T. Sommer: At the full build out scale, this action would likely not reduce the risk of harmful algal blooms to delta smelt. Harmful |

| # | Effect Hypothesis | Estimation Method |
|---|---|---|
| | Augmented summer outflow levels move the Low Salinity Zone (LSZ) seaward placing more of the principle Delta Smelt habitat into downstream areas where toxic algal blooms (*mycrocystins)* are less intense and common. Factors believed to be linked to more intense harmful algal blooms include warmer water temperatures, lower flows, high nitrogen levels and relatively clear water (IEP MAST 2015). Of these factors, direct flow augmentation will reduce residence time and dilute nitrogen levels reducing the chances for a bloom (DFW, 2016).<br><br>Also see Moyle et al. (2016, pg. 16). | algal blooms occur in August and September and 250,000 AF of water would be used up well before August (pers. comm., T. Sommer, Aug.4, 2017).<br><br>C. Wilcox: Not a lot is known about the potential adverse effects of harmful algal blooms to Delta Smelt. A qualitative description of possible risks is all that is possible at this time to characterize this effect pathway with respect to Delta Smelt (pers. comm. C. Wilcox, July 27, 2017).<br><br>Note: IEP is putting together a Drought Synthesis report that may have relevant information (Louise Conrad is the lead). |
| N/A | **Augmented flow → Reduced spread/growth of invasive aquatic plants.**<br><br>Lower flow, warm, clear, and nutrient rich water are good conditions for invasive aquatic plant growth (pers. comm. C. Wilcox, July 27, 2017). | L. Conrad suggested that a preliminary analysis of this effect hypothesis could look at aquatic vegetation coverage and flow data and see if there is a relationship between flow and vegetation cover. She stated that reports from the field this year are that floating aquatic vegetation coverage is significantly down and this is thought to be related to the high winter flows. She also referenced a PhD thesis that linked water velocities with aquatic weed coverage to determine velocity limits at which some weeds are no longer established. (pers. comm. Aug. 11, 2017). |
| ***Socio-economic Considerations*** | | |
| 3-8 | **Augmented flow → Improved water quality for anyone doing in-Delta water diversions**<br><br>There are numerous in-Delta water diversions for municipal and agricultural purposes. The users of water from these in-Delta water diversions prefer fresher water. For example, Contra Costa has an in-Delta water intake that is vulnerable to salting up (pers. comm. T. Sommer, Aug. 4, 2017). | Compass spoke to Deanna Sereno from the Contra Costa Water District briefly on Aug. 14, 2017. Key points from this call:<br>• The full build out scale of this action would likely have negligible benefits for Contra Costa Water District as they divert water from their eastern (fresher water) intakes in the summer. They've made infrastructure upgrades already that allow them to adapt to saltier Delta conditions.<br>• A more comprehensive analysis of this action should include looking into if making the Delta fresher during the summer period would make it saltier in the fall. |

| # | Effect Hypothesis | Estimation Method |
|---|---|---|
| ***Resources Required*** | | |
| 3-9 | **Augmented flow → Cost to obtain water**<br>The details for how the water would be obtained to implement this action have not been determined yet. But generally, the water would likely be obtained through willing sellers in agricultural water districts. A price per acre foot of water would need to be negotiated with the willing sellers. A key uncertainty associated with this action is whether the full 250 TAF could be obtained from willing sellers in the desired years (pers. comm., T. Sommer, Aug. 4, 2017). Previous analysis put this cost for the summer of 2016 at $500/acre foot (CSAMP, 2016).<br>On the Aug. 11 CAMT SDM Core Team call, it was discussed whether agricultural effects of this change in water use need to be incorporated into the SDM analysis. It was generally agreed that these agricultural sector effects do not need to be included. Key discussion points included:<br>• S. Hamilton pointed out that net farm income would not be negatively impacted because these are willing sellers that would not sell water if they could make more income from using the water.<br>• Using this water for ecological purposes rather than agricultural purposes could have an effect of fallowing more agricultural land and lower farm employment, but this does not need to be factored into the SDM analysis (at least at this time). | At the Aug. 11 CAMT SDM Core Team meeting, the following water costs were recommended for use in the SDM analysis as ball-park estimates (recognizing that even within different water year types there can be considerable variation in negotiated water prices):<br>• Representative above normal water year: $125/AF<br>• Representative below normal water year: $250/AF<br>• Representative dry water year: $500/AF |
| 3-10 | **Augmented flow → Direct management costs** | Historical experience for the cost of monitoring and adaptive management around these types of flow actions is in the range of $5 million per flow action (pers. comm. C. Wilcox, July 27, 2017). |

**Table 17: Best-case scenario assumptions for changes in average monthly X2 positions for model years 2000 to 2005 (based off of DWR modeling of the full build out scale scenario).**

| | Average X2 (Baseline) | | | | Average X2 (Augmented scenario) | | | | Base X2 minus Augmented X2 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Year | June | July | August | September | June | July | August | September | June | July | August | September |
| 2000 | 73 | 78 | 80 | 84 | 73 | 78 | 79 | 82 | 0 | 0 | 1 | 2 |
| 2001 | 78 | 83 | 87 | 88 | 78 | 81 | 85 | 88 | 0 | 2 | 3 | 0 |
| 2002 | 77 | 81 | 85 | 88 | 77 | 80 | 82 | 87 | 0 | 2 | 2 | 1 |
| 2003 | 69 | 77 | 79 | 86 | 69 | 77 | 78 | 84 | 0 | 0 | 1 | 2 |
| 2004 | 81 | 80 | 82 | 85 | 80 | 78 | 80 | 84 | 1 | 2 | 2 | 1 |
| 2005 | 61 | 72 | 80 | 82 | 61 | 72 | 79 | 79 | 0 | 0 | 1 | 2 |

Table 18: Assumed changes in delta smelt distribution from spring/summer outflow augmentation action

**Assumptions**

Outflow augmentation results in more delta smelt in Suisun Bay strata compared to baseline in proportion to the relationship between X2 and delta smelt distributions in years 1997-2005.

Distribution in Suisun Marsh is the same in augmented scenario as in baseline.

Distribution in non SB and SM strata are decreased in proportion to their relative distribution under the baseline.

**Distributions of Delta Smelt Across Rose et al. (2013) strata for Augmented Scenarios**

| LOC | Month | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 |
|---|---|---|---|---|---|---|---|
| Sac | June | 3% | 7% | 9% | 7% | 12% | 11% |
| | July | 5% | 6% | 7% | 8% | 17% | 10% |
| | August | 6% | 6% | 5% | 7% | 21% | 8% |
| | September | 7% | 7% | 6% | 6% | 24% | 7% |
| Sdelta | June | 3% | 1% | 2% | 2% | 2% | 1% |
| | July | 3% | 1% | 1% | 1% | 1% | 2% |
| | August | 3% | 1% | 1% | 1% | 1% | 2% |
| | September | 3% | 1% | 1% | 1% | 2% | 2% |
| Edelta | June | 2% | 1% | 3% | 1% | 2% | 1% |
| | July | 3% | 1% | 2% | 1% | 1% | 2% |
| | August | 3% | 1% | 1% | 1% | 1% | 2% |
| | September | 3% | 1% | 1% | 1% | 2% | 2% |
| LowSac | June | 14% | 49% | 37% | 14% | 40% | 3% |
| | July | 14% | 54% | 51% | 29% | 36% | 6% |
| | August | 13% | 52% | 52% | 43% | 34% | 8% |
| | September | 12% | 56% | 52% | 49% | 33% | 10% |
| LowSJ | June | 9% | 14% | 19% | 12% | 7% | 5% |
| | July | 9% | 5% | 5% | 6% | 3% | 5% |
| | August | 9% | 3% | 2% | 3% | 2% | 4% |
| | September | 8% | 2% | 1% | 2% | 2% | 4% |
| Conf | June | 47% | 17% | 20% | 39% | 20% | 14% |
| | July | 41% | 15% | 23% | 34% | 21% | 24% |
| | August | 33% | 14% | 24% | 25% | 21% | 31% |
| | September | 27% | 18% | 29% | 17% | 21% | 33% |
| SE Suisun | June | 8% | 4% | 1% | 6% | 3% | 13% |
| | July | 9% | 6% | 2% | 8% | 4% | 13% |
| | August | 11% | 6% | 3% | 8% | 3% | 13% |
| | September | 12% | 4% | 2% | 8% | 2% | 12% |
| NE Suisun | June | 3% | 2% | 3% | 8% | 3% | 17% |
| | July | 3% | 3% | 2% | 8% | 5% | 11% |
| | August | 4% | 4% | 3% | 7% | 6% | 8% |
| | September | 6% | 4% | 3% | 6% | 7% | 6% |
| Marsh | June | 3% | 2% | 1% | 6% | 4% | 3% |
| | July | 4% | 3% | 1% | 3% | 2% | 2% |
| | August | 5% | 3% | 1% | 2% | 1% | 2% |
| | September | 6% | 4% | 2% | 2% | 1% | 2% |
| SW Suisun | June | 4% | 1% | 1% | 1% | 3% | 3% |
| | July | 5% | 2% | 2% | 1% | 4% | 3% |
| | August | 7% | 3% | 3% | 1% | 4% | 3% |
| | September | 7% | 1% | 1% | 2% | 3% | 4% |
| NW Suisun | June | 5% | 2% | 4% | 3% | 4% | 28% |
| | July | 4% | 5% | 4% | 2% | 6% | 23% |
| | August | 6% | 7% | 6% | 3% | 5% | 18% |
| | September | 9% | 3% | 3% | 6% | 4% | 16% |

**Distributions of Delta Smelt Across Rose et al. (2013) strata: % points difference between Augmented and Baseline**

| LOC | Month | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 |
|---|---|---|---|---|---|---|---|
| Sac | June | 0% | 0% | 0% | 0% | 0% | 0% |
| | July | 0% | 0% | 0% | 0% | -2% | 0% |
| | August | 0% | -1% | -1% | 0% | -2% | 0% |
| | Septembe | -1% | 0% | 0% | -1% | -1% | -1% |
| Sdelta | June | 0% | 0% | 0% | 0% | 0% | 0% |
| | July | 0% | 0% | 0% | 0% | 0% | 0% |
| | August | 0% | 0% | 0% | 0% | 0% | 0% |
| | Septembe | 0% | 0% | 0% | 0% | 0% | 0% |
| Edelta | June | 0% | 0% | 0% | 0% | 0% | 0% |
| | July | 0% | 0% | 0% | 0% | 0% | 0% |
| | August | 0% | 0% | 0% | 0% | 0% | 0% |
| | Septembe | 0% | 0% | 0% | 0% | 0% | 0% |
| LowSac | June | 0% | 0% | 0% | 0% | -2% | 0% |
| | July | 0% | -3% | -3% | 0% | -3% | 0% |
| | August | -1% | -6% | -5% | -1% | -3% | -1% |
| | Septembe | -2% | 0% | -2% | -5% | -1% | -1% |
| LowSJ | June | 0% | 0% | 0% | 0% | 0% | 0% |
| | July | 0% | 0% | 0% | 0% | 0% | 0% |
| | August | 0% | 0% | 0% | 0% | 0% | 0% |
| | Septembe | -1% | 0% | 0% | 0% | 0% | -1% |
| Conf | June | 0% | 0% | 0% | 0% | -1% | 0% |
| | July | 0% | -1% | -1% | 0% | -2% | 0% |
| | August | -1% | -2% | -2% | -1% | -2% | -2% |
| | Septembe | -4% | 0% | -1% | -2% | -1% | -5% |
| SE Suisun | June | 0% | 0% | 0% | 0% | 1% | 0% |
| | July | 0% | 1% | 1% | 0% | 2% | 0% |
| | August | 1% | 2% | 2% | 0% | 1% | 1% |
| | Septembe | 1% | 0% | 0% | 1% | 0% | 1% |
| NE Suisun | June | 0% | 0% | 0% | 0% | 0% | 0% |
| | July | 0% | 0% | 0% | 0% | 0% | 0% |
| | August | 0% | 0% | 0% | 0% | 0% | 0% |
| | Septembe | 1% | 0% | 0% | 1% | 0% | 1% |
| Marsh | June | 0% | 0% | 0% | 0% | 0% | 0% |
| | July | 0% | 0% | 0% | 0% | 0% | 0% |
| | August | 0% | 0% | 0% | 0% | 0% | 0% |
| | Septembe | 0% | 0% | 0% | 0% | 0% | 0% |
| SW Suisun | June | 0% | 0% | 0% | 0% | 0% | 0% |
| | July | 0% | 1% | 1% | 0% | 2% | 0% |
| | August | 1% | 2% | 2% | 0% | 1% | 1% |
| | Septembe | 1% | 0% | 0% | 1% | 1% | 1% |
| NW Suisur | June | 0% | 0% | 0% | 0% | 1% | 0% |
| | July | 0% | 2% | 2% | 0% | 4% | 0% |
| | August | 2% | 4% | 4% | 1% | 3% | 2% |
| | Septembe | 4% | 0% | 2% | 4% | 2% | 5% |

## 3.3 Original Action in Resiliency Strategy and Updates

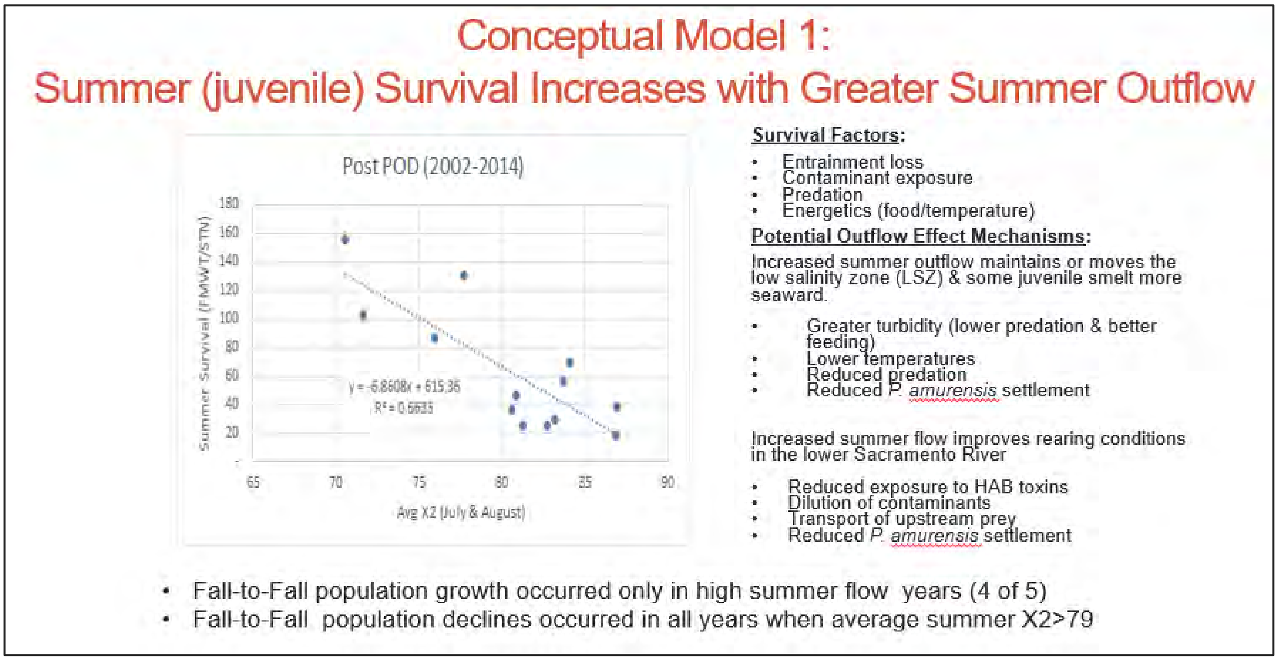
**Summary of Action:** This adaptive management effort will occur in the spring and summer of 2017 and 2018. In 2016, Reclamation will provide 85 thousand acre-feet (TAF) to 200TAF additional outflow above what is required under D-1641 for release in the summer. In the spring and summer of 2017 and 2018, DWR and/or Reclamation will provide up to an additional 250TAF of outflow above D-1641 requirements. A variety of methods may be used to augment outflow, including transfers from willing sellers, changes in export or other CVP/SWP Delta operations, and/or storage releases. These flows must be consistent with the 2009 salmon biological opinion as determined by NMFS and CDFW.

**Update:** Additional outflows did not occur in the spring and summer of 2016 because no water was apportioned for the action. Water year 2016-17 was one of the wettest on record. State scientists are studying how the massive outflow affects ecosystem and species. (edits to the original update text suggested by Erin Gleason, Aug. 1, 2017)

**Linkage to Conceptual Models:** The CMs suggest that seasonally augmented outflows could affect two Environmental Drivers: Turbidity and Hydrology. Habitat Attributes that could be affected include Predation Risk, Harmful Algal Blooms, and Food Availability and Quality. This management action would also test the recent hypothesis that the location of the Low Salinity Zone (LSZ) is important at times of year besides fall. The extent to which these Environmental Drivers and Habitat Attributes can be positively affected through outflow augmentation will be the subject of a targeted research action.

## 3.4 Additional Background

**Figure 18: Slides from CSAMP (2016)**



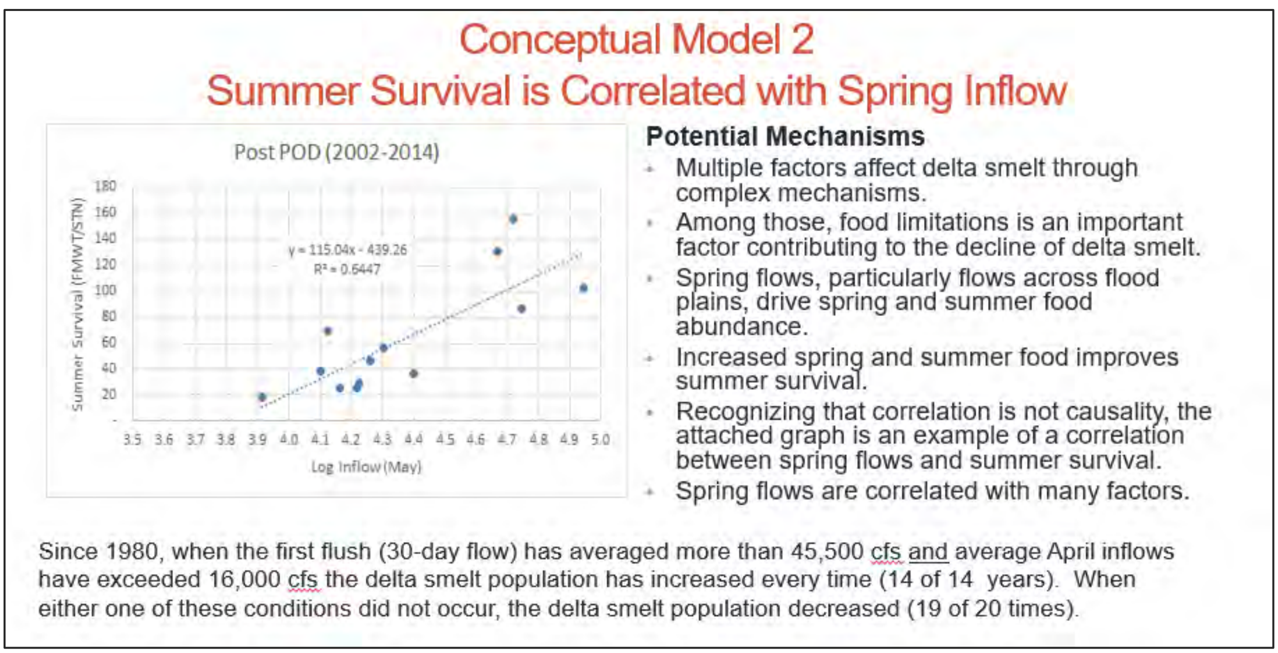



**Table 19: Performance of delta smelt associated with average X2 location by season (table produced by Scott Hamilton).**

| Performance Category | Average of Spring Mar-May | Average of Summer Jun-Aug | Average of Fall Sep-Nov | Frequency (# years) | Average of Pcnt Change in FMWT Index |
|---|---|---|---|---|---|
| Excellent | 61.0 | 73.9 | 80.7 | 7 | 563% |
| Good | 66.4 | 79.1 | 83.2 | 12 | 151% |
| Poor | 69.6 | 79.8 | 80.6 | 9 | 87% |
| Bad | 70.5 | 80.2 | 84.3 | 17 | 39% |
| Percentile Ranking of X2 Locations | | | | | |
| Excellent | 35% | 27% | 41% | | |
| Good | 48% | 44% | 50% | | |
| Poor | 60% | 45% | 41% | | |
| Bad | 64% | 46% | 58% | | |

## 3.5 References


CSAMP. 2016. Presentation to the Collaborative Science and Adaptive Management Program Policy Group Technical Forum: "Outflow Augmentation For Delta Smelt", Aug. 29, 2016.

DFW. 2016. "CDFW Rationale for Summer Delta Flow Augmentation for Improving Delta Smelt Survival", July 8, 2016.

DWR. 2017. Office Memo from Kevin Kao and Sanjaya Seneviratne, Bay-Delta Office of the Department of Water Resources, September 22, 2017. Subject: Keeping X2 below 80 km with 250 TAF from March to August. (This analysis was produced specifically for the Structured Decision Making for Delta Smelt project).

IEP MAST. 2015.

Sommer, T. Meija, F. (2013). "A Place to Call Home: A Synthesis of Delta Smelt Habitat in the Upper San Francisco Estuary", *San Francisco Estuary and Watershed Science,* 11(2).

### 3.6 DWR (2017) (Memo reproduced below)

State of California Agency | DEPARTMENT OF WATER RESOURCES | California Natural Resources

**OFFICE MEMO**

| | | | |
|---|---|---|---|
| **TO:** | Erik Reyes<br>Bay-Delta Office | **DATE:** | 9/22/2017 |
| **FROM:** | Kevin Kao, Sanjaya Seneviratne | **SUBJECT:** | Keeping X2 below 80 km with 250 TAF from March to August |


Summary:

A DSM2 planning model with CalSim3 input is used to estimate the effect of 250 TAF water on the X2 during March to August for selected year 2012, 2009, and 1994. The goal is to keep X2 below 80 km as long as possible.


Methodology:

The required NDO to keep X2 equals 80 km is estimated based on a NDO-X2 relationships with a temporal resolution of one month, and the flow augmentation is calculated and distributed evenly for a month, until 250 TAF is reached. A DSM2 planning model with CalSim3 input is run with these augmented flows and then X2 is calculated for both monthly and daily values.

Results:

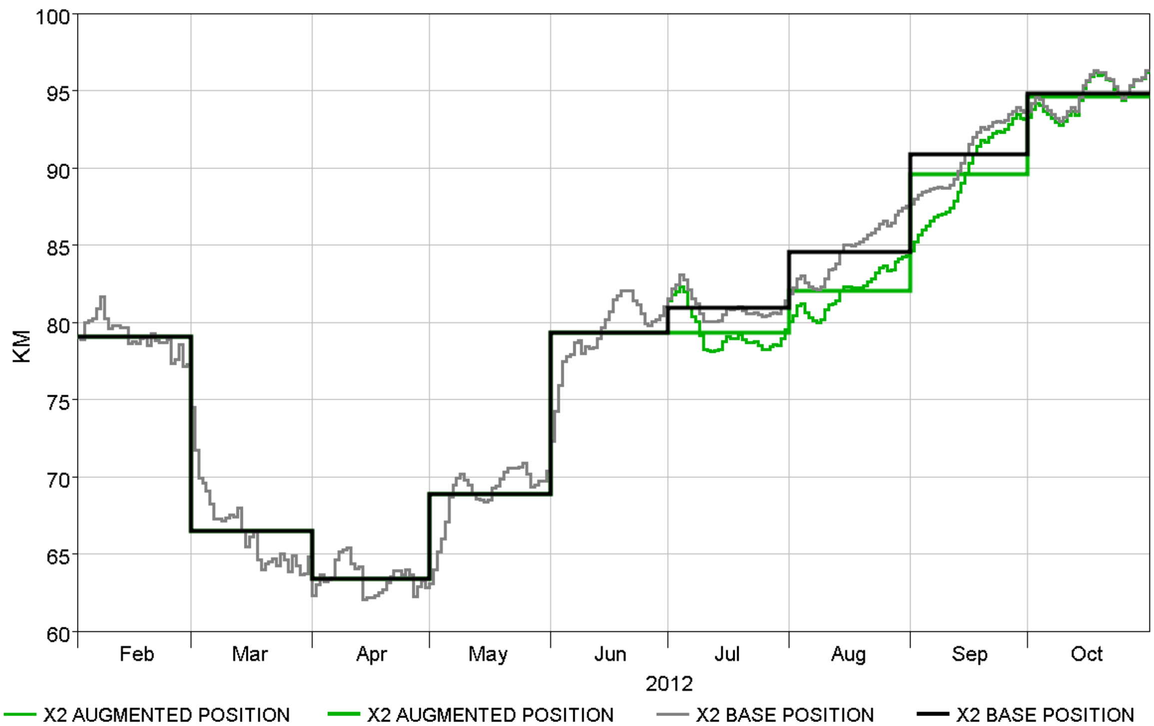
The tables and plots are shown in the following page. The base cases are plotted in black and gray, and the augmented cases are in green. Year 2009 is drier than 2012, but the number of days that X2<80 km is significantly more than that in 2012. Ideally an optimization algorithm with finer temporal resolution can be scripted to run the model and increase the X2<80 km days, but a cursory investigation can provide preliminary estimate in less time.

| 2012 | (above normal) | MAR | APR | MAY | JUN | JUL | AUG | Total |
|---|---|---|---|---|---|---|---|---|
| Base | X2 (km) | 66.5 | 63.4 | 68.9 | 79.3 | 80.9 | 84.6 | |
| | days X2<80 | 31 | 30 | 31 | 16 | 0 | 0 | 108 |
| Augmented | X2 (km) | 66.5 | 63.4 | 68.9 | 79.3 | 79.3 | 82.0 | |
| | days X2<80 | 31 | 30 | 31 | 16 | 23 | 1 | 132 |
| | water added (taf) | | | | | 133 | 117 | |

| 2009 | (below normal) | MAR | APR | MAY | JUN | JUL | AUG | Total |
|---|---|---|---|---|---|---|---|---|
| Base | X2 (km) | 66.1 | 69.8 | 72.6 | 75.3 | 78.8 | 84.5 | |
| | days X2<80 | 31 | 30 | 31 | 30 | 18 | 0 | 140 |
| Augmented | X2 (km) | 66.1 | 69.8 | 72.6 | 75.3 | 78.8 | 80.6 | |
| | days X2<80 | 31 | 30 | 31 | 30 | 18 | 6 | 146 |
| | water added (taf) | | | | | | 250 | |

- Releasing 250TAF in July may increase few additional days.

| 1994 | (dry) | MAR | APR | MAY | JUN | JUL | AUG | Total |
|---|---|---|---|---|---|---|---|---|
| Base | X2 (km) | 77.8 | 81.9 | 83.9 | 88.4 | 87.4 | 89.3 | |
| | days X2<80 | 23 | 0 | 0 | 0 | 0 | 0 | 23 |
| Augmented | X2 (km) | 77.8 | 79.5 | 81.6 | 87.4 | 87.3 | 89.3 | |
| | days X2<80 | 23 | 20 | 4 | 0 | 0 | 0 | 47 |
| | water added (taf) | | 179 | 71 | | | | |



100
95
90
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80
75
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65
60
KM
Feb
Mar
Apr
May
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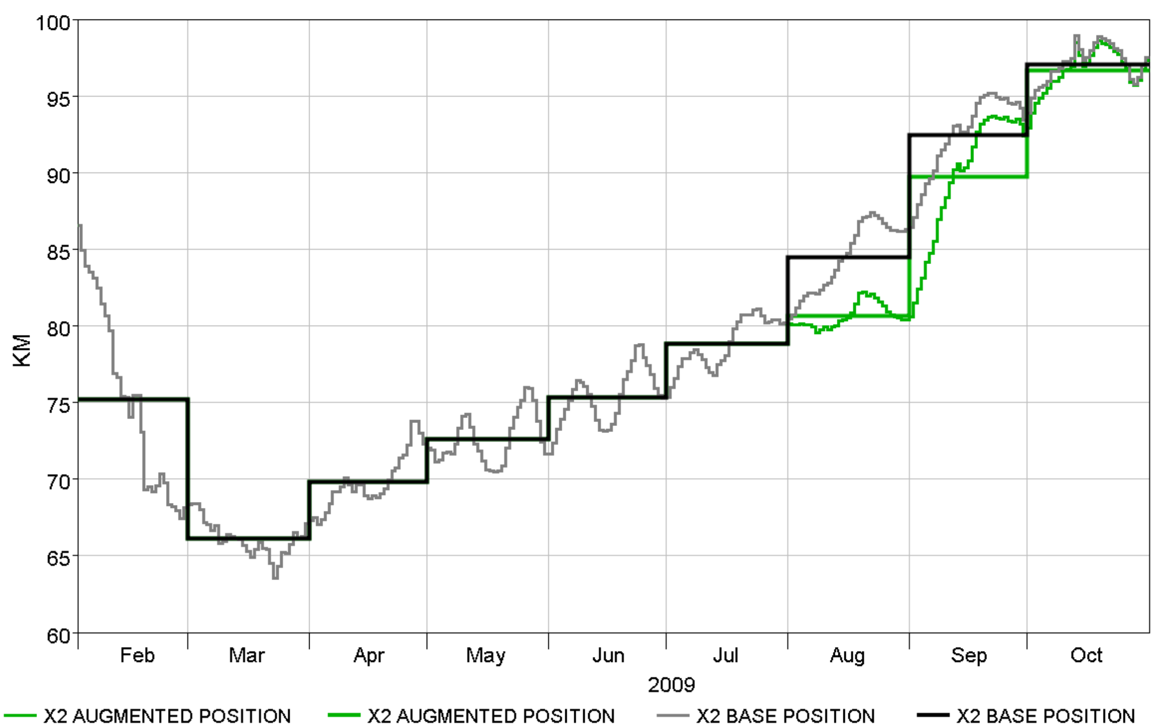
2012
X2 AUGMENTED POSITION
X2 AUGMENTED POSITION
X2 BASE POSITION
X2 BASE POSITION

100
95
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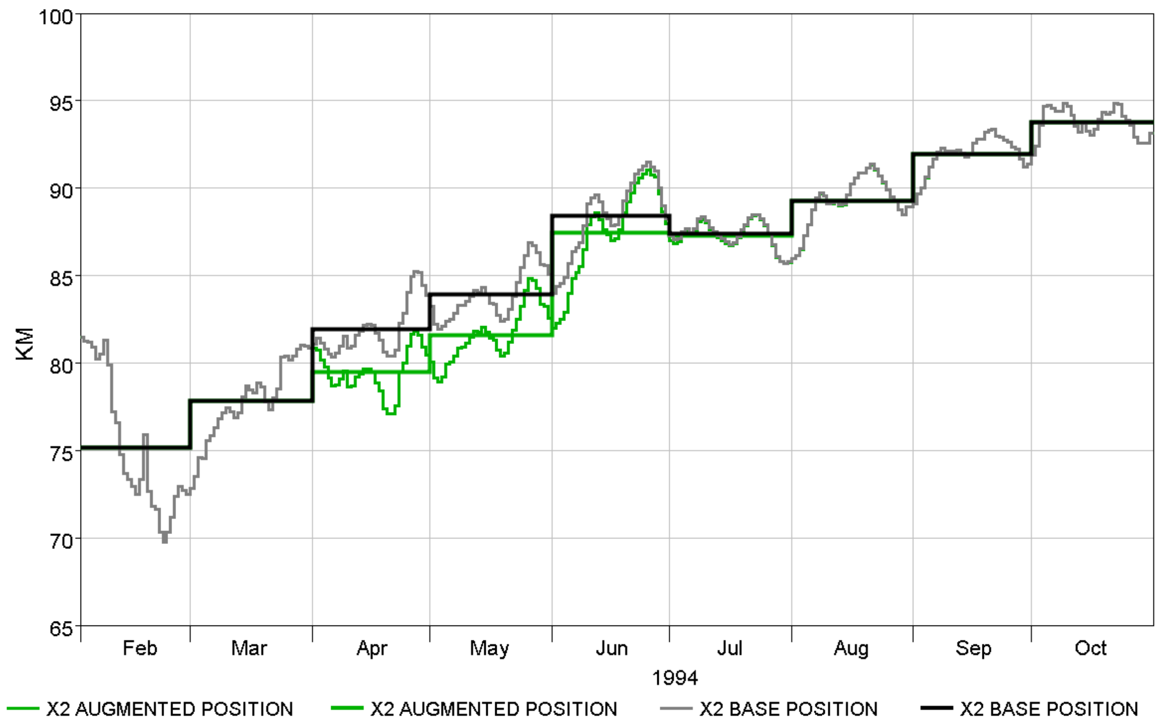
2009
X2 AUGMENTED POSITION
X2 AUGMENTED POSITION
X2 BASE POSITION
X2 BASE POSITION



100
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X2 AUGMENTED POSITION
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X2 BASE POSITION

# 4 Reoperation of the Suisun Marsh Salinity Control Gates

## 4.1 Action Summary

Scientists believe that the Suisun Marsh in the western Delta contains good delta smelt habitat likely because of food availability, proximity to emergent marsh, high turbidity, and potential temperature and predation refuges (pers. comm., T. Sommer, Aug. 4, 2017). However, during dry periods, high salinity levels in the marsh are less suitable for delta smelt, which prefer lower salinity (Sommer and Mejia, 2013). The Suisun Marsh Salinity Control Gates, which are normally operated from October to May, prevent saltwater from entering the marsh during high tide and open to allow freshwater into the marsh during low tide, thereby reducing marsh salinity. The Strategy suggests that through off-season operation of these gates during dry summer months, habitat suitability can be improved for delta smelt such that they will make more use of this area (pers. comm., T. Sommer, Aug. 4, 2017).

**Table 20: Scale of action under the Resiliency Strategy and full build out scale scenario**

| Resiliency Strategy Scale | Full Build Out Scale | Scaling Criteria and Reference for Full Build Out |
|---|---|---|
| Operate the salinity gates in the off-season (summer) to reduce salinity and attract delta smelt to the area (note: no adaptive management plan mentioned). | • Assume that reoperation of the salinity control gates would change salinity conditions in the Marsh for a dry or below normal water year to conditions under an average above normal water year in July, August, and September.<br>• No action for above normal, wet, or critical water years.<br>• Outflow augmentation would accompany the operation of the SMSCG to offset increases in salinity in the Delta.<br>• The action would be done using an adaptive management approach that promotes learning and decision making. | Ted Sommer advised on best case scenario assumption for what SMSCG could achieve.<br><br>A proposal for an adaptive management plan is under development by G. Long, D. Murphy, B. Noon, and S. Bartell. |

## 4.2 Influence Diagram

**Figure 19: Influence diagram for the Suisun Marsh Salinity Control Gates action.**

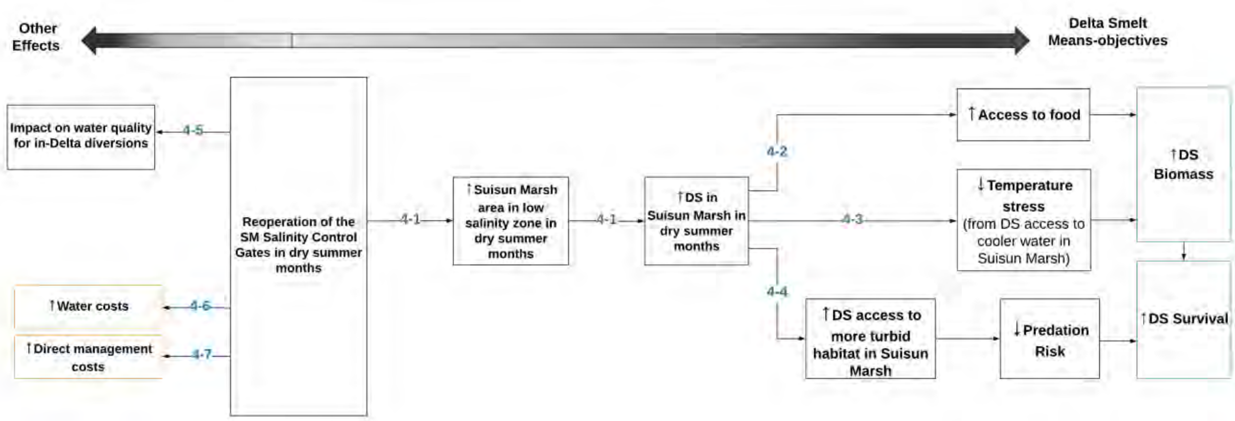


**Table 21: Effect hypotheses for the Suisun Marsh Salinity Control Gates action to be assessed in SDM analysis.**

| # | Effect Hypothesis | Estimation Method |
|---|---|---|
| ***Delta Smelt*** | | |
| 4-1 | **Operation of the SMSCG as per full build out scale definition → Suisun Marsh in the Low Salinity Zone in July, August, September → Increased DS in Suisun Marsh in dry summer months**<br><br>Increasing the amount of time that Suisun Marsh is in the low salinity zone in summer is hypothesized to allow DS better access to this area, which tends to have higher zooplankton abundance and other attractive habitat features compared to other parts of the estuary at this time of year. | **Rose BEM modeling method:** The TWG undertook a simple analysis to relate the spatial distribution of delta smelt with X2 position. For the years examined (1997 to 2005), the analysis showed that a higher proportion of DS were found in Suisun Marsh when X2 was less than 85 km than in drier years when X2 was greater than 85 km in summer months. Suisun Marsh is in the Low Salinity Zone when X2 < 85 km (MacWilliams and Bever LSZ flip book). To model this pathway, we assumed that DS spatial distributions from July-Sept for dry and below normal years would be the same as the highest proportion of distribution observed in in the above normal water years between 1997 and 2005. See Table 22 and Table 23 below for the assumed delta smelt distribution values that were used as model inputs to simulate this action. |
| 4-2 | **Increase DS in Suisun Marsh in dry summer months → Increased access to food**<br><br>Suisun Marsh tends to have higher zooplankton densities compared to other areas of the estuary in the summer. | **Rose BEM modeling method:** The model includes variation in zooplankton densities across the 11 model strata based on historical zooplankton survey data for model years 2000 to 2005. The assumed presence of more DS in Suisun Marsh as a result of this action will provide access to the higher zooplankton densities in Suisun Marsh for these DS. |
| 4-3 | **Increase DS in Suisun Marsh in dry summer months → Reduced DS temperature stress → Increased DS biomass growth**<br><br>Suisun Marsh tends to be cooler in dry summer months compared to the Delta. | **Rose BEM modeling method:** The model includes variation in temperature across the 11 model strata. The assumed presence of more Delta Smelt in Suisun Marsh as a result of this action will provide reduced temperature stress for that portion of the delta smelt population, which will be a benefit for biomass growth. |
| 4-4 | **Increase DS in Suisun Marsh in dry summer months → DS access to more turbid habitat in Suisun Marsh → Reduced DS predation**<br><br>Suisun Marsh tends to be more turbid than the Delta. | **Rose BEM modeling method:** The model includes variation in turbidity across the 11 model strata and relates turbidity levels to predation based on TWG assumptions informed by the Ferrari et al. (2014) study (discussed under pathway 1-4). |
| N/A | **Operation of the SMSCG under an adaptive management plan to answer fundamental questions around DS → DS learning (general DS science)** | The benefit of this action for DS learning is scored by the Technical Working Group using a constructed scale to qualitatively describe their consensus opinion. |

| # | Effect Hypothesis | Estimation Method |
|---|---|---|
| | This action is proposed as an adaptive management program to understand relationships between salinity, prey availability, and DS abundance/growth in Suisun Marsh. | |
| ***Other Ecological Endpoints*** | | |
| N/A | **Action → Salmon**<br>Because this is a summer action, juvenile salmon will not be in the estuary and therefore will not likely be directly affected by this action (pers. comm. B. Cavallo, July 27, 2017). | The effects of this action on this pathway are scored by the Technical Working Group, Brett Harvey and Brad Cavallo using a constructed scale to qualitatively describe their opinion on the effects of this action to salmon. |
| N/A | **Action → Other native estuarine species** | The effects of this action on this pathway are scored by the Technical Working Group using a constructed scale to qualitatively describe their consensus opinion on the effects of this action to other native estuarine species. |
| ***Socio-economic Considerations*** | | |
| 4-5 | **SG operation → Increase in Delta salinity → potential impact on water quality for in-Delta diversions**<br>The users of water from in-Delta water diversions prefer fresher water.<br>Water salinity targets set by the State Water Resources Control Board are assumed to be as inviolable as they are today. If operations affect the anticipated achievement of these targets, water resource managers must take appropriate actions to ensure the targets are upheld.<br>However, changes in salinity in the Delta due to the operations of the SMSCGs are expected to be <1 psu and therefore negligible. The current expectation is that minimal operational changes would be needed to meet water quality objectives. | See presentation titled "Hydrodynamic Modeling for Delta Smelt Resiliency Strategy Evaluation of SMSCG Reoperation, Michael MacWilliams and Aaron Bever, Dec. 4, 2017", which shows:<br>• The reoperation of the SMSCG in July to September in a below normal year (2012) would result in a change of <1 depth-averaged salinity (psu) (see slide 7, 23).<br>• For the hydrology year 2012 (below normal water year), if this action is accompanied by about 60 TAF of outflow augmentation than salinity in the Delta is practically unchanged with the operation of the SMSCG in July and August and fresher in September and October (see slide 18). |
| N/A | **SG operation → reduced navigation ability**<br>Salinity gate operations may affect navigation into Suisun Marsh depending on whether the boat locks are in operation. Note that the boat locks will | For this analysis, we assume no effect on navigation. |

| # | Effect Hypothesis | Estimation Method |
|---|---|---|
| | be in operation for a proposed pilot SMSCG action in summer 2018. | |
| ***Resources Required*** | | |
| 4-6 | **Water costs**<br>Hydrodynamic Modeling done by MacWilliams and Bever initially predictedinitially predicted that about 60 TAF of water is needed to offset the increased salinity in the Delta from operation of the SMSCG as suggested in this action in a below normal year (2012 hydrology was used for modeling). See presentation titled "Hydrodynamic Modeling for Delta Smelt Resiliency Strategy Evaluation of SMSCG Reoperation, Michael MacWilliams and Aaron Bever, Dec. 4, 2017". However, revised analyses by DWR's Bay Delta office suggest that the amount needed in 2018, another Below Normal Year, would be much lower. The initial estimate is 30 TAF, but DWR operators emphasize that actual water costs could be even lower (or non-existant) based on real-time conitions. | At the Aug. 11 CAMT SDM Core Team, the following water costs were recommended for use in the SDM analysis as ball-park estimates (recognizing that even within different water year types there can be considerable variation in negotiated water prices):<br>• Representative above normal water year: $125/AF<br>• Representative below normal water year: $250/AF<br>• Representative dry water year: $500/AF |
| 4-7 | **Direct management costs per time this action is done in dry and below normal water years:**<br>• No capital costs identified to date to complete this action<br>• Operating costs (e.g. staff time, maintenance)<br>• Monitoring costs | A cost analysis for this action has not been completed, but Ted Sommer (DWR) provided preliminary ballpark estimates based on general experience (pers. comm., Dec. 21, 2017):<br>• Operating Costs: $100,000 per year this action is done<br>• Monitoring Costs: $200,000 per year this action is done |

**Table 22: Delta smelt distribution in Suisun Marsh for baseline model years and for SMSCG full build out scale scenario**

| Model Year | SCG Operation in July, Aug, and Sept? | Baseline Distribution (Suisun Marsh) June | July | August | Sept | SMSCG Action Distribution (Suisun Marsh) June | July | August | Sept |
|---|---|---|---|---|---|---|---|---|---|
| 2000 | No | 3% | 4% | 5% | 6% | 3% | 4% | 5% | 6% |
| 2001 | Yes | 2% | 3% | 3% | 4% | 2% | 4% | 5% | 6% |
| 2002 | Yes | 1% | 1% | 1% | 2% | 1% | 4% | 5% | 6% |
| 2003 | No | 6% | 3% | 2% | 2% | 6% | 3% | 2% | 2% |
| 2004 | Yes | 4% | 2% | 1% | 1% | 4% | 4% | 5% | 6% |
| 2005 | No | 3% | 2% | 2% | 2% | 3% | 2% | 2% | 2% |

**Best case scenario Assumption:**

When SMSCG are operating to keep SM in the LSZ, the distribution of DS is assumed to be the highest proportion observed in AN (Sac) Water years (2000, 2003, 2005)

**Table 23: Assumed spatial distribution of delta smelt across all strata for the full build out scale SMSCG action compared to baseline distributions.**

**Assumptions**

Distribution in Suisun Marsh changes with action.

Fish numbers are decreased in other strata to make up for additional fish in SM.

**Distributions of Delta Smelt Across Rose et al. (2013) strata for SMSCG Scenario**

| LOC | Month | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 |
|---|---|---|---|---|---|---|---|
| Sac | June | 3% | 7% | 9% | 7% | 13% | 11% |
| | July | 5% | 6% | 7% | 8% | 18% | 10% |
| | August | 6% | 6% | 6% | 7% | 21% | 9% |
| | September | 7% | 7% | 6% | 7% | 23% | 8% |
| Sdelta | June | 3% | 1% | 2% | 2% | 2% | 1% |
| | July | 3% | 1% | 1% | 1% | 1% | 2% |
| | August | 3% | 1% | 1% | 1% | 1% | 2% |
| | September | 3% | 1% | 1% | 1% | 2% | 3% |
| Edelta | June | 2% | 1% | 3% | 1% | 2% | 1% |
| | July | 3% | 1% | 2% | 1% | 2% | 2% |
| | August | 3% | 1% | 1% | 1% | 2% | 2% |
| | September | 4% | 1% | 1% | 1% | 2% | 3% |
| LowSac | June | 14% | 49% | 37% | 14% | 42% | 3% |
| | July | 14% | 56% | 52% | 29% | 39% | 6% |
| | August | 13% | 57% | 55% | 44% | 35% | 9% |
| | September | 13% | 54% | 51% | 54% | 32% | 11% |
| LowSJ | June | 9% | 14% | 19% | 12% | 7% | 5% |
| | July | 9% | 6% | 5% | 6% | 3% | 5% |
| | August | 9% | 3% | 2% | 3% | 2% | 4% |
| | September | 9% | 2% | 1% | 2% | 2% | 4% |
| Conf | June | 47% | 17% | 20% | 39% | 21% | 14% |
| | July | 41% | 16% | 24% | 34% | 23% | 24% |
| | August | 35% | 16% | 25% | 26% | 22% | 33% |
| | September | 31% | 17% | 28% | 19% | 21% | 38% |
| SE Suisun | June | 8% | 4% | 1% | 6% | 2% | 13% |
| | July | 9% | 4% | 1% | 8% | 2% | 13% |
| | August | 10% | 5% | 1% | 8% | 2% | 12% |
| | September | 11% | 4% | 1% | 7% | 2% | 11% |
| NE Suisun | June | 3% | 2% | 3% | 8% | 3% | 17% |
| | July | 3% | 2% | 2% | 8% | 4% | 11% |
| | August | 4% | 3% | 2% | 7% | 6% | 8% |
| | September | 5% | 3% | 2% | 6% | 6% | 6% |
| Marsh | June | 3% | 2% | 1% | 6% | 4% | 3% |
| | July | 4% | 4% | 4% | 3% | 4% | 2% |
| | August | 5% | 5% | 5% | 2% | 5% | 2% |
| | September | 6% | 6% | 6% | 2% | 6% | 2% |
| SW Suisun | June | 4% | 1% | 1% | 1% | 3% | 3% |
| | July | 5% | 1% | 1% | 1% | 2% | 3% |
| | August | 6% | 1% | 1% | 1% | 2% | 2% |
| | September | 6% | 1% | 1% | 1% | 2% | 2% |
| NW Suisun | June | 5% | 2% | 4% | 3% | 2% | 28% |
| | July | 4% | 2% | 2% | 2% | 2% | 23% |
| | August | 5% | 3% | 1% | 2% | 2% | 17% |
| | September | 5% | 3% | 1% | 2% | 2% | 12% |

**Distributions of Delta Smelt Across Rose et al. (2013) strata: % points Difference between SMSCG scenario and Baseline**

| LOC | Month | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 |
|---|---|---|---|---|---|---|---|
| Sac | June | 0% | 0% | 0% | 0% | 0% | 0% |
| | July | 0% | 0% | 0% | 0% | 0% | 0% |
| | August | 0% | 0% | 0% | 0% | -1% | 0% |
| | Septembe | 0% | 0% | 0% | 0% | -1% | 0% |
| Sdelta | June | 0% | 0% | 0% | 0% | 0% | 0% |
| | July | 0% | 0% | 0% | 0% | 0% | 0% |
| | August | 0% | 0% | 0% | 0% | 0% | 0% |
| | Septembe | 0% | 0% | 0% | 0% | 0% | 0% |
| Edelta | June | 0% | 0% | 0% | 0% | 0% | 0% |
| | July | 0% | 0% | 0% | 0% | 0% | 0% |
| | August | 0% | 0% | 0% | 0% | 0% | 0% |
| | Septembe | 0% | 0% | 0% | 0% | 0% | 0% |
| LowSac | June | 0% | 0% | 0% | 0% | 0% | 0% |
| | July | 0% | -1% | -2% | 0% | -1% | 0% |
| | August | 0% | -1% | -2% | 0% | -1% | 0% |
| | Septembe | 0% | -1% | -2% | 0% | -2% | 0% |
| LowSJ | June | 0% | 0% | 0% | 0% | 0% | 0% |
| | July | 0% | 0% | 0% | 0% | 0% | 0% |
| | August | 0% | 0% | 0% | 0% | 0% | 0% |
| | Septembe | 0% | 0% | 0% | 0% | 0% | 0% |
| Conf | June | 0% | 0% | 0% | 0% | 0% | 0% |
| | July | 0% | 0% | -1% | 0% | -1% | 0% |
| | August | 0% | 0% | -1% | 0% | -1% | 0% |
| | Septembe | 0% | 0% | -1% | 0% | -1% | 0% |
| SE Suisun | June | 0% | 0% | 0% | 0% | 0% | 0% |
| | July | 0% | 0% | 0% | 0% | 0% | 0% |
| | August | 0% | 0% | 0% | 0% | 0% | 0% |
| | Septembe | 0% | 0% | 0% | 0% | 0% | 0% |
| NE Suisun | June | 0% | 0% | 0% | 0% | 0% | 0% |
| | July | 0% | 0% | 0% | 0% | 0% | 0% |
| | August | 0% | 0% | 0% | 0% | 0% | 0% |
| | Septembe | 0% | 0% | 0% | 0% | 0% | 0% |
| Marsh | June | 0% | 0% | 0% | 0% | 0% | 0% |
| | July | 0% | 2% | 3% | 0% | 2% | 0% |
| | August | 0% | 2% | 4% | 0% | 4% | 0% |
| | Septembe | 0% | 2% | 4% | 0% | 5% | 0% |
| SW Suisun | June | 0% | 0% | 0% | 0% | 0% | 0% |
| | July | 0% | 0% | 0% | 0% | 0% | 0% |
| | August | 0% | 0% | 0% | 0% | 0% | 0% |
| | Septembe | 0% | 0% | 0% | 0% | 0% | 0% |
| NW Suisun | June | 0% | 0% | 0% | 0% | 0% | 0% |
| | July | 0% | 0% | 0% | 0% | 0% | 0% |
| | August | 0% | 0% | 0% | 0% | 0% | 0% |
| | Septembe | 0% | 0% | 0% | 0% | 0% | 0% |

## 4.3 Implementation

Potential activities under this action are subject to legal and regulatory constraints too numerous to list here, but to which the designers of this action must be fully familiar. Key examples relevant to initial planning include the following:

- The gates are operated by the CA Department of Water Resources (Suisun Marsh Program). A contractual agreement between DWR and landowners in and around Suisun Marsh allows for operating the SMSCG between October and May *only when needed to meet Suisun Marsh salinity standards.* Otherwise, the gates must be left open. For this action to move forward, it will be necessary for this constraint to be renegotiated.
- US Army Corp of Engineers would need to issue permits.
- The spatial scope of a potential adaptive management plan is entirely within an area designated as critical habitat for Delta Smelt under the federal ESA and there are restrictions on experimental take of Delta Smelt. It will be critical to fully explore and define this constraint prior to the development of experimental design.
- Salinity targets in the Delta must be met and if salinity changes in the Delta, it will need to be mitigated (however these are assumed to be negligible – see "Neighbors" above).

## 4.4 Original Action in Resiliency Strategy and Updates

**Summary of Action:** DWR will operate the Suisun Marsh Salinity Control Gates to reduce salinity in the Suisun Marsh during summer months. This management action may attract Delta Smelt into the high-quality Suisun Marsh habitat and reduce their use of the less food-rich Suisun Bay habitat. This management action would need to be monitored closely to ensure it does not result in unintended salinity changes in Suisun Bay and the confluence area.

**Update:** State Water Contractors, which represents the water districts that take delivery of water from the State Water Project, have prepared an adaptive management plan on the reoperation of the gates, which restrict the flow of higher salinity water from Grizzly Bay into Montezuma Slough during incoming tides and retain lower salinity Sacramento River water from the previous ebb tide. DWR has also initiated a feasibility study that includes engineering, modeling, and permitting evaluations. Pilot reoperation is proposed for summer 2018.

**Linkage to Conceptual Models**: This management action is proposed as an alternative to the Summer Outflow Augmentation action described above and would benefit juvenile and sub-adult life stages. The primary Habitat Attribute that would be affected is Food Availability.

## 4.5 References


Bever, A.J., MacWilliams, M.L, Herbold, B., Brown, L.R., and Feyrer, F.D. 2016. Linking hydrodynamic complexity to Delta Smelt (*Hypomesus transpacificus*) distribution in the San Francisco Estuary, USA. San Francisco Estuary and Watershed Science, 14(1): Article 3.

Enright, C. 2008. Suisun Marsh Salinity Control Gate: Purpose, Operation, and Hydrodynamics/Salinity Transport Effect. CWEMF presentation.

Sommer, T. and Mejia, F. 2013. A place to call home: A synthesis of Delta Smelt habitat in the Upper San Francisco Estuary. San Francisco Estuary and Watersehd Science, 11(2).

Sommer, T. Aug 4, 2017. Personal communication.

# 5 Sediment Supplementation in the Low Salinity Zone

## 5.1 Action Summary

Delta smelt have shown a preference for low salinity and turbid water during their juvenile, sub-adult and pre-spawning life stages (add best reference). However, low salinity areas in the Delta do not always overlap with turbid areas of the Delta. Generally, Suisun Bay and the Western Delta are more naturally turbid than the eastern areas of the Delta. In below normal water years, when the LSZ has low overlap with areas that have naturally high turbidity (e.g. water year 2010), this action aims to increase the overlap of low salinity zones with turbid zones by adding sediment to increase turbidity in the low salinity zone.

**Table 24: Scale of action under the Resiliency Strategy and full build out scale scenario**

| Resiliency Strategy Scale | Full Build Out Scale | Scaling Criteria and Reference for Full Build Out |
|---|---|---|
| • No scale specified<br>• Feasibility study undertaken | • In years when the LSZ has low overlap with areas that have naturally high turbidity (e.g. water year 2010), add sediment to the LSZ to increase turbidity by approximately **10 nephelometric turbidity units (NTU)** between Emmaton and Mallard Island for the period between **May 1 and Sept. 30**.<br>• Assume sediment is supplemented in the manner described in MacWilliams and Bever (2017) for a total sediment input of 1.08 million kg per day or 165.24 million kg total for the period between May 1 and Sept. 30 (153 days) to meet the 10 NTU target. This would be approximately 3,552 cubic yards[3] of sediment per day or a total of 543,000 cubic yards for that period (MacWilliams and Bever, 2017). | • A rule of thumb is that Delta Smelt prefer turbidity above 10 NTU and below 60-80 NTU. (TWG call, Nov. 9, 2017) |

[3] The average dump truck holds anywhere from 10 to 14 cubic yards of sediment. At 14 cy per dump truck, supplying 3,552 cy/day of sediment would require 254 dump truck trips per day.

## 5.2 Influence Diagram

**Figure 20: Influence diagram for the sediment supplementation action.**

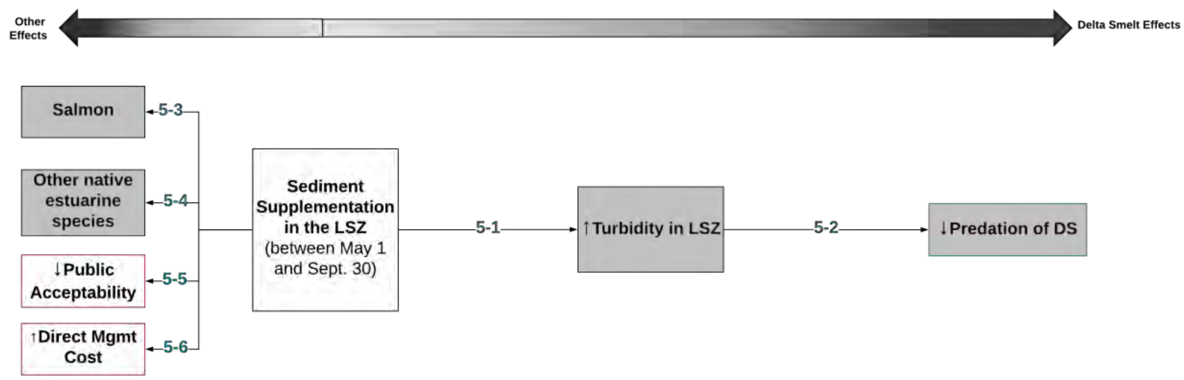



**Table 25: Effect hypotheses for the sediment supplementation action to be assessed in SDM analysis.**

| # | Effect Hypothesis | Estimation Method |
|---|---|---|
| ***Delta Smelt*** | | |
| 5-1 | **Sediment Supplementation in LSZ → Increased turbidity in LSZ.** | **Rose BEM modeling method:** Use modeling results from MacWilliams and Bever (2017) to characterize increased turbidity levels from the addition of 1.08 million kg per day in model years 2001, 2002 and 2004 (drier years). No changes to turbidity levels were made for model years 2000, 2003 and 2005 (wetter years). |
| 5-2 | **Increased turbidity → Decreased predation**<br>Ferrari et al. (2014) finds that turbidity probably assists delta smelt in avoiding predators. | **Rose BEM modeling method:** Use Ferrari et al. (2014) relationship to alter the natural mortality parameter in the model such that it is scaled to turbidity.<br>**Assumption for modeling:**<br>• 0 to 10 NTU, no change to natural mortality parameter;<br>• 10 NTU to 20 NTU: mortality decreases linearly where at 10 NTU, mortality is 100% of base model natural mortality parameter and at 20 NTU, mortality is 67% of the base model natural mortality parameter<br>• 20 NTU and above: mortality is 67% of base model value. |
| N/A | **Increased turbidity → Increased food visibility for DS larvae**<br>Studies have shown that Delta Smelt larvae need turbidity to see their prey (Baskerville-Bridges et al., 2004; Hasenbein et al., 2016; Moyle et al., 2016). However, no studies show this relationship for adult and juvenile DS. | **Pathway excluded from analysis:** This action may provide some benefits for food visibility for post-larvae in May, but the majority of this action from June to September would not provide benefits for food visibility (according to currently available information that have not found a food visibility benefit of turbidity for DS juveniles and adults). |

| # | Effect Hypothesis | Estimation Method |
|---|---|---|
| ***Other Ecological Endpoints*** | | |
| 5-3 | **Increased turbidity → Salmon.**<br>Notes from discussion with B. Cavallo (July 27, 2017)<br>• A benefit of increased turbidity to juvenile salmon in the Delta is reduced predation risk.<br>• Management actions for Delta Smelt may have implications for juvenile salmon if the effects of these actions align with juvenile salmon use of the San Francisco Estuary in the period from December to June. | The effects of this action on this pathway are scored by the Technical Working Group, Brett Harvey and Brad Cavallo using a constructed scale to qualitatively describe their opinion on the effects of this action to salmon. |
| 5-4 | **Increased turbidity → Other native estuarine species** | The effects of this action on this pathway are scored by the Technical Working Group using a constructed scale to qualitatively describe their consensus opinion on the effects of this action to other native estuarine species. |
| ***Socio-economic Considerations*** | | |
| 5-5 | **Public acceptability**<br>The TWG has advised that any action where substances are added to the water typically raise significant public concerns – for e.g. around the cleanliness of the sediment and the perception of "dumping" sediment into the Delta. | The effects of this action will be scored using a constructed scale for "Expected level of local public acceptance with no new information or outreach to explain benefits and management of risks". |
| ***Resources Required*** | | |
| 5-6 | **Direct Management Costs** | CAMT (2017) estimates the annual cost of the action at $8 Million, given a reduction in the amount of sediment supplemented in MacWilliams and Bever (2017) by 20%. |

## 5.3 Implementation

The following factors are challenges for the implementation of this action:

- A source of sediment at this scale has not yet been identified. (CAMT, 2017)
- Significant permitting hurdles would have to be overcome (e.g. Discharge permit) (CAMT, 2017)

## 5.4 Original Action in Resiliency Strategy and Updates

**Summary of Action:** DWR will assess the feasibility of sediment supplementation in the LSZ to promote turbidity corresponding to outflow actions (described above for Outflow Augmentation). If this management action is determined to be feasible, DWR will implement sediment supplementation activities in 2017 and 2018 as a pilot project to evaluate its effectiveness and its potential as a long-term management program.

**Update:** The State Water Contractors evaluated whether sediment supplementation was a feasible action to effectively increase turbidity in the low-salinity zone. Modeling was done to assess whether sediment supplementation is feasible, what magnitude of supplementation would be required in order to affect turbidity, and the spatial and temporal extent to which sediment supplementation would affect turbidity. Results are under review. If this action is determined to be technically feasible, next steps include assessing the feasibility of permitting and implementation.

**Linkage to Conceptual Models:** This management action would benefit all life stages and the primary Environmental Driver that would be affected is Turbidity.

## 5.5 Additional Background

**Figure 21: Predicted Average Turbidity Increase of Sediment Supplementation During June (MacWilliams and Bever, 2017)**

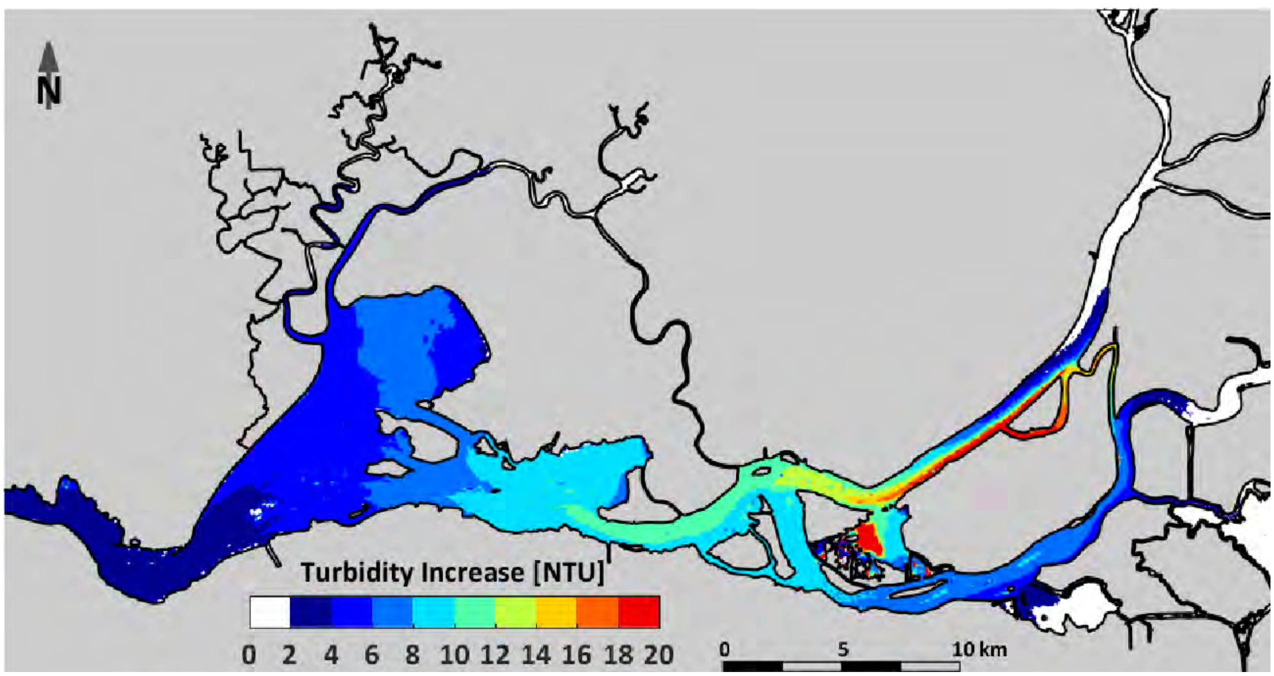


Figure 22: Predicted Average Turbidity Increase of Sediment Supplementation During July (MacWilliams and Bever, 2017)

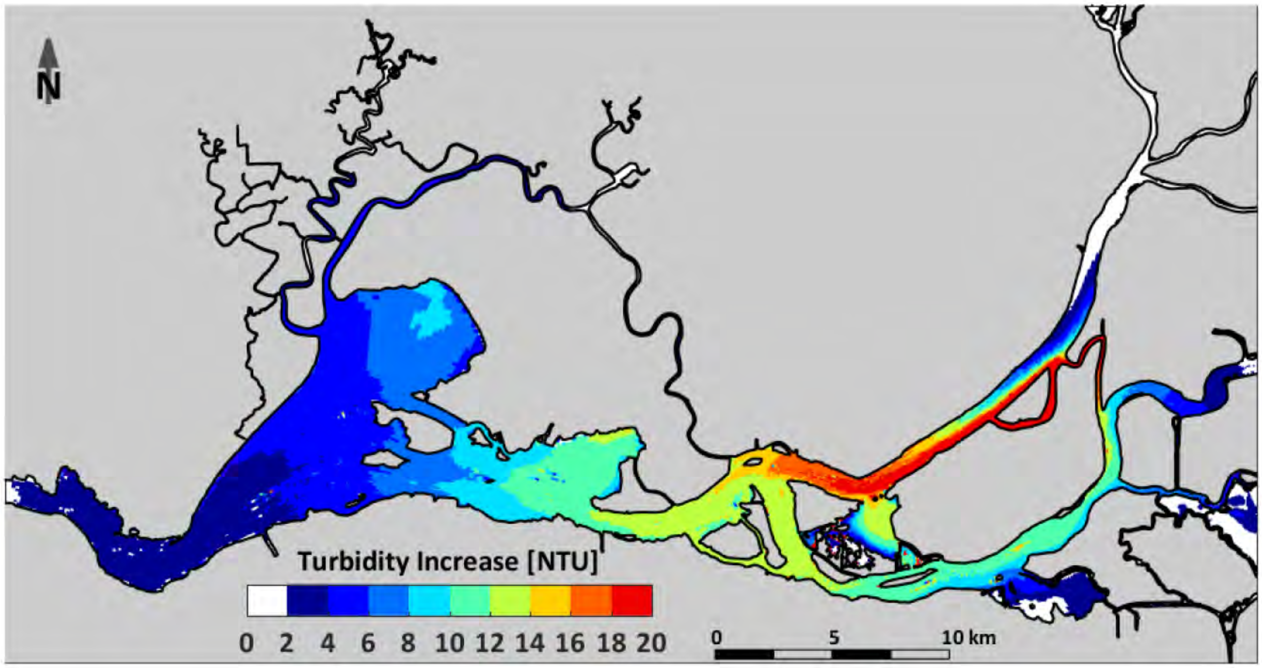



Figure 23: Predicted Average Turbidity Increase of Sediment Supplementation During August (MacWilliams and Bever, 2017)

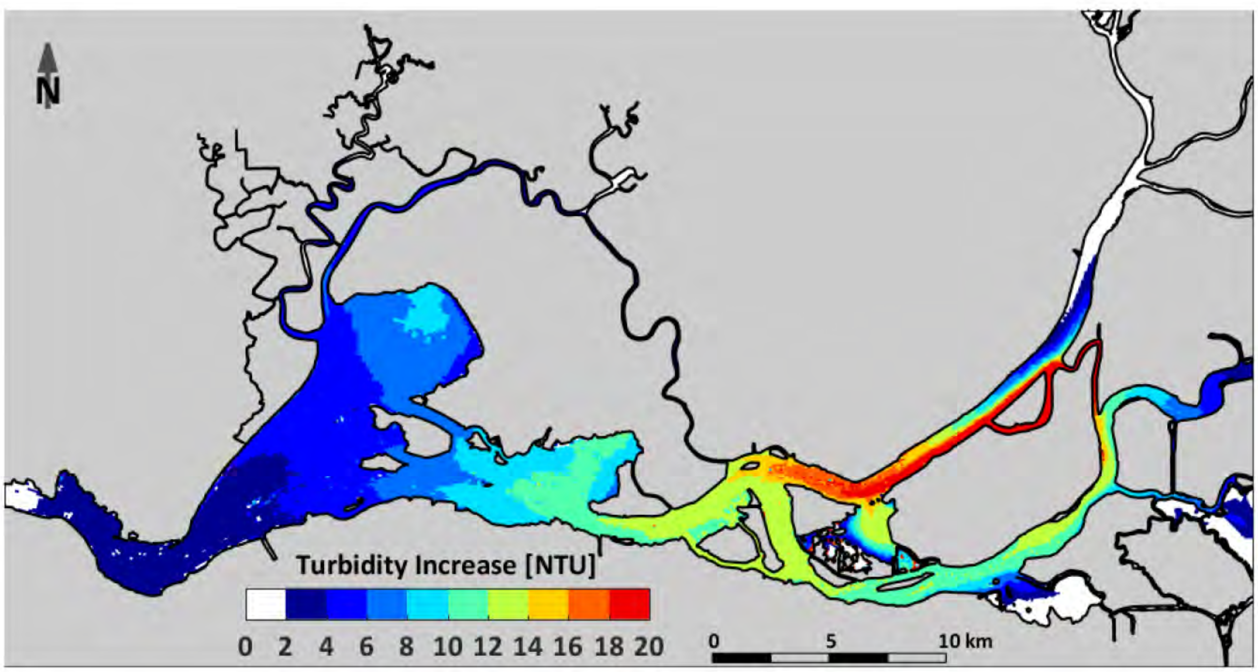
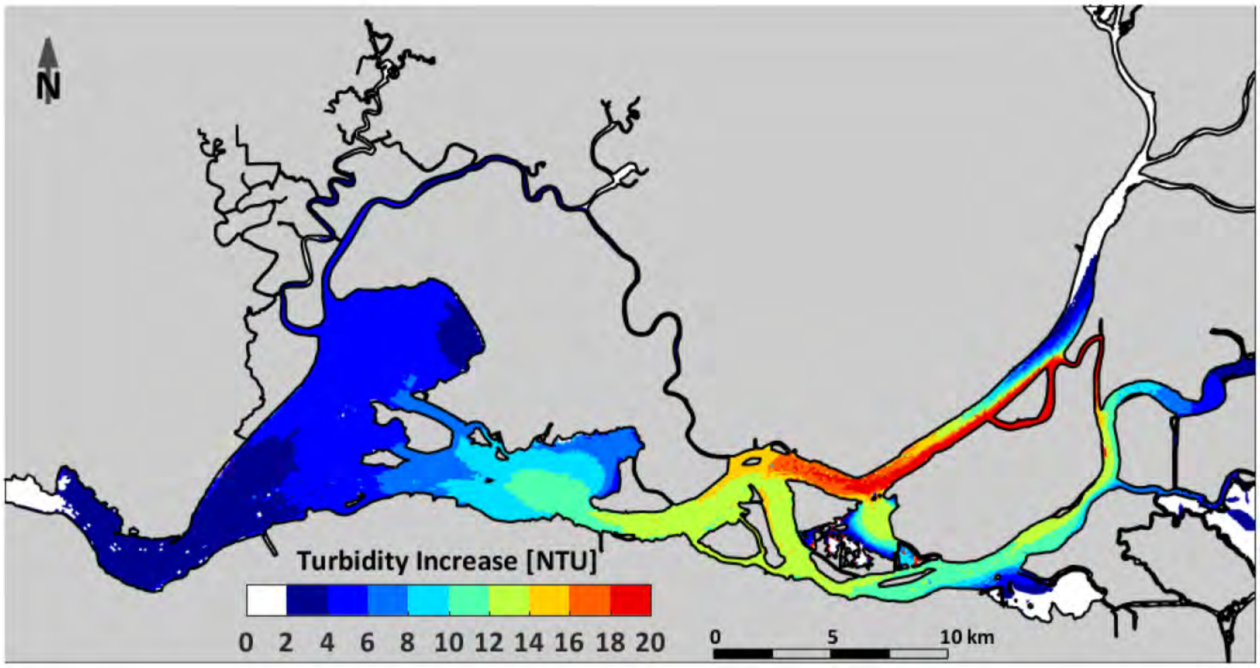


**Figure 24: Predicted Average Turbidity Increase of Sediment Supplementation During September (MacWilliams and Bever, 2017)**




## 5.6 References

CAMT, (2017). *Sediment Supplementation Action Initial Analysis.* Presentation to the Collaborative Adaptive Management Team, February, 21, 2017.

MacWilliams and Bever, (2017). Michael MacWilliams, Ph.D. P.E., and Aaron Bever, Ph.D., Anchor QEA. *Draft Memorandum: Evaluation of Sediment Supplementation in the Low Salinity Zone.* January 23, 2017.

# 6 Spawning Habitat Augmentation

## 6.1 Action Summary

The Resiliency Strategy calls on DWR to evaluate the availability of suitable spawning substrates in Suisun Marsh and Cache Slough, and if necessary, introduce sand in areas where pre-spawning adults have been found in higher densities. The Delta Science Program (Scott Brandl) was tasked with developing a map of substrates in the Delta to provide information on whether certain types of substrates (esp. sandy substrates) were limiting. Available studies were gathered to develop this map but it was determined that a map could not be created because of the high level of variability of substrates for a given location both within a year and between years (pers. comm. S. Brandl, Aug. 16, 2017).

The TWG decided to not include this action in the structured decision making analysis as it is largely complete with the conclusion of the substrate mapping exercise and no one seems to be supportive of the idea of introducing sand to augment spawning habitat.

A variation of this Resiliency Strategy action has been proposed by Jim Hobbs that involves pulling out invasive arundo in the sandy shoal areas of the Lower Sacramento. The rationale for this action is as follows (pers. comm. S. Brandl, Aug. 16, 2017; Hobbs, 2017):

- We are fairly certain DS are spawning in the Lower Sacramento - between Rio Vista and the confluence and there's sandy shoals there that have been covered up by arundo.
- Uncovering existing sandy shoals rather than adding sand is thought to be preferable for several reasons: (1) more likely to be appropriate spawning material for Delta Smelt; (2) more likely that this sand will remain in the same location (3) easier to permit.

## 6.2 Influence Diagram

**Figure 25: Influence diagram for uncovering sandy shoals to increase spawning substrate**


**Table 26: Effect hypotheses for the spawning habitat augmentation action**

| # | Effect Hypothesis |
|---|---|
| 6-1 | **Uncover sandy shoals → Increase potential spawning substrates**<br>The hypothesis supporting this action is that uncovering sandy shoals will increase spawning substrates. There is limited evidence to support this hypothesis. As of August 2017, Delta Smelt biologists working on spawning have still not been able to identify what Delta Smelt use as spawning substrates. The best guess is that they spawn on sandy shoals, but there have not been any direct observations of this. Based on where they observe spawning adults and larvae, there is knowledge of general spawning areas, but this knowledge is not enough to identify spawning substrates. In laboratory studies, Delta Smelt have avoided spawning on rip rap gravel (pers. comm. S. Brandl, Aug. 16, 2017). |
| 6-2 | **More sandy shoals in Delta (possible spawning substrates) → DS eggs**<br>Since it is not known if spawning substrates are limiting, if sandy shoals are made more available in the Delta, incremental increase in eggs could be zero or above zero. It is unlikely that augmenting substrates would lead to an incremental decrease in eggs – i.e. harming DS is unlikely through this action (pers. comm. S. Brandl, Aug. 16, 2017). |

## 6.3 Original Action in Resiliency Strategy and Updates

**Linkage to Conceptual Models:** The CMs do not include spawning substrates; however, spawning substrate is a component of the USFWS-designated critical habitat for Delta Smelt. Therefore, this management action could benefit spawning adults and eggs.

**Summary of Action:** DWR will evaluate the availability of suitable spawning substrates in Suisun Marsh and Cache Slough in 2016. If suitable substrate is determined to be absent or limiting, DWR will introduce sand and other likely-favored spawning substrates in key areas of Suisun Marsh and Cache Slough (i.e., where pre-spawning adults have been found in higher densities than in other parts of the estuary). This management action will be monitored to assess its effectiveness.

**Update**: DWR and the Delta Science Program are compiling data on the current status of substrates in order to consider targeted supplementation of sediment.

### 6.4 References

Call with Scott Brandl, Senior Environmental Scientist, Delta Science Program/Delta Stewardship Council, Aug. 16, 2017.

Hobbs, J. “Where Do Delta Smelt Spawn and What Do They Use as Substrate? Potential Spawning Habitat in the Lower Sacramento River”. University of California Davis. Nov. 13, 2017. Document emailed to Compass by Jim Hobbs.

# 7 Roaring River Distribution System Food Production

## 7.1 Action Summary

Grizzly Bay is part of the Suisun Marsh in the western Delta, and potentially offers good delta smelt habitat. To increase smelt food production in the Grizzly Bay area, the Strategy calls on DWR to install drain gates on the western end of the Roaring River Distribution System in order to drain food-rich water from the canal into Grizzly Bay.

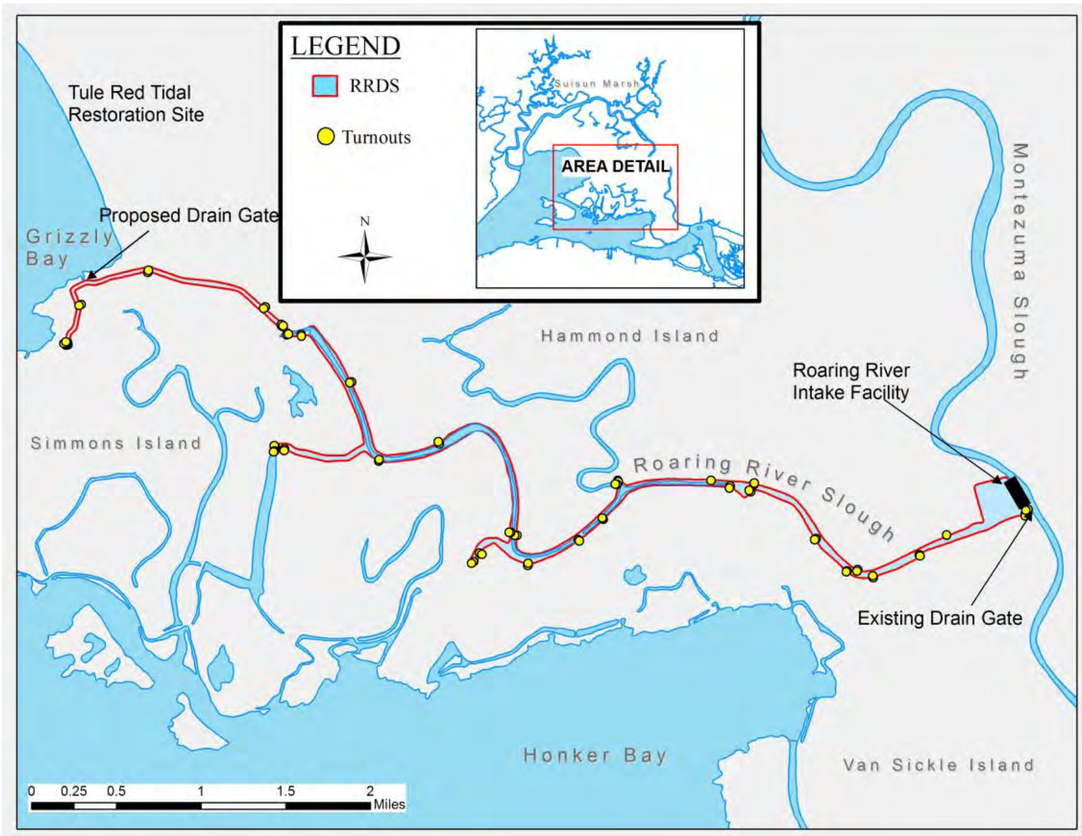
**Table 27: Scale of action under the Resiliency Strategy and full build out scale scenario**

| Resiliency Strategy Scale | Full Build Out Scale | Scaling Criteria and Reference for Full Build Out |
|---|---|---|
| Timing and duration for draining food-rich water into Grizzy Bay or Suisun Marsh is not specified in the Strategy. | **Assumed temporal and spatial scale of action:**<br>• **June 1 to Aug. 31:** Assume that RRDS could be used **100%** of the time for food production purposes.<br>• **Sept. 1 to Oct. 30:** Assume that RRDS is not available for use for food production purposes.<br>• **Nov. 1 to Feb. 28:** Assume that RRDS could be used for food production purposes **25%** of the time<br>• **March 1 to May 30:** Assume that RRDS could be used for food production purposes **75%** of the time<br>• For each time period, assume that 50% of the food rich water is drained into Montezuma Slough and 50% is drained into Grizzly Bay.<br>• RRDS has an estimated volume of 580 acre-feet.<br><br>Assume that this action is carried out in a way that meets water quality standards (e.g. BOD standards). | Best guess at the maximum amount feasible (using approximate assumptions) as recommended by Erik Loboschefsky (pers. comm, 2017). |

Roaring River Intake Facility is a conveyance facility that takes water from Montezuma Slough across Grizzly Island to the other end. Managed wetlands take water from Roaring River system because water from Montezuma Slough is fresher than water in Honker Bay or Grizzly Bay. Managed wetlands in this area are mostly owned by private duck clubs and there are also some DFW managed wetlands in this area (pers. comm, E. Loboschefsky, 2017).

The mechanism to produce food in this action is for the Roaring River Distribution System to be used as a producer of food-rich water. It would operate like a reservoir where water is brought in and retained in the system until food is produced and then food-rich water is drained out. Water could be drained through the existing drain gate into Montezuma Slough near the intake facility. A new drain gate is also planned for the west end of the Distribution System. This is a simple construction project targeted for summer 2018 that would involve excavating out the existing berm and putting in a pipe and drain gate that can be done in a few days. The Governor's proposed budget for 2017-18 includes $1 million for implementation of this project. The additional drain in the west will help convey water more quickly across the system from east to west, which will help meet duck club needs and will help foster relationships between duck clubs and DFW/DWR (pers. comm, E. Loboschefsky, 2017).

Typically, peak demand for water from the RRDS is from mid-Sept to end of October and then demand is lower from November to February. There is close to no demand for water from March to mid-September. The RRDS could be used for food production with some limitations between November to February and with no limitations between March and September (pers. comm, E. Loboschefsky, 2017).




There has not yet been monitoring within the RRDS to quantify food resources. DWR is hoping to do baseline monitoring in 2017. To estimate the food production capability of the RRDS, need to consider (pers. comm, E. Loboschefsky, 2017):

- The residence time for food production would be between 2 to 7 days. Would probably target cycling the water through every 5-6 days. Less than that and the food isn't big enough. More than that (residence time of 2-3 weeks), issues could occur with harmful algal blooms.
- The food production capability of the RRDS could be characterized by the volume of water that can be retained in the system – it is 7 miles long, 20-40 ft wide, and varies in depth. DWR calculated a total volume of the RRDS as 580 acre feet (715, 418 m3).
- The rate at which phytoplankton and zooplankton is exported from the RRDS will be determined by the volume of water discharged over a given time period, which is driven by the drainage infrastructure (# and size of drainage gates). Drainage can only occur at low tides. DWR estimated the drain speed of the RRDS as follows:
    - It takes 5 days (i.e. from 0 to 5 days) to drain the Roaring River from 4.8 ft to 3.56 ft in which the drainage volume is 256 acre-ft
    - It take another 7.4 days (i.e. from 5 to 12.4 days) to drain the Roaring River down to 2.8 ft with a total drainage volume to be 413 acre-ft
    - For another 5 days (i.e. from 12.4 to 17.4 days), the Roaring River will be lowered to 2.4 ft with a total drainage volume to be 495 acre-ft.
    - To completely drain the water from 4.8 ft to 2.0 ft takes about 30 days and total drainage volume is 580 ac-ft.

- o Note that DWR needed to make a number of assumptions for these estimates so these drain times are not precise estimates.
- In regards to whether the RRDS would be drained fully or drained half way, E. Loboschefsky notes: "Only draining it half-way during the winter and spring months when the system is still being used by the adjoining landowners would likely be a good solution for them. In doing so, I don't think it would interfere with their water delivery. If we were to drain it fully during that time it would likely interfere with their water delivery and thus create a point of conflict. During the summer months, it really isn't used much (if at all) so it probably wouldn't really matter either way. From an operational standpoint, it's probably better on the system to not fully dewater and I think the repetitive dewatering could have a negative effect on the integrity of the earthen embankments that line the system."
- Food could be exported through the eastern gate into Montezuma Slough and this food would move downstream. Food could also be exported through the planned western gate into Grizzly Bay.

Other notes:

- RRDS is a screened intake facility and so appropriate approach velocity needs to be maintained to protect fish as a standard operating procedure (pers. comm, E. Loboschefsky, 2017).
- Retaining water during the summer period will result in increased mosquito production in this area, but this area is not close to population centres. The Mosquito Abatement Program currently targets managed wetlands in the Northern area of Suisun Marsh that are closer to population centres (pers. comm, E. Loboschefsky, 2017).
- Contaminants in the RRDS could be discharged into the Estuary and may have adverse impacts. The system is under a NDPES permit and monitoring data should be evaluated when making decisions about discharge timing to reduce contaminant loading.

## 7.2 Influence Diagram

**Figure 26: Influence diagram for the Roaring River action.**

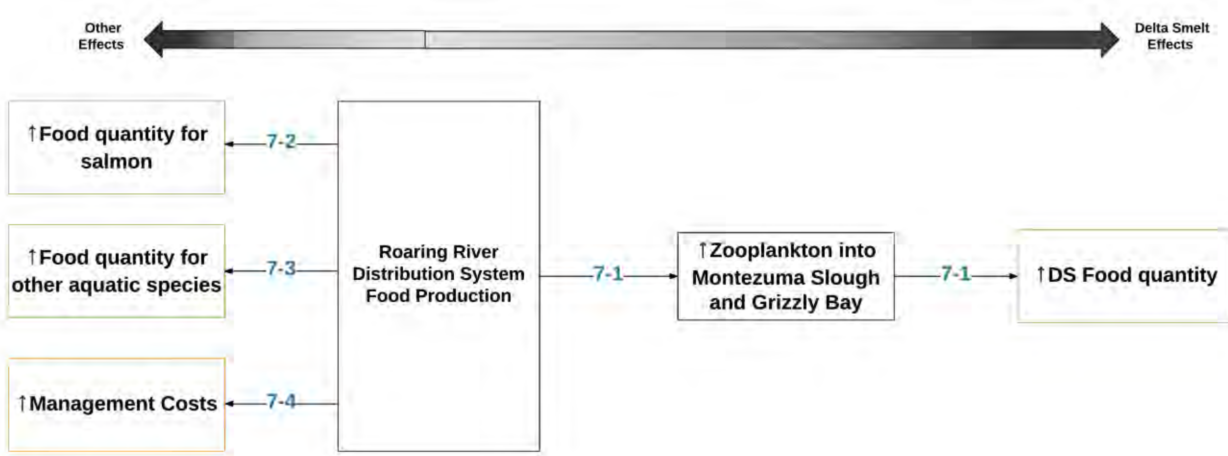



**Table 28: Effect hypotheses for the Roaring River action to be assessed in SDM analysis.**

| # | Effect Hypothesis | Estimation Method |
|---|---|---|
| 7-1 | **Increase Zooplankton → Increase in DS food availability** | **Rose BEM Modeling method:** A back of the envelope analysis was done based on advice from the TWG to estimate the zooplankton biomass that could be produced with the full build out scale of action. The baseline zooplankton density in the Rose BEM was |

| # | Effect Hypothesis | Estimation Method |
|---|---|---|
| | | increased to represent the increase in zooplankton estimated for the strata and time periods defined in the full build out scale. See Table 29 for assumed values. |
| 7-2 | **Salmon**<br>Benefits from food production. | The effects of this action on this pathway are scored by the Technical Working Group, Brett Harvey and Brad Cavallo using a constructed scale to qualitatively describe their opinion on the effects of this action to salmon. |
| 7-3 | **Other ecological endpoints**<br>Improving food supply will help other aquatic species (e.g. longfin smelt) | The effects of this action on this pathway are scored by the Technical Working Group using a constructed scale to qualitatively describe their consensus opinion on the effects of this action to other native estuarine species. |
| 7-4 | **Management Costs**<br>• $1 million for new drain gate at western end of RRDS<br>• Intake system is remotely operated<br>• Drain gates are manually operated, requiring someone to be physically at the RRDS.<br>• Additional wear and tear on intake facility an drainage gates from additional use. | Some assumptions for full build out scale:<br>• **Staff time:** 0.25 FTE for operating drainage gates and cleaning fish screens (~1-2 days per week at the upper end) (E. Loboschefsky (2017))<br>• **Infrastructure maintenance:** Assumed 10% of capital costs for new drain gate = $100,000 per year (Compass assumption). |
| ***Implementation*** | | |
| Time | This action can be implemented in the near term. The Governor's proposed budget for 2017-18 includes $1 million for implementation of this project. | |

**Table 29: Assumed % increase in zooplankton from baseline years for Roaring River action**

| Rose Model Inputs for Simulating Roaring River Distribution System Full-build out Scenario | | |
|---|---|---|
| % increase in zooplankton density from baseline | | |
| | Strata | |
| **Month** | **Marsh** | **NW Suisun Bay** |
| **June** | 14% | 22% |
| **July** | 9% | 13% |
| **August** | 4% | 6% |
| **September** | 0% | 0% |
| **October** | 0% | 0% |
| **November** | 5% | 6% |
| **December** | 6% | 13% |
| **January** | 0% | 0% |

## 7.3 Original Action in Resiliency Strategy and Updates

**Linkage to Conceptual Models:** This management action would benefit juvenile and sub-adult life stages and the primary Environmental Driver that would be affected is Food Production.

**Summary of Action:** DWR will install drain gates on the western end of the Roaring River Distribution System that can be used for most months of the year to drain food-rich water from the canal into Grizzly Bay to augment Delta Smelt food supplies in that area. This area is also adjacent to the Tule Red Restoration Project, which is proposed to begin construction in 2016 as discussed below for Near-term Delta Smelt Habitat Restoration. In addition to new drain gates, DWR will repair of the existing outfall gate/water control structure on Montezuma Slough which, in addition to a new gate onto Grizzly Bay, would further increase operational flexibility to maximize export of productivity to adjacent open water habitat used by Delta Smelt.

**Update**: The Governor's proposed budget for 2017-18 includes $1 million for implementation of this project.

## 7.4 References

Loboschefsky, Erik. 2017. Department of Water Resources. Phone call, August, 8, 2017 and email correspondence in Fall 2017.

# 8 Coordinate Managed Wetland Flood and Drain Operations in Suisun Marsh

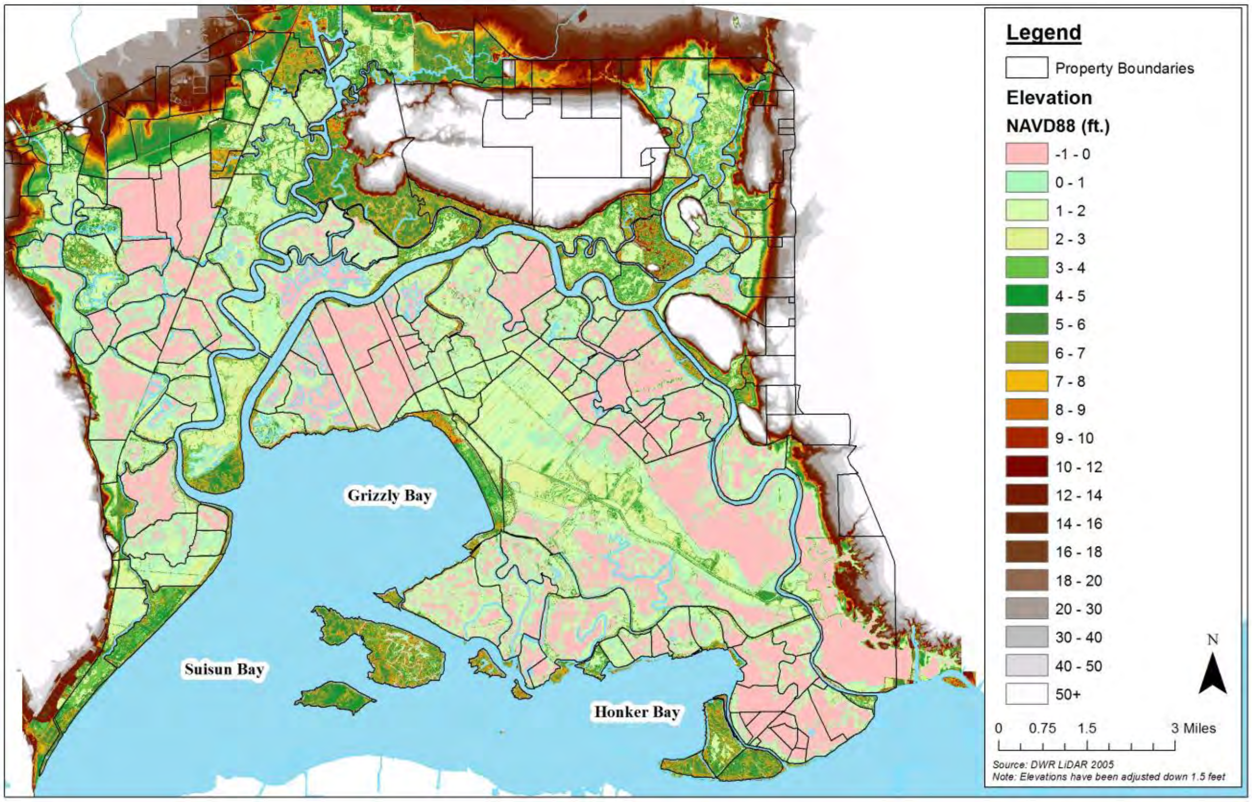
## 8.1 Action Summary

The managed wetlands of Suisun Marsh have the potential to generate the microscopic plants and animals at the base of the food chain, which could help Delta smelt. Under the Strategy, DWR will coordinate with the Suisun Resource Conservation District, the Department of Fish and Wildlife and owners and managers of private duck clubs to develop a plan for flooding and draining the managed wetlands into adjacent tidal sloughs and bays to boost food production.

**Table 30: Scale of action under the Resiliency Strategy and full build out scale scenario**

<table>
<tr><th>Resiliency Strategy Scale</th><th>Full Build Out Scale</th><th>Scaling Criteria and Reference for Full Build Out</th></tr>
<tr><td>A scale was not specified in the Strategy. E. Loboschefsky described what was envisioned in terms of a first step for implementing this action as follows:<br>• To get an incremental increase in food available for delta smelt, make slight shifts in the normal flood and drain operations for the managed wetlands that drain to areas more commonly used by Delta Smelt.<br>• This would involve getting the voluntary participation of private duck clubs to coordinate the draining of their wetlands in such a way to maximize the food value to delta smelt in the time period from Jan. 15 to Feb. 28. There are about 50 private duck clubs that have wetlands that drain to areas commonly used by delta smelt.</td><td>The maximum scale at which this action could be applied is limited by the extent to which flood and drain operations desired for delta smelt food purposes are agreeable to owners of the managed wetlands (e.g. private duck clubs, DFW).<br>For the purposes of this analysis, the Technical Working Group had to make a guess of a plausible level of participation that might be possible given outreach and incentives to owners of managed wetlands.<br>Assumed temporal and spatial scale of action:<br>• 25% of floodable acres in Suisun Marsh participate across all seasons. The location of these floodable acres would vary throughout the year and in the summer/fall would likely be located more in the eastern Marsh because of having greater access to fresh water.<br>• There are 30,000 floodable acres in Suisun Marsh (Cliff Feldheim, DWR)<br>Assume that this action is carried out in a way that meets water quality standards (e.g. through slow exchange of water rather than draining 100% of flooded wetland at once).</td><td>• Balancing maximizing benefits to delta smelt with getting participation from owners of managed wetlands (esp. private duck clubs).<br>• Involves requesting changes to normal flood and drain operations that would not produce unacceptable impacts to using the wetland for waterfowl purposes, and where impacts do occur they can be made acceptable through incentives.</td></tr>
</table>

**Figure 27: Suisun Marsh. Wetlands are pink and green in figure below, black lines identify (for the most part) individually managed wetlands. Most of these wetlands are managed by private duck clubs for overwintering waterfowl.**




Normal operations of the managed wetlands is to flood them in October, circulate the water on the site through the duck season and then drain the wetlands in late January and early February. After draining, most duck clubs engage in a series of quick flooding and draining cycles to flush accumulated salts out of the wetlands (pers. comm, E. Loboschefsky, 2017).

The result of flooding these wetlands over the duck season is that they become large 'food engines' for zooplankton, phytoplankton, and small invertebrates. When the wetlands are drained in late January/early February, this food is exported into the receiving sloughs and channels around the marsh. It is also known that reduction in Dissolved Oxygen (DO) result from these draining as well as contaminants are discharged from the ponds and are currently regulated. The hypothesis is that this food then becomes available for delta smelt and longfin smelt to feed upon. Mid-winter is a period when Delta Smelt are present in the Suisun Marsh area because salinity levels are lower at this time (pers. comm, E. Loboschefsky, 2017).

The flooding and draining of these wetlands is already coordinated at some level by the Suisun Resource Conservation District. This Resiliency Strategy action involves improving this coordination through draining the wetlands in a sequence that is hypothesized to be the best benefit to Delta Smelt. It has not yet been determined what sequence of draining the food-rich water into the surrounding area would be most beneficial to Delta Smelt. One strategy would be to prolong the draining process as much as possible to have a more stable and continuous output of food. Another strategy would be to have all wetlands drain at once and have a large spike in food available (pers. comm, E. Loboschefsky, 2017) but increase the risk of DO stress as well as contaminant loading which may prohibit this alternative.

To date, investigations have been done and are ongoing to quantify the level of productivity of the managed wetlands, including the temporal variation in productivity (Kimmerer, 2017). The idea is that through quantifying and better understanding the food production capabilities of these wetlands, methods can be developed to use the wetlands to produce incremental benefits for delta smelt. One method is to strategically improve on the normal draining operations in late January/early February to maximize food benefits for delta smelt. This would involve only a small shift to the normal drain operations (e.g. moving up or back the draining date of a wetland by a week). Another method could be to approach the owners of the managed wetlands and see if there is interest in making more significant changes in flood and drain operations, for example by doing more frequent flooding and draining throughout the duck season or at other times of the year. Spring time is the other time of year where this action might be helpful (delta smelt do not typically use Suisun Marsh in the summer). Possibly instead of having quick leach cycles after the main drain event in late January/early February, clubs could hold the water on site for long enough to produce food and reduce contaminants (pers. comm, E. Loboschefsky, 2017).

Regardless of the specific method, making incremental improvements in the food production of the wetlands for delta smelt would be dependent on the voluntary participation of the wetland owners. Providing incentives may be needed to achieve desired levels of participation. Incentives would likely need to be proportionate to the magnitude of change that is being requested from normal operations and/or how much this change is expected to impact the use of the wetland for waterfowl purposes (pers. comm, E. Loboschefsky, 2017).

At this point (as of Aug 2017), DWR and partners are still formulating a proposal for discussion with the private duck clubs. In the first phase of implementing this action, they will likely focus on getting participation from the private duck clubs that have wetlands around the major sloughs where Delta Smelt are known to use (there are about 50 of these duck clubs) (pers. comm, E. Loboschefsky, 2017).

Some possible barriers or impacts to changing normal flood and drain operations include:

- Some clubs are not able to open their flood gates after mid-February because of diversion restrictions for salmon. These clubs tend to drain in early February so that they can complete their salt leaching cycle. Higher salt concentrations in the wetland affects the growth of vegetation (duck food) for the next season. These clubs can still flood within these salmon diversion restriction windows, they just can not flood as fast (pers. comm, E. Loboschefsky, 2017).
- For the most part, most clubs fully drain their sites by late April/mid May and let the wetlands dry out so that they can do intensive vegetation management (mowing, cleaning out channels). Holding water on the wetlands for longer would delay when the site is sufficiently dry to allow for maintenance work (pers. comm, E. Loboschefsky, 2017).
- Mosquitos: Most of Suisun Marsh is subject to being treated for mosquitos if they hold water at the wrong time (need to talk to Mosquito Abatement Program for more information, e.g. what's the time period when mosquitoes are an issue and does the mosquito spray impact the food value of the water) (pers. comm, E. Loboschefsky, 2017).
- Discharge from the ponds is known to have increased Biological oxygen demand and contaminants. Therefore discharges are regulated to reduce the impacts of the contaminants and potential reduction in DO. Changing the operations would need to be sure that their permit still covers the change and that cumulative effects are evaluated as permits are usually evaluated on a discharge by discharge basis with only some consideration of what the nearby dischargers would be doing.

In support of this Resiliency Strategy action, DWR is working on doing an Infrastructure Assessment of all the clubs in the Marsh. This assessment will collect data on each managed wetland's floodable acres and the status of their flood and drain infrastructure (pipe and drain locations, diameter of pipes etc.) (pers. comm, E. Loboschefsky, 2017).

## 8.2 Influence Diagram

**Figure 28: Influence diagram for the flood and drain operations action.** **(Effect pathways in grey are not included in SDM analysis)**

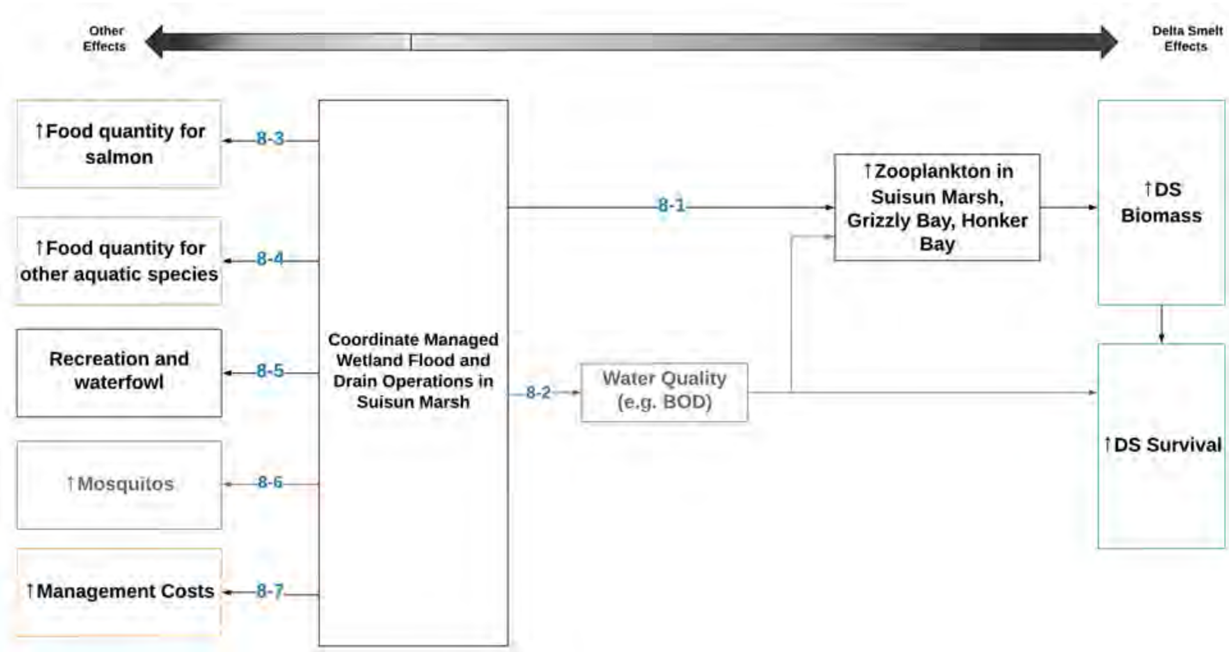



**Table 31: Effect hypotheses for the flood and drain operations action to be assessed in SDM analysis.**

| # | Effect Hypothesis | Estimation Method |
|---|---|---|
| 8-1 | **Action → Increase Zooplankton** | **Rose BEM modeling method:** John Durand (UC Davis) provided an opinion on the range of zooplankton density that could be achieved from flooding managed wetlands (pers. comm., J. Durand, Dec 2017). This opinion informed the TWG decision on what assumptions to use to simulate this action. See Table 32 below for assumed values.<br><br>Note: Wim Kimmerer also has data that from a study of zooplankton production on Joice Island in Suisun Marsh that would be relevant for estimating this pathway (Kimmerer, 2017), but W. Kimmerer was not available to provide input on this project in this timeline. |
| 8-2 | **Action → Water Quality (e.g. BOD)**<br>Flooding and draining managed wetlands will affect the water quality of receiving waters. A key concern related to water quality and this action is the effect on dissolved oxygen as well as contaminant loading in receiving waters from draining | **Pathway excluded from analysis:** We have not assessed this pathway within the SDM analysis. The full build out scale of this action assumes that this action is carried out in a way that meets water quality standards (e.g. through slow exchange of water rather than draining 100% of flooded wetland at once). If this action advances, |

| # | Effect Hypothesis | Estimation Method |
|---|---|---|
| | water with high organic content (S. Acuña, Jan 2018). | a more thorough analysis on water quality effects will be needed. |
| **8-3** | **Salmon**<br>Benefits from food production. | The effects of this action on this pathway are scored by the Technical Working Group, Brett Harvey and Brad Cavallo using a constructed scale to qualitatively describe their opinion on the effects of this action to salmon. |
| **8-4** | **Effects to other native estuarine species**<br>Improving food supply will help other aquatic species (e.g. longfin smelt) | The effects of this action on this pathway are scored by the Technical Working Group using a constructed scale to qualitatively describe their consensus opinion on the effects of this action to other native estuarine species. |
| **8-5** | **Recreation and Waterfowl**<br>E. Loboschefsky does not know if/how changing operations during the winter time on the wetlands would impact waterfowl. If water is retained on the wetlands in the spring time this could be a benefit for waterfowl because they become brood ponds for waterfowl (a few clubs already hold water in the spring time for brood ponds). | Since the action would require the willing participation of the private duck clubs that own/manage the wetlands, assume that there is no recreational loss to these duck clubs for the SDM analysis (Compass judgement). |
| **8-6** | **Mosquitos**<br>Retention of water in the wetlands can lead to increased mosquitos during the mosquito breeding season (summer and fall). Mosquitos are more of a problem in managed wetlands that are located nearer to urban areas. | **Pathway excluded from analysis:** This pathway was not included in the SDM analysis. If this action is implemented, mosquitos could be a constraining factor on where and when managed wetlands are flooded. However, mitigation opportunities may also be available. S. Hamilton has noted that mosquito fish have been used effectively in other managed wetlands to manage mosquitos (pers. comm., S. Hamilton, Jan. 5, 2017). |
| **8-7** | **Direct Management Costs**<br>• Coordination – the action would require more people on the ground to ensure coordination is happening.<br>• Infrastructure improvements to optimize the effectiveness of the flooding and draining operations for food production.<br>• Financial incentives for duck clubs to participate if significant deviations from normal operations are desired or to offset costs to duck clubs.<br>• Costs to doing these additional floods for duck clubs include getting unwanted | Cost assumptions for full build out scale:<br>• Coordination costs: 1 FTE ($100,000/year) (Compass assumption)<br>• Infrastructure costs: $10 million (Compass assumption)<br>• Operating and Maintenance: $20/acre-foot of water flooded and drained (assumption by S. Hamilton)<br>• Incentive to get managed wetlands on board for more significant changes could be in the order of $3-$5/floodable acre. Some of this incentive would compensate private duck clubs for increased management costs from |

| # | Effect Hypothesis | Estimation Method |
|---|---|---|
| | species (like cattails) that duck clubs would then need to spend time/money removing, plus potential reduction of food for ducks (C. Feldheim, 2017)<br>• Funding for this action would come from government funding and a potential partnership with the Delta Conservancy (C. Feldheim, 2017) | changed operations (initial guess by E. Loboschefsky). |

**Table 32: Assumed % increase in zooplankton from baseline years for managed wetlands action**

| % increase in zooplankton biomass density from baseline | | |
|---|---|---|
| | Strata | |
| Month | Marsh | NW Suisun Bay |
| June | 1400% | 2000% |
| July | 850% | 1250% |
| August | 400% | 600% |
| September | 700% | 850% |
| October | 650% | 800% |
| November | 900% | 1125% |
| December | 1150% | 2500% |
| January | 1750% | 3800% |

## 8.3 Original Action in Resiliency Strategy and Updates

**Summary of Action:** Based on the findings of a current study on Joice Island, DWR will coordinate with the Suisun Resource Conservation District and DFW to develop a management plan for managed wetland flood and drain operations that can promote food export from the managed wetlands to adjacent tidal sloughs and bays.

**Update**: DWR and San Francisco State University are in the midst of a field evaluation of the food web effects of such an approach. They are adding transmitters to 7 different species of waterfowl to evaluate the effects of these additional drain events on the food web and on waterfowl.

DWR is also doing an inventory on water management infrastructure. Right now, the fastest any duck club can release water is 30 days (Feldheim, 2017).

**Linkage to Conceptual Models:** This management action would benefit all life stages and the primary Environmental Driver that would be affected is Contaminants and the Habitat Attribute that would be affected in Food.

## 8.4 References


Durand, John. 2017. Personal communication, December 2017 (phone and email).

Feldheim, Cliff. 2017. Personal communication, November 17, 2017.

Kimmerer, Wim. 2017. "Investigating plankton production and export from shallow areas in Suisun Bay". Presentation. (As of Aug. 8, 2017 report is not available yet – this is the Joice Island study referenced in Resiliency Strategy)

Loboschefsky, Erik. 2017. Phone call, August 8, 2017.

# 9 Adjust Fish Salvage Operations during Summer and Fall

## 9.1 Action Summary

This Resiliency Strategy action involves adjusting summer fish salvage operations at the California's State Water Project (SWP) and Central Valley Project (CVP) export facilities. The purpose of this action is to reduce the numbers of predators and competitors for delta smelt. The SWP and CVP export facilities, operated by California Department of Water Resources and U.S. Bureau of Reclamation respectively, divert water from the Sacramento-San Joaquin Delta (Delta) for agricultural and urban uses. To minimize impacts on fish at these pumping facilities, fish collection facilities were constructed at both sites so that entrained fish can be collected and returned into the Delta (hence, fish are "salvaged"). CNRA (2016) proposed that the California Department of Water Resources and the U.S. Bureau of Reclamation evaluate a potential change in these operations. Specifically, the CNRA suggested that the water agencies should consider the feasibility of not returning salvaged non-native fish back into the Delta during the summer and fall, when few native or sensitive species are present. The removal of these non-native fishes from the Delta is presumed to be beneficial to delta smelt because non-native fish species can be competitors and/or predators of delta smelt (Mahardja and Sommer, 2017).

**Table 33: Scale of action under the Resiliency Strategy and full build out scale scenario**

| Resiliency Strategy Scale | Full Build Out Scale | Scaling Criteria and Reference for Full Build Out |
|---|---|---|
| • During summer, non-native salvaged fish will not be returned to Delta.<br>• Normal fish salvage operations will resume when monitoring indicates that juvenile Chinook salmon and steelhead are entering the Delta in the fall. | • Same as Resiliency Strategy scale – all non-native fish would not be returned during a three month period (July 1 to September 30). | • Maximum feasible scale within windows that will not cause potential impacts for juvenile Chinook salmon and steelhead. |

## 9.2 Influence Diagram

**Figure 29: Influence diagram for the fish salvage operations action.**

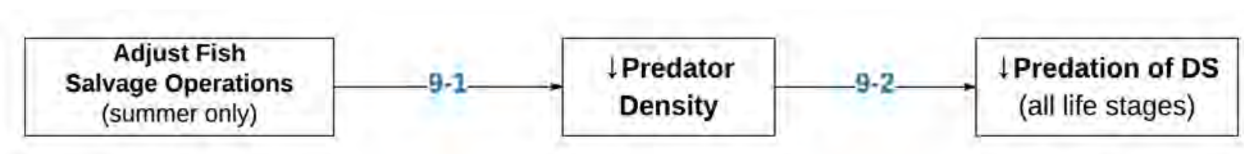



**Table 34: Effect hypotheses for the fish salvage operations action to be assessed in SDM analysis.**

| # | Effect Hypothesis | Effect Characterization |
|---|---|---|
| 9-1 | **Adjust fish salvage operations from July to September → lower predator density** | The Mahardja and Sommer (2017) analysis estimated the amount of non-native fish biomass that could be removed from undertaking this action from July 1 to Sept. 30 and found that this biomass was less than 1% of Striped Bass biomass estimates. |

| # | Effect Hypothesis | Effect Characterization |
|---|---|---|
| | | The Mahardja and Sommer (2017) analysis concludes that "it appears **unlikely** that the fish removal action will have population-level impact for the non-native fish species".<br>They had the following qualifications on this conclusion:<br>• A localized, beneficial impact on native fishes such as Delta Smelt remains a possibility<br>• Another non-native fish species with much smaller population size or biomass than the Striped Bass could be impacted by the fish removal effort<br>• They did not assess the potential of cumulative impact on non-native fishes from several consecutive years of removal at the salvage facilities. |
| 9-2 | **Lower predator density → lower predation of DS** | **Rose BEM modeling method:** Informed by analysis by Mahardja and Sommer (2017), we modeled a best case scenario for how this action might affect predation rate by decreasing predation rates by 1% in areas where predators would be released (in Lower San Joaquin and Lower Sacramento stratas). |
| | **Direct Management Costs** | Very limited effort has been put into thinking through how this action would be logistically completed. Mahardja and Sommer (2017) remark that "it may be expensive and logistically challenging to isolate non-native fishes from the pool of salvaged fish, particularly if an additional goal of the process is to save native fishes.".<br>T. Sommer provided a best guess at a ball-park estimate for cost as follows and emphasizes that no cost analysis has been done to back up these figures:<br>• **Capital costs:** $5 million<br>• **Operating costs:** $1 million |

## 9.3 Original Action in Resiliency Strategy and Updates

**Summary of Action:** DWR and Reclamation will adjust summer salvage operations beginning in 2016 so that non-native salvaged fish will not be returned to the Delta. Collection and counting will still occur. Normal fish salvage operations will resume when monitoring indicates that juvenile Chinook salmon and steelhead are entering the Delta in the fall. In addition, USFWS will coordinate with DFW on an outreach program to ensure recreational anglers understand the benefit of catch, without release, of fish that prey on Delta Smelt.

**Update**: DWR used historical fish data to evaluate this proposal and found that the quantity of non-native fish potentially removed would be modest compared to total predator populations in the Delta. Several logistical issues also were identified with this concept. The Bay Delta Office within DWR is currently working on predation projects and studies that could influence future actions.

**Linkage to Conceptual Models:** This management action would benefit all life stages and the primary Environmental Driver that would be affected is Predation.

## 9.4 References


Mahardja and Sommer (2017). *Evaluating potential impact of fish removal at the salvage facility as part of the Delta Smelt Resiliency Strategy*. File name "2070321 – Salvage Facility_IEP Newsletter Manuscript". Brian Mahardja (DWR) brian.mahardja@water.ca.gov; Ted Sommer (DWR) ted.sommer@water.ca.gov .

Schreier, Brian. (2016) "What have we learned about predation on Delta Smelt?", Presentation to Delta and Longfin Smelt Symposium, March 29, 2016, http://ats.ucdavis.edu/ats-video/?kpid=0_5b5wmf2b .

# 10 Stormwater Discharge Management

## 10.1 Action Summary

To reduce contaminants in the Delta, the Strategy calls for state agencies to consider funding entities such as the Sacramento Stormwater Quality Partnership and counties and cities that discharge stormwater to Delta channels.

**Table 35: Scale of action under the Resiliency Strategy and full build out scale scenario**

| Resiliency Strategy Scale | Full Build Out Scale Scenario | Scaling Criteria and Reference for Full Build Out |
|---|---|---|
| • Up to $90 million in 2017-18 budget for the State Water Resources Control Board's Storm Water Grant Program. | • Reduce urban contaminant loading into Ulatis Creek (in the Cache Slough area) during rain events by ~50% through applying stormwater management practices.<br>• Assume constructed wetlands are the stormwater management practice applied because they are the least expensive to construct and maintain (not considering land costs).<br>• Ulatis Creek watershed is 96,000 acres. Using MDT (2005) as a reference, TWG assumed that the constructed wetland would be 3% of the Ulatis Creek watershed or 2,800 acres and would require an efficiency of removing contaminants of 68%. | • Ball-park estimate for a reduction that would result in a significant local benefit to Delta Smelt.<br>• Prioritized Ulatis Creek to simplify the evaluation in the hopes of upscaling this action in future evaluations to the rest of the watersheds linked to the Delta smelt Arc.<br>• Urban contaminant loading and Cache Slough area targeted based on findings in Weston et al. (2015) that identified this as a significant source and findings in Weston et al. (2014) which found lower higher stormwater toxicity concerns in Cache Slough Complex compared to Suisun Marsh compared to Cache Slough Complex. |

## 10.2 Influence Diagram

**Figure 30: Influence diagram for the stormwater discharge management action.**

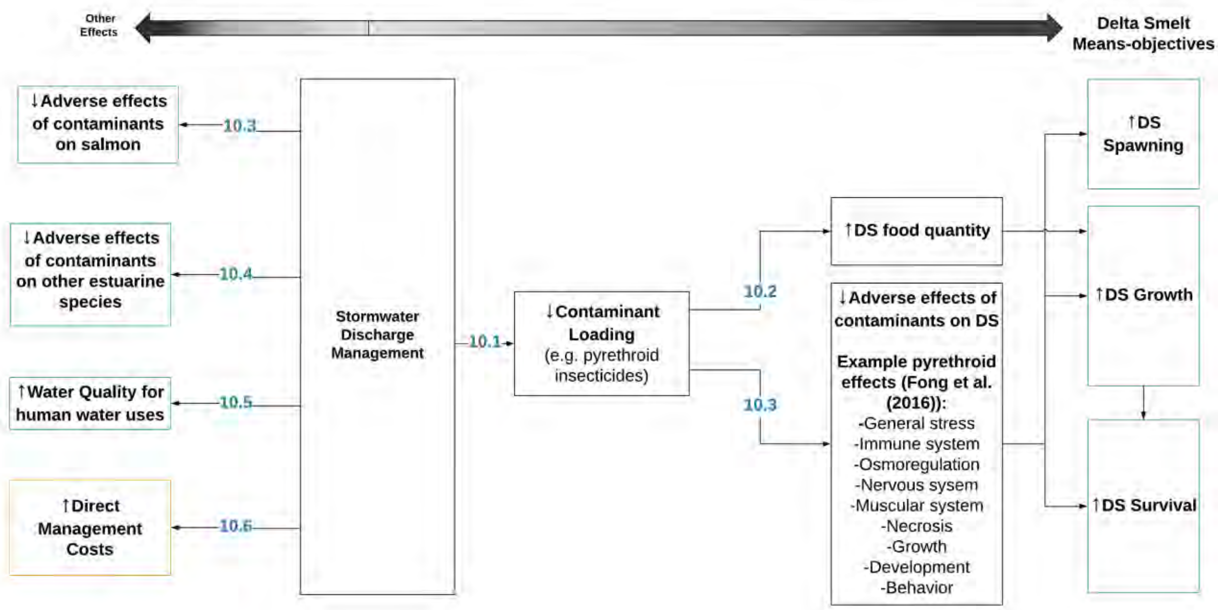



**Table 36: Effects hypotheses for the stormwater discharge management action to be assessed in SDM analysis.**

| # | Effect Hypothesis | Estimation Method |
|---|---|---|
| ***Delta Smelt*** | | |
| 10-1 | **Stormwater Discharge Management to reduce contaminant loading into Cache Slough Area**<br>In a study of urban and pesticide inputs of chlorpyrifos and pyrethroids into the Cache Slough Complex, Weston et al. (2014) finds the dominant pyrethroid source to be urban runoff entering a creek 21 km upstream of Cache Slough. The study also finds that pyrethroids of urban origin were supplemented by agricultural inputs of pyrethroids and chlorpyrifos as the creek flowed toward Cache Slough. Other contaminants were not evaluated. | Use Weston et al. (2014) and the stormwater management practices effectiveness values in MDT (2005) to determine the scale of stormwater management practices needed to reach target. |
| 10-2 | **Action → Zooplankton Density**<br>Reducing contaminant loading from stormwater is hypothesized to increase zooplankton density. | **Rose BEM Modeling method:** TWG (S. Acuña) advised on an assumption for the increased zooplankton density that could result from this action. See Table 37 below for assumed values. |
| 10-3 | **Reduced contaminant loading into Delta → Reduced adverse effects to Delta Smelt**<br>Fong et al. (2016) has been identified as a key reference for characterizing the influence of | The effects of this action on this pathway are scored by the Technical Working Group using a constructed scale to |

| # | Effect Hypothesis | Estimation Method |
|---|---|---|
| | contaminants on delta smelt. This study concludes: "Recent studies provide multiple lines of evidence that contaminants affect species of concern in the Bay–Delta (e.g., the decline of several important fish species referred to as the "Pelagic Organism Decline" or POD). Contaminants occur as dynamic complex mixtures and exert effects at multiple levels of biological organization. Multiple chemicals impair processes at cellular and physiological levels (measured as growth, development, and behavior abnormalities), and when viability and reproductive output are affected, populations are affected. As an important example, the population decline of the endangered delta smelt (*Hypomesus transpacificus*) is significantly associated with multiple stressors, including insecticide use. New analyses presented in this paper show significant correlations between pyrethroid use and declining abundance of POD fish species. Water sampled from the Bay–Delta causes multiple deleterious effects in fish, and delta smelt collected from the Bay–Delta exhibit contaminant effects. Fish prey items are also affected by contaminants; this may have an indirect effect on their populations. Co-occurrence with thermal changes or disease can exacerbate contaminant effects." | qualitatively describe their consensus opinion on the effects of this action to:<br>(1) DS spawning/ recruitment<br>(2) DS resiliency to random events<br>TWG discussion on this pathway (Nov. 13, 2017):<br>• Decided to not model the sub-lethal effects to Delta Smelt from contaminants which would affect growth and survival, and that increasing zooplankton as a result of stormwater management can be considered somewhat of a proxy for modeling these sub-lethal effects to DS.<br>• Discussed that some fish show avoidance behaviour to higher toxicity areas. Also discussed that by Jan/Feb, Delta Smelt are not growing very much as they are entering spawning season.<br>• Discussed possible benefits of stormwater management at the larvae stage (larvae would be more vulnerable to increased contaminant loading as they can not move away from higher toxicity areas).<br>• Discussed that it would be the larvae in March that are more exposed to large storm events (as opposed to the larvae present in April/May timeframe).<br>• S. Acuña explained that there would be a benefit of stormwater management at the larvae stage – explaining that studies showed the LC50 for pesticides and delta smelt larvae is in the µg/L scale and pesticide concentrations can be in the mg/L scale during storm events. |
| ***Other Ecological Endpoints*** | | |
| 10-3 | **Reduce contaminant loading during run-off events → Benefits to salmon**<br>See Fong et al. (2016) | The effects of this action on this pathway are scored by the Technical Working Group, Brett Harvey and Brad Cavallo using a constructed scale to qualitatively |

| # | Effect Hypothesis | Estimation Method |
|---|---|---|
| | | describe their opinion on the effects of this action to salmon. |
| 10-4 | **Reduce contaminant loading during run-off events → Benefits to other estuarine species/ecosystem**<br>See Fong et al. (2016) | The effects of this action on this pathway are scored by the Technical Working Group using a constructed scale to qualitatively describe their consensus opinion on the effects of this action to other native estuarine species. |
| ***Socio-economic Considerations s*** | | |
| 10-5 | **Reduce contaminant loading during run-off events → Improvement to water quality → benefit for human water uses** | |
| ***Resources Required*** | | |
| 10-6 | **Direct Management Costs** | S. Acuña did a back-of-the envelope calculation on the cost of stormwater management in the full build out scale of this action. His analysis was based on information in MDT (2005), a reference that was recommended to him by Annalisa Kihara, Storm Water Planning Unit Chief, California Water Boards. |

**Table 37: Assumed % change in zooplankton with stormwater management action in Ulatis Creek**

| Model Year | Month | Assumed % change in zooplankton baseline for Ulatis Creek area as a result of stormwater* | Assumed% change in zooplankton baseline for Sacramento Strata as a result of stormwater entering Ulatis Creek | Assumed % change in zooplankton as a result of stormwater management in Ulatis Creek area |
|---|---|---|---|---|
| All | Dec | -0.50 | -0.05 | 0.05 |
| All | Jan | -0.50 | -0.05 | 0.05 |
| *assuming a linear relationship between contaminant loading and zooplankton survival - so 50% increase in contaminants means 50% increase in zooplankton mortality | | | | |

## 10.3 Original Action in Resiliency Strategy

**Summary of Action:** The State will provide funding to entities such as the Sacramento Stormwater Quality Partnership, and/or counties and cities whose stormwater discharges to Delta waterways under National Pollutant Discharge Elimination System Municipal Separate Storm Sewer System stormwater permits. The funding would enable the entities to implement additional actions to reduce contaminant loading in the Delta.

**Update**: The Governor’s proposed 2017-18 budget includes $90 million for the State Water Resources Control Board’s Storm Water Grant Program, which funds storm water and dry weather runoff projects that best advance the goals of improving water quality and realizing multiple benefits from the use of storm water and dry weather runoff as a resource. Local governments must apply for the funding.

**Linkage to Conceptual Models:** This management action would benefit all life stages. The Environmental Driver that would be affected is Contaminant Loading and the Habitat Attribute that would be affected is Toxicity.

### 10.4 Additional Background Context

- The Central Valley Regional Water Quality Control Board is currently establishing a control program for pyrethroid insecticides to protect Bay-Delta watershed aquatic life (Fong et al., 2016)
- Other direct effects on reproduction were not included at this time and was suggested to be evaluated in future efforts on the SDM. Contaminants such as the ubiquitous pyrethroids have been found to have reproductive effects (Brander et al 2012, 2013, 2016).

### 10.5 Key References


Brander, S. M., Connon, R. E., He, G., Hobbs, J. A., Smalling, K. L., Teh, S. J., ... & Cherr, G. N. (2013). From 'omics to otoliths: responses of an estuarine fish to endocrine disrupting compounds across biological scales. PloS one, 8(9), e74251.

Brander, S. M., Jeffries, K. M., Cole, B. J., DeCourten, B. M., White, J. W., Hasenbein, S., ... & Connon, R. E. (2016). Transcriptomic changes underlie altered egg protein production and reduced fecundity in an estuarine model fish exposed to bifenthrin. Aquatic Toxicology, 174, 247-260.

Brander, S. M., He, G., Smalling, K. L., Denison, M. S., & Cherr, G. N. (2012). The in vivo estrogenic and in vitro anti-estrogenic activity of permethrin and bifenthrin. Environmental toxicology and chemistry, 31(12), 2848-2855.

Fong et al. (2016). Stephanie Fong, Stephen Louie, Inge Werner, Jay Davis, and Richard E. Connon. "Contaminant Effects on California Bay-Delta Species and Human Health". *San Francisco Estuary and Watershed Science,* Vol. 14 (4).

MDT. (2005). Minnesota Department of Transportation. "The Cost and Effectiveness of Stormwater Management Practices", June 2005.

Weston et al. (2014). Donald P. Weston, Aundrea M. Asbell, Sarah A. Lesmeister, Swee J. The, and Michael J. Lydy. "Urban and Agricultural Pesticide Inputs to a Critical Habitat For the Threatened Delta Smelt (*Hypomesus Transpacificus*). *Environmental Toxicology and Chemistry,* Vol. 33, No. 4, pp. 920-929, 2014.

Weston et al. (2015). Donald P. Weston, Da Chen, Michael J. Lydy. "Stormwater-related transport of the insecticides bifenthrin, fipronil, imidacloprid, and chlorpyrifos into a tidal wetland, San Francisco Bay, California." *Science of The Total Environment,* Vol. 527-528, 15 Sept. 2015, Pg. 18-25.

# 11 Rio Vista Estuarine Research Station and Fish Technology Center

## 11.1 Action Summary

**Table 38: Scale of action under the Resiliency Strategy and full build out scale scenario**

| Resiliency Strategy Scale | Full Build Out Scale | Scaling Criteria and Reference for Full Build Out |
|---|---|---|
| • A new Delta field station in Rio Vista that will consolidate existing IEP delta smelt monitoring and research activities, and will include a new Fish Technology Center (FTC).<br>• The FTC will be designed to house a refuge population for delta smelt to be used for species conservation and research.<br>• Until construction, the primary activity will be to conduct technical studies to identify the potential uses of the refuge population as part of a conservation strategy for delta smelt. This information is a key data gap for a future management plan for a potential future conservation hatchery. | Construction of the Rio Vista Research Station and Fish Technology Centre as described in the Resiliency Strategy.<br><br>Note that a separate initiative to build a fish production facility at this site is currently under consideration (pers. comm., T. Sommer, Jan. 4, 2018) but for the purposes of this exercise, the full build out scale does not include the augmentation of wild populations with cultured fish. | Ted Sommer advised on full build out scale definition. |

## 11.2 Influence Diagram

**Figure 31: Influence diagram for the Rio Vista Estuarine Research Station and Fish Technology Center.**

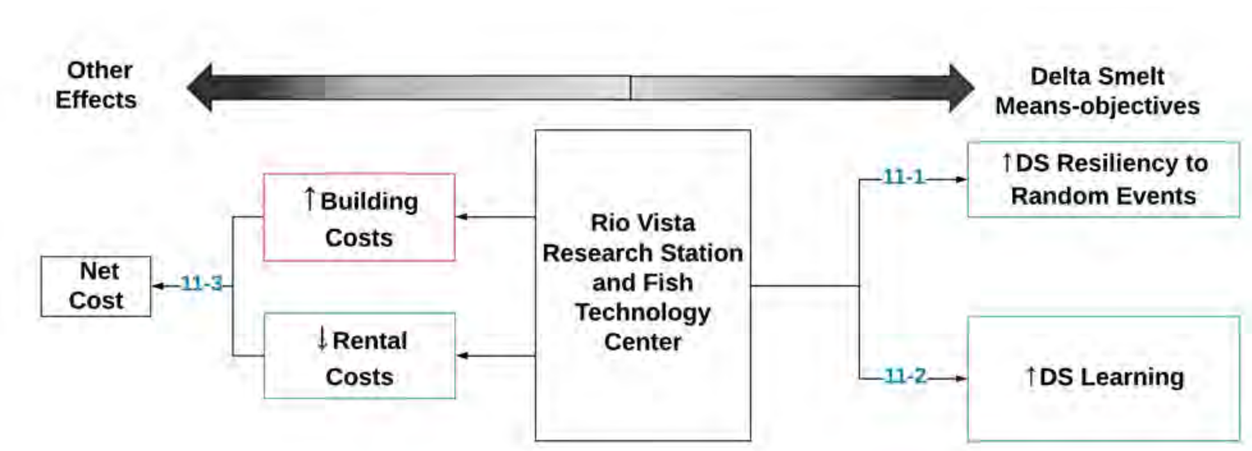



**Table 39: Effect hypotheses the Delta Smelt supplementation action to be assessed in SDM analysis.**

| # | Effect Hypothesis | Estimation Method |
|---|---|---|

| | | |
|---|---|---|
| 11-1 | **Action → DS resiliency to random events** | The effects of this action on this pathway are scored by the Technical Working Group using a constructed scale to qualitatively describe their opinion on the effects of this action to DS resiliency to random events. |
| 11-2 | **Action → DS Learning** | The effects of this action on this pathway are scored by the Technical Working Group using a constructed scale to qualitatively describe their opinion on the benefits of this action for advancing knowledge on Delta Smelt and management actions to benefit Delta Smelt. |
| 11-3 | **Action → Cost** | A cost analysis has been completed to compare two scenarios for IEP facilities:<br>*(1) Separate:* Continue operating "As Is", with each IEP member agency housed in separate leased facilities.<br>*(2) RVERS:* Aggregate IEP member agencies at the Rio Vista Estuarine Research Station (RVERS) to achieve greater collaboration and efficiency.<br>Cost analysis provided by Ted Sommer. |

## 11.3 Original Action in Resiliency Strategy and Updates

**Summary of Action:** A new Delta field station in Rio Vista that will consolidate existing IEP Delta Smelt monitoring and research activities, and will include a new Fish Technology Center (FTC) is expected to be completed in 2019. The FTC will be designed to house a refuge population for Delta Smelt to be used for species conservation and research. Until construction, the primary activity will be to conduct technical studies to identify the potential uses of the refuge population as part of a conservation strategy for Delta Smelt. This information is a key data gap for a future management plan for a potential future conservation hatchery.

**Update**: DWR and USFWS reached a significant milestone recently with the release of final environmental documents for the Rio Vista Estuarine Research Station, which will include office space, laboratories, and boat storage.

**Linkage to Conceptual Models:** This management plan would benefit all life stages. Although no specific Environmental Drivers would be affected, this management action would help guard the Delta Smelt population (Tier 1 in the MAST CM) against extinction by creating an additional refuge population.

## 11.4 Additional Background – Using Cultured Fish to Augment Wild Populations

Although the action evaluated doe not include the use of cultured fish to supplement the smelt population, the facility would provide a potential tool to support use of cultured fish for conservation. Hence, we provide background information on the current effort to support cultured fish, and some of the concerns.

As it became clear that the Delta Smelt was in severe decline, the UC Davis Fish Conservation and Culture Laboratory (FCCL) was established in 1996 at the State Water Project pumping plant in Byron, California. The purpose of the facility initially was to rear smelt in captivity for use in various experimental studies, because of their increasing unavailability in the wild. By 2004, the laboratory had the capacity to rear Delta Smelt through their entire life cycle. The program was remarkably successful in breeding a very delicate annual fish about which little was known in terms of culture (Lindberg et al. 2013). As a result, researchers had a ready supply of experimental fish. In 2008, the focus of the FCCL also became to establish a “refuge population” as a hedge against extinction in the wild. The breeding program was then set up to have strong genetic basis with reproductive success tracked for individuals and families. After starting with 2-year-old fish from the initial culture operation, wild fish were brought in every year to spawn with fish already in captivity, to enhance genetic diversity. The program has easily met its goals of having an annual spawning population of 500 fish, derived from a pool of 6,000 adults. An additional backup population was established at the Livingston Stone Hatchery below Shasta Dam.

The facility produces about 20,000 Delta smelt per year, which are used for studies in a Delta smelt refuge program, and in aquaculture, research, and collaborative programs. This Culture Lab goes to great lengths to maintain the genetic diversity of this hatchery population, including parentage analysis and pedigree reconstruction to minimize inbreeding. As a result of these efforts, UC Davis researchers have concluded that the captive Delta smelt population is currently genetically similar to the wild population. However, the longer we wait to release these fish, the more difficult it will be to maintain this diversity: the smaller the wild population, the more likely reintroduced fish will swamp their genetic diversity (FishBio, 2017).

In May 2017, a workshop held in Davis, California explored how to move from using hatchery Delta smelt in experiments to supplementing fish in the wild. The workshop was hosted by the California Department of Water Resources as part of the Delta Smelt Resiliency Strategy, and followed a previous meeting examining whether delta and longfin smelt extinction was inevitable. The extinction workshop, held in 2016, found a surprising consensus that cultured smelt should be considered part of the species recovery tool box. While hatcheries can be a useful tool, they are not without risks, such as the transfer of pathogens, competition with wild fish, disrupting natural spawning, and reducing reproductive fitness or genetic diversity. Despite these concerns, the recent hatchery workshop concluded that action on this topic is required soon, and discussed potential pathways forward. Speakers discussed the need to build consensus among stakeholders on the fundamental objectives of reintroduction as a next step for moving forward with a plan. There appears to be a reasonable consensus on the urgent need to utilize captive delta smelt, while recognizing that successful reintroduction requires a long-term commitment and thoughtful planning (FishBio, 2017).

At the May (2017) hatchery workshop, the risks in the following table were identified for a Delta Smelt hatchery program that augments wild populations.

**Table 40: Draft precautionary risk-based evaluation framework for a Delta Smelt hatchery program (developed at Delta Smelt workshop in May 2017, which discussed risks of using hatchery fish to augment populations. Provided by Ted Sommer[4]).**

| Risk type | Risk factor | Summary |
|---|---|---|
| Ecological | Interspecific interactions | Impacts of competition or predation to other components of the aquatic community and food web. |
| | Pathogen transfer | Increased incidence of disease resulting from transmission in and from the hatchery. |

[4] See Workshop Program: https://www.eventbrite.com/e/delta-smelt-culture-program-from-experiments-to-reinforcement-tickets-32329995888#

| Risk type | Risk factor | Summary |
|---|---|---|
| | Lack of suitable habitat for reintroduction | Habitat restoration efforts may not be successful or may require more time than estimated persistence for Delta smelt population. |
| | Lack of suitable spawning or early life habitat conditions | Spawning and early life habitat conditions may be unsuitable (during most/low water years?) for successful natural production or survival of stocked early life stages. |
| | Behavioral changes | Behavioral selection from hatchery rearing could result in fish adopting in-hatchery behaviors that reduce post-release growth or survival. |
| Demographic | Intraspecific interactions | Depression of wild Delta smelt survival, growth, or maturation due to competition or predation (i.e. density dependent effects). |
| | Broodstock mining | Removal to the hatchery of a significant fraction of the annual reproductive population resulting in decreases in natural recruitment in areas and years of favorable conditions. |
| | Spawner disruption | Disruption of wild spawning by simultaneous capture of wild adults for the hatchery. |
| Genetic | Loss of diversity | Low effective spawning population size resulting from use of a limited number of broodstock. |
| | Inbreeding depression | Unbalanced contribution of only a few fish to the next generation that accrues deleterious recessive traits and reduces fitness. Also result of using highly related broodstock. |
| | Selection | Directional change in genetic composition due to domestication or inadvertent selection over time in the hatchery. |
| Uncertainty | Measurement error | Uncertainty in estimates of population parameters upon which the hatchery program is scaled (survival, growth, carrying capacity, limiting factors, etc.). Uncertainty about the effectiveness of monitoring plans. |
| | Process Error | Incomplete understanding of limiting factors and population dynamics that can produce unintended consequences. |
| | Implementation error | Failure to operate the Delta smelt hatchery program in an effective and timely manner based on best available plans, information, and practices. |
| | Stakeholder engagement and buy-in | Changing political climate may impact hatchery program. Failure to build trust and engagement across stakeholders.<br><br>Insufficient program support |

As part of this project, Compass interviewed Evan Carson at FWS to get his input on the idea of augmenting DS wild populations with cultured fish. His input is summarized below (pers. comm., E. Carson, 2017):

- If augmentation of Delta smelt moves forward, need to take a **conservation based approach** that is tied to outcomes in the field and improving habitat (as opposed to an approach that continues to add fish regardless of field outcomes, and adds fish instead of improving habitat, which runs the risk of deteriorating habitat further).
- A conservation approach to augmenting fish would be to bolster a fish population so that they can either take advantage of favourable conditions or circumvent bad conditions/vulnerable life stages.
- As Delta Smelt is an annual species, their populations are particularly affected by 'bad years' – augmentation could focus on bolstering Delta Smelt population to buffer these bad years – for e.g. for a given cohort, if surveys of larvae and juveniles have returned low numbers, augmentation could happen at sub-adult/adult stage to maintain spawning levels; or if adult spawning adults are known to be low, could augment at the egg stage.
- The long-term goal of any fish augmentation and fish habitat program should be to return the population to self-sustaining levels.
- The short-term goals of any fish augmentation program should be (1) avoid extinction/extirpation (2) keep the population from getting too small and losing genetic diversity.
- Augmentation programs to learn from: Rio Grande Silvery Minnow (cautionary story of implications of a non-conservation approach) and Lake Mohave Razorback Sucker (took a conservation approach)

## 11.5 References

Carson, Evan. 2017. Personal communication, Dec. 8, 2017.

"Economic Analysis for IEP Facility Options". Author unknown. Provided by T. Sommer.

FishBio, 2017. "Hatchery Delta Smelt: Hope For the Species?", Fish Report, July 17, 2017. Downloaded from: http://fishbio.com/field-notes/the-fish-report/hatchery-delta-smelt-hope-species. Downloaded on: Aug. 18, 2017.

## 12 Near-term Delta Smelt Habitat Restoration

### 12.1 Action Summary

More than 90 percent of the Delta's original wetlands are gone. State agencies are advancing several projects to restore tidal wetlands to the western Delta, which could benefit smelt and many other species.

**Table 41: Scale of action under the Resiliency Strategy and full build out scale scenario**

| Resiliency Strategy Scale | Full Build Out Scale | Scaling Criteria and Reference for Full Build Out |
|---|---|---|
| • 11,000 acres of near-term tidal restoration projects had been committed to when the Strategy was written. Construction is targeted to begin on these projects on or before 2019 and takes 1-4 years per project.<br>• The Strategy also calls for progress under the Cal EcoRestore program which aims to restore at least 30,000 acres of tidal wetlands in the estuary. | 11,000 acres of tidal wetland restoration, mostly located in the North Delta Arc from Suisun Marsh to Cache Slough (pers. comm., C. Wilcox, Aug. 10, 2017)<br><br>As of 2017, tidal restoration sites have been identified for about 70% of the 11,000 acres. For this project, we have assumed that the other 30% of tidal wetland restoration sites would be in the Cache Slough complex based on advice from Erik Loboschefsky (DWR, pers. comm., Dec. 2017) who said this area is more likely to locate additional tidal wetlands (over and above sites currently identified) than Suisun Marsh. | 11,000 acres includes the following:<br>• 9,000 acres of EcoRestore projects. 8,000 of which are requirements for DWR under the current Biological Opinions for the State Water Project. 1,000 of which are additional projects that have been around for a long time (trying to implement for the last 10 years).<br>• 2,000 acres are proposed mitigation actions for the California WaterFix Project |

The following table shows how the tidal restoration sites are distributed across the Rose et al. (2013) model strata for the purposes of this analysis.

**Table 42: Assumed distribution of tidal wetland restoration sites across Rose Model strata for full build out scale scenario.**

<table>
<tr><th>Rose et al. Strata</th><th>Restoration Site Name or Assumption</th><th>Tidal Wetland Area (Acres)</th><th>Total Tidal Wetlands by Strata (Acres)</th></tr>
<tr><td rowspan="5">Suisun Marsh</td><td>Tule Red</td><td>610</td><td rowspan="5">2,073</td></tr>
<tr><td>Hill Slough</td><td>750</td></tr>
<tr><td>Arnold Slough</td><td>145</td></tr>
<tr><td>Bradmoor Island</td><td>488</td></tr>
<tr><td>Goat Island</td><td>80</td></tr>
<tr><td>Confluence</td><td>Winter Island</td><td>589</td><td>589</td></tr>
<tr><td>Lower Sacramento River Region</td><td>Decker Island</td><td>110</td><td>110</td></tr>
<tr><td rowspan="5">Sacramento River Region (includes Cache Slough area)</td><td>Lower Yolo Ranch</td><td>1,650</td><td rowspan="5">7,668</td></tr>
<tr><td>Prospect Island</td><td>1,500</td></tr>
<tr><td>McCormack-Williamson Tract</td><td>1,314</td></tr>
<tr><td>Lindsey Slough</td><td>228</td></tr>
<tr><td>Other Cache Slough sites not yet identified</td><td>2,976</td></tr>
<tr><td>Lower San Joaquin River Region</td><td>Dutch Slough (classified as tidal/sub-tidal, riparian forest, and managed marsh)</td><td>560</td><td>560</td></tr>
<tr><td>Total</td><td colspan="3">11,000</td></tr>
</table>

## 12.2 Influence Diagram

**Figure 32: Influence diagram for the habitat restoration action** (DS effects pathways in grey are not included in Rose BEM modeling)**.**

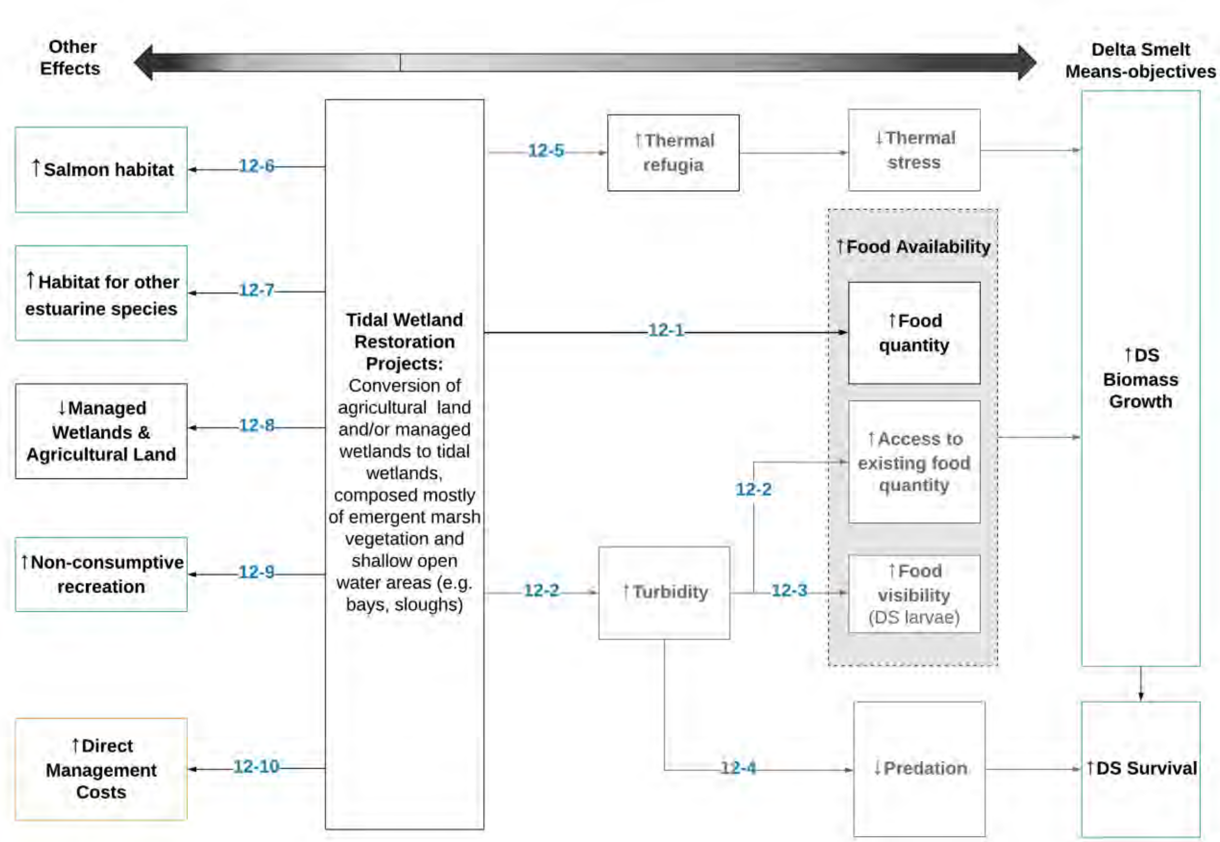



**Table 43: Effect hypotheses for tidal wetland restoration.**

| # | Effect Hypothesis | Effect Characterization |
|---|---|---|
| ***Delta Smelt*** | | |
| 12 | **Land → shallow open water areas**<br>Prior to restoration, tidal wetland restoration sites are predominantly agricultural land or managed wetlands, and are therefore essentially unusable habitat for delta smelt and other aquatic species.<br>Once restored, the sites are predominantly composed of emergent marsh vegetation and shallow open water areas (including sloughs). | Discussed pathway with Rosemary Hartman (Nov. 7, 2017). She explained that in a tidal wetland restoration site, the acreage devoted to shallow open water areas varies considerably depending on the design – e.g. could by 0% or 60% etc.. She said to ask DWR (Erik Loboschefsky) if we want to get expected open water areas for each restoration site.<br>E. Loboschefsky recommended that we use 20% as a rough estimate for the average amount of shallow open water areas across tidal wetland restoration sites (pers. comm., Dec 2017). |

| # | Effect Hypothesis | Effect Characterization |
|---|---|---|
| 12-1 | **Restoration of tidal wetlands → food quantity**<br><br>**Zooplankton:** Converting agricultural or managed wetlands to tidal wetlands will provide a net increase in zooplankton simply through converting land to water.<br><br>Depending on the design of a restored tidal wetland site, the shallow open water around and within the site may have higher productivity on account of having higher residence time and greater land/water interaction.<br><br>**Benthic Invertebrates:**<br><br>Diet studies have found that Delta smelt eat benthic invertebrates. The TWG hypothesized that the shallow open waters in and around tidal wetland sites provide delta smelt with increased access to benthic invertebrates because more benthic invertebrates get swept into the pelagic zone through bottom water mixing into the water column. The TWG thought that the hypothesis that tidal wetlands provide greater access to benthic invertebrates for delta smelt is more likely than the hypothesis that tidal wetlands have a higher density of benthic invertebrates (TWG call, Dec. 15, 2017). | **Rose BEM modeling method:** Opinions differ on whether the shallow open water around and within restored tidal wetland sites is likely to have higher productivity. John Durand (UC Davis) recommended that we assume zooplankton density in these shallow open waters is the same as surrounding areas. In making this recommendation, he made a distinction between the water residence time at planned tidal wetland restoration sites which tend to be isolated sites and historical tidal wetland complexes, explaining that he expects residence time will be lower at restored sites than historic tidal wetland complexes (pers. comm., Dec. 2017). Ted Sommer, based on comparing zooplankton density data of a North Delta tidal slough with the West Delta, recommended assuming a range of 0% to 200% increase in zooplankton density in the shallow open waters in and around restored tidal wetland areas.<br><br>For a low-end estimate, our analysis assumed that the shallow open waters of restored tidal wetland sites would have the same zooplankton density of surrounding waters.<br><br>For a high-end estimate, our analysis assumed that these shallow open waters would have 200% higher zooplankton density than surrounding waters and have an additional benthic invertebrate food value equivalent to the zooplankton density of surrounding waters.<br><br>The assumed values for increased prey biomass are provided in Table 44 below.<br><br>**Benthic Invertebrates:** Steve Slater has delta smelt gut contents data that could be analysed for % zooplankton and % benthic invertebrates for tidal wetland/slough sites vs. deeper channel sites. Compass was not able to access this dataset within the timeline of this project.<br><br>**Advice from Rosemary Hartman:** Discussed pathway with Rosemary Hartman (Nov. 7, 2017). She said that the Fisheries |

| # | Effect Hypothesis | Effect Characterization |
|---|---|---|
| | | Restoration Program only has 1 year of data on zooplankton in tidal wetland restoration sites. She suggested contacting John Durand or Wim Kimmerer and Fred Feyrer/Matt Young (USGS). She also stated though that to get an estimate of this pathway, we would be piecing together datasets and still having to make a lot of assumptions. She cautioned that there's debate whether sites are a net-export or net import of productivity and that its hard to gauge average trends through looking at datasets. Her advice was that a gross ball park assumption based on for example relative area being influenced might provide just as much predictive value for a 'best case scenario' as hunting down the datasets. |
| 12-2 | **Restoration of tidal wetlands → Turbidity**<br>Increasing shallow areas increases turbidity from wind and wave interaction with the sediment (Sherman et al., 2017). | **Pathway excluded from modeling:** Discussed pathway with Rosemary Hartman (Nov. 7, 2017). She did not know of any data that would provide average turbidity increase in these shallow areas, but she was confident that areas would be more turbid.<br>TWG decided not to model this pathway, however, this pathway was a consideration in making assumptions on the food value (zooplankton increase) of these sites as turbid areas are hypothesized to provide delta smelt with greater access to food. |
| 12-3 | **Turbidity → Increased Food Visibility**<br>See action #1 for description of turbidity and food visibility link. | **Pathway excluded from Rose BEM modeling.**<br>Benefits of this pathway partially covered in SDM analysis through constructed scales for (1) spawning/recruitment and (2) DS resiliency to random events. |
| 12-4 | **Turbidity → Reduced predation**<br>See action #1 for description of turbidity and predation link. | **Pathway excluded from Rose BEM modeling.**<br>Benefits of this pathway partially covered in SDM analysis through constructed scales for (1) spawning/recruitment and (2) DS resiliency to random events. |

| # | Effect Hypothesis | Effect Characterization |
|---|---|---|
| 12-5 | **Restoration of tidal wetlands → Reduce thermal stress**<br>Tidal wetlands provide pockets of thermal refugia. | **Pathway excluded from Rose BEM modeling.**<br>Benefits of this pathway partially covered in SDM analysis through constructed scales for (1) spawning/recruitment and (2) DS resiliency to random events. |
| ***Other Ecological Endpoints*** | | |
| 12-6 | **Restoration of tidal wetlands → Improved salmon habitat** | The effects of this action on this pathway are scored by the Technical Working Group, Brett Harvey and Brad Cavallo using a constructed scale to qualitatively describe their opinion on the effects of this action to salmon. |
| 12-7 | **Restoration of tidal wetlands → Improved habitat for other estuarine species** | The effects of this action on this pathway are scored by the Technical Working Group using a constructed scale to qualitatively describe their consensus opinion on the effects of this action to other native estuarine species. |
| ***Socio-economic Considerations*** | | |
| 12-8 | **Restoration of tidal wetlands → Reduced managed wetlands for duck hunting & reduced agricultural lands** | Refer to Suisun Marsh Plan (2010) which represents an agreed to balance among competing uses of the Marsh and determined that a reasonable balance was to set an objective of restoring 5,000 to 7,000 acres of tidal wetlands.<br>Based on this Plan, which acknowledges the historical losses of tidal wetlands and need to re-balance competing land and water uses in the estuary, we assume no adverse social impacts for the conversion of agricultural and managed wetlands to tidal wetlands. |
| 12-9 | **Restoration of tidal wetlands → Improved non-consumptive recreational activities (bird watching, boating)** | |
| ***Resources Required*** | | |
| 12-10 | **Restoration of tidal wetlands → Direct Management Costs**<br>**Upfront Costs:** Rule of thumb is that it costs between $20,000 to $30,000/acre to restore tidal wetlands. This includes planning, buying land, permitting and construction. A | Ball-park upfront costs provided by Carl Wilcox (DFW, Aug. 10, 2017):<br>• Low end - $20,000 per acre * 11,000 acres<br>• High end - $30,000 per acre * 11,000 acres |

| # | Effect Hypothesis | Effect Characterization |
|---|---|---|
| | key factor in the upfront cost is the cost of land and how much land adjacent to the wetland needs to also be protected (pers. Comm., C. Wilcox, Aug. 10, 2017).<br><br>**Operating costs:** If there's no levee, ongoing operational costs for tidal wetlands are low. Costs could include some policing of the site (access, dumping) and vegetation management. If there is a levee or water control structure, then costs would be quite a bit higher. If the site is designed well and water velocity through tidal channels is high enough, aquatic weeds will not establish themselves. The more saline sites (e.g. Suisun Marsh sites) will face less risk of aquatic weed intrusion than the fresher water sites (pers. Comm., C. Wilcox, Aug. 10, 2017).<br><br>For the 8,000 acres that are mitigation for the water projects, the long-term operations and management of these projects will be covered by the projects. For the other 1,000 acres identified under EcoRestore, long-term funding will be more challenging. The capital portion of these projects is payed for through bonds, which can not be used for ongoing management. The McCormick-Williamson project is currently facing issues along these lines – it's owned by the Nature Conservancy, but they do not have operational funding so they are looking for a state agency to take over the land and manage (pers. Comm., C. Wilcox, Aug. 10, 2017). | • Total: \$220 - \$330 million<br><br>Assumption for operating costs (C. Wilcox, Jan. 2018):<br>• Low end – \$250 / acre<br>• High end – \$500 / acre |

| # | Effect Hypothesis | Effect Characterization |
|---|---|---|
| *Implementation* | | |
| Time | Comments from C. Wilcox, March 29, 2016, Delta Smelt Symposium, 40 – 41 min: "I thought restoring wetlands in the Delta would be a great idea as a way to offset the effects of the projects. Here we are eight years after the BiOps were written and after IRTP was done and there isn't anything that's been restored other than a CalFed project or ERP project on Lindsey Slough for 170 acres. Fortunately it's in a place where the John Durand and the UCD folks are sampling and we'll be able to actually get some idea [of effects] because we had pre-project information and we'll have post-project sampling. The nub of it is that we can't get out of our own way to implement these things. We have Liberty Island, it restored itself. It is our paradigm and if we can't do more of those, the prospects are pretty grim. The idea that we're going to see some acceleration in the near term – we'll be lucky if we get half way to restoring 8,000 acres in ten years from now. Just because it is so difficult, unless we can find a way as agencies to help facilitate that process."<br>**Update:** A previous barrier to advancing these projects was that public agencies could only pay fair market value for land (the appraised highest and best use of the land). A new process to request proposals for complete tidal wetland projects is being implemented now and is expected to achieve quicker results (pers. Comm., C. Wilcox, Aug. 10, 2017). | |

**Table 44: Assumed % increase in zooplankton from baseline years for tidal wetland restoration action**

| | | | | | | Increase food available to Delta Smelt across entire strata by: | |
|---|---|---|---|---|---|---|---|
| Rose BEM Model Strata | Restoration Site Name or Assumption | Tidal Wetland Area (Acres) | Total Tidal Wetlands by Strata (Acres) | Acres of new shallow open water | % of Rose strata that is new shallow open water area | Low Estimate | High Estimate |
| Suisun Marsh | Tule Red | 610 | 2,073 | 415 | 14% | 14% | 54% |
| | Hill Slough | 750 | | | | | |
| | Arnold Slough | 145 | | | | | |
| | Bradmoor Island | 488 | | | | | |
| | Goat Island | 80 | | | | | |
| Confluence | Winter Island | 589 | 589 | 118 | 1% | 1% | 6% |
| Lower Sacramento River Region | Decker Island | 110 | 110 | 22 | 1% | 1% | 3% |
| Sacramento River Region (includes Cache Slough area) | Lower Yolo Ranch | 1,650 | 7,668 | 1534 | 11% | 11% | 43% |
| | Prospect Island | 1,500 | | | | | |
| | McCormack-Williamson Tract | 1,314 | | | | | |
| | Lindsey Slough | 228 | | | | | |
| | Other Cache Slough sites not yet identified | 2,976 | | | | | |
| Lower San Joaquin River Region | Dutch Slough (classified as tidal/sub-tidal, riparian forest, and managed marsh) | 560 | 560 | 112 | 1% | 1% | 3% |
| **Total** | | 11,000 | | | | | |

## 12.3 Original Action in Resiliency Strategy (July 2016) and Update (June 2017)

**Summary of Action:** DWR and other state agencies are planning restoration projects that are likely to benefit delta smelt, and are very close to breaking ground (Table 45). Construction of each project will take 1–4 years. Details on the timing and characteristics can be found at http://resources.ca.gov/ecorestore. In addition to these projects, the State's EcoRestore program, which includes the projects listed in Table 45, has committed to implementing restoration of 9,000 acres of inter-tidal wetland habitat in the Delta and Suisun Marsh by the end of 2018 and to initiate of work to enhance fish habitat in the Yolo Bypass.

**Update**: State, local, and federal agencies and private interests broke ground last fall on the Tule Red project, which will reopen 400 acres of former duck hunting club lands in Suisun Marsh to daily tidal action. DWR also launched a first-of-its-kind approach to speeding the pace of restoration by soliciting project proposals from private companies, non-profit groups, and individuals. Two projects involved approximately 700 acres have been selected, with a second solicitation expected soon. Construction is expected to begin on restoration projects in the coming year on Dutch Slough, Hill Slough, Decker Island, Lower Yolo Ranch and Bradmoor Island.

**Linkage to Conceptual Models:** This management action would benefit all life stages. The primary Environmental Drivers affected is Food Production and Predators, which affects two Habitat Attributes, Food Availability/Visibility and Predation Risk.

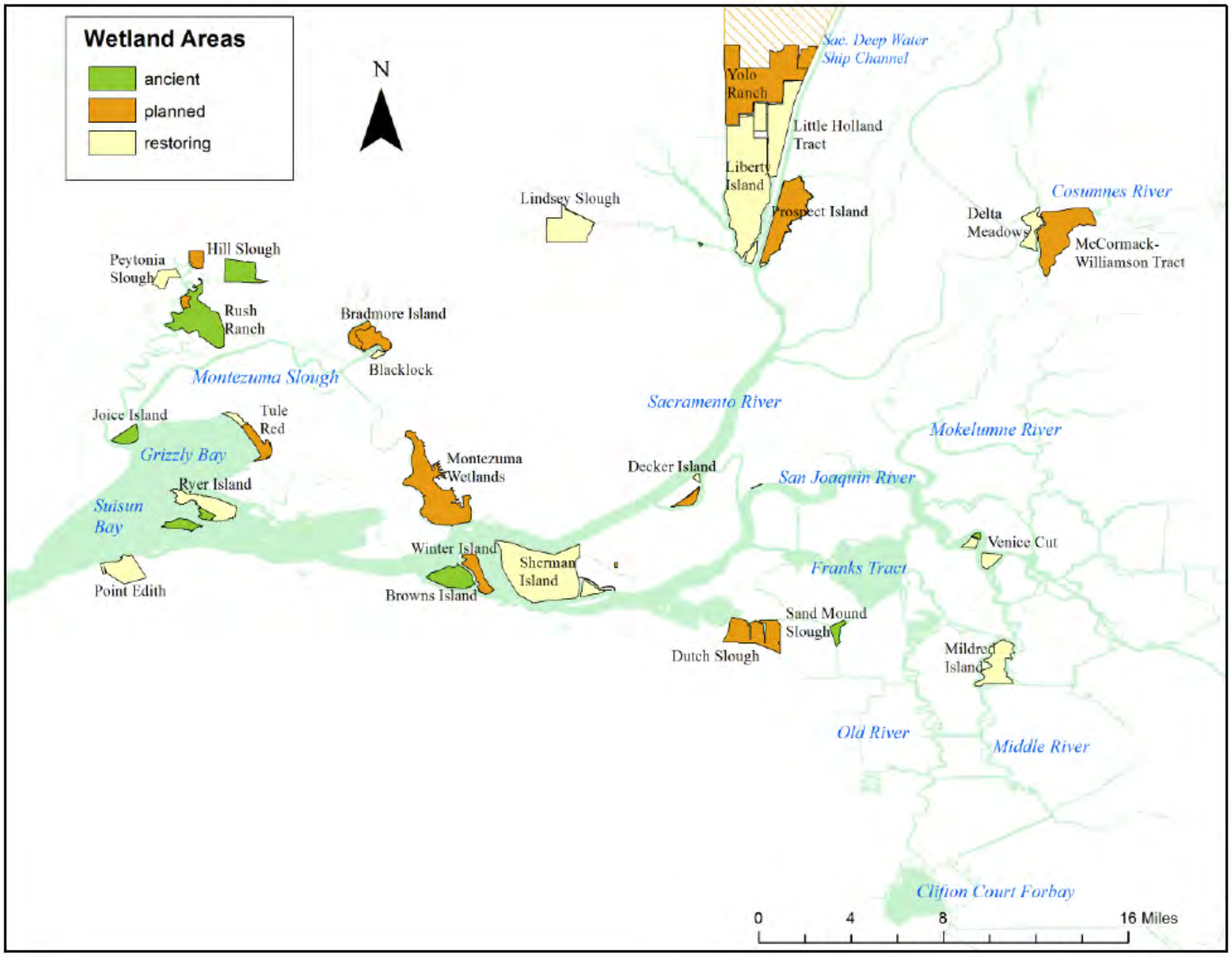
**Table 45: Summary of Near-Term (2016–2019) Tidal Restoration Actions that Will Benefit Delta Smelt**

| Restoration Site | Tidal Wetland (acres) | Construction Begins |
|---|---|---|
| Tule Red | 600 | 2016 |
| Dutch Slough | 660 | 2016 |
| Hill Slough | 750 | 2016 |
| Decker Island | 140 | 2017 |
| Lower Yolo Ranch | 1,600 | 2017 |
| Bradmoor Island | 280 | 2018 |
| Prospect Island | 1,500 | 2019 |
| **TOTAL** | **5,530** | |

## 12.4 Additional Background

- DWR must restore 8,000 acres of tidal wetland and associated subtidal habitat to offset impacts of SWP (2008 USFWS Bi-Op for Delta Smelt, 2009 NMFS Bi-Op for Salmon, CDFW ITP for Longfin Smelt). Implemented through the Fish Restoration Program agreement with the CDFW.
- The Tidal Wetlands Project Workteam is evaluating whether and by how much the restoration of tidal wetlands will help Smelt. They are looking at monitoring the restoration of Prospect Island in the Cache Slough area. Constraints on restoration include: Land acquisition and what the State is allowed to pay for this land, Environmental Permits for construction and for monitoring Smelt, Engineering challenges of moving earth on wet sites, taking into account salinity changes from restoration, managing conflicts with other endangered species such as garder snake habitat on Prospect Island, scientific unknowns (e.g. put sand for spawning substrate or other) (Hartman, 2016).
- Tidal wetlands elsewhere make broad, multi-faceted contributions to fish habitat, productivity and resilience. However, the present Delta has comparatively little tidal marsh (less than 5% of the historical extent) and so its role is little understood. (Herbold et al., 2014). Overall, wetland area exceeded open-water area by about 14:1; today, wetland area is less than open water area by a ratio of 1:6, an 80-fold switch in dominant habitat types (Whipple et al. 2012).

Figure 33: Location of tidal wetland restoration sites and relic tidal wetlands in the Upper SFE (from Sherman et al., 2017)




## 12.5 References

Hartman, R. (2016). “Are tidal wetlands the new miracle cure?”, Presentation to Delta and Longfin Smelt Symposium, March 29, 2016, http://ats.ucdavis.edu/ats-video/?kpid=0_5b5wmf2b

Sherman, S., Hartman, R., Contreras, D., “Effects of Tidal Wetland Restoration on Fish: A Suite of Conceptual Models”. Interagency Ecological Program Technical Report. Nov. 2, 2017.

# 13 Franks Tract Restoration Feasibility Study

## 13.1 Action Summary

Located near the confluence of the Sacramento and San Joaquin rivers, the flooded Delta island called Franks Tract may be suitable for low-salinity habitat preferred by Delta smelt.

**Table 46: Scale of action under the Resiliency Strategy and full build out scale scenario**

| Resiliency Strategy Scale | Full Build Out Scale | Scaling Criteria and Reference for Full Build Out |
|---|---|---|
| • Feasibility study | Restore Franks Tract with the following objectives:<br>• Biological (preliminary)<br>o Enhance habitat conditions for Delta Smelt and other native fish species through creating a 'speed bump' that prevents water currents from drawing native fish into the South Delta.<br>o Minimize habitat for non-native fish and invasive plant species (SAV/FAV).<br>o Create elevations to establishment large area of emergent marsh vegetation.<br>• Physical<br>o Modify tidal circulation to create conditions similar to historic condition (pre-reclamation). Tide entering and exiting primarily through False River.<br>o Eliminate tidal flow through Franks Tract into Old River.<br>o Create conditions within Franks Tract to enhance turbidity through wind wave action both onsite and downstream.<br>• WQ<br>o Limit salinity movement thought Franks Tract to Old River<br>o Increase residence time | • Preliminary project objectives from Carl Wilcox (DFW) and T. Sommer |

**Figure 34: Map of Franks Tract**


**Figure 35: Draft Conceptual Design of Franks Tract Restoration (received from C. Wilcox)**

## 13.2 Influence Diagram

**Figure 36: Influence diagram for Franks Tract Restoration**

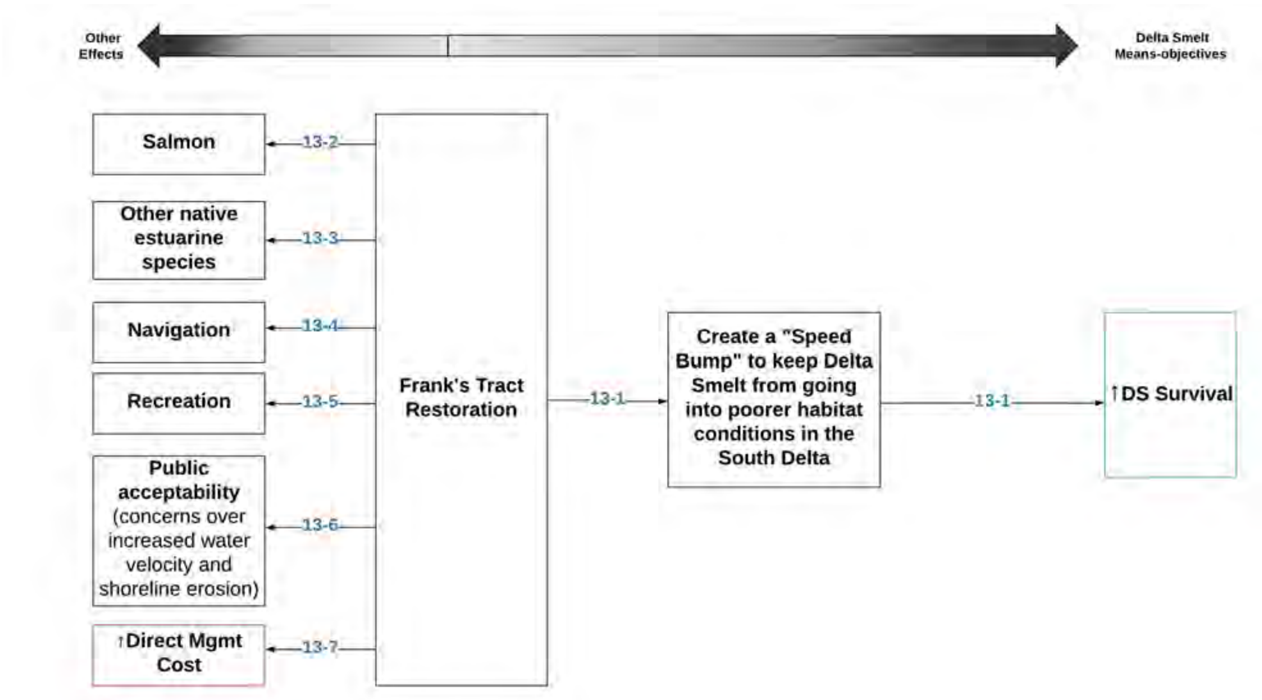



**Table 47: Effect hypotheses for Franks Tract Restoration to be assessed in SDM analysis.**

| # | Effect Hypothesis | Effect Characterization |
|---|---|---|
| ***Delta Smelt*** | | |
| 13-1 | Franks Tract Restoration → 'Speed Bump' to keep Delta Smelt from going into poorer habitat conditions in the South Delta. → reduce DS mortality through predation, entrainment, and other stressors in the South Delta<br>Hydrodynamic modeling done by DWR predicts that Franks Tract restoration would be effective at reducing DS entrainment (pers. comm., T. Sommer, Jan. 4, 2017). | **Rose BEM Modeling method:** There is not much evidence available on the effects of Franks Tract Restoration to Delta Smelt. The TWG thought a reasonable range of benefits to Delta Smelt from this action would be that it decreases DS mortality by 10-25% when Old and Middle River flows are negative (and therefore there is increased risk of the water projects pulling DS into the South Delta). The high end of this range was used to simulate this action in the Rose model. |
| N/A | **Restoration of Franks Tract → Zooplankton** | **Pathway excluded from analysis.**<br>Note: In a short-term study, Lucas et al. (2002) found that Franks Tract is a net sink for primary production because the combination of benthic grazing and respiration sinks exceeded the algal growth rate. |

| # | Effect Hypothesis | Effect Characterization |
|---|---|---|
| ***Other Ecological Endpoints*** | | |
| 13-2 | **Restoration of Franks Tract → Improved salmon habitat** | The effects of this action on this pathway are scored by the Technical Working Group, Brett Harvey and Brad Cavallo using a constructed scale to qualitatively describe their opinion on the effects of this action to salmon. |
| 13-3 | **Restoration of Franks Tract → Improved habitat for other estuarine species** | The effects of this action on this pathway are scored by the Technical Working Group using a constructed scale to qualitatively describe their consensus opinion on the effects of this action to other native estuarine species. |
| ***Socio-economic Considerations*** | | |
| 13-4 | **Restoration of Franks Tract → Navigation (general)**<br>Implementing Franks Tract restoration will change boating routes. Currently, boats can cut straight across Franks Tract. | Input from C. Wilcox on magnitude of this effect (pers. comm., Aug. 10, 2017):<br>• Once restored, boats will have to go around, adding approximately ten minutes to their journey. |
| 13-4 and 13-6 | **Restoration of Franks Tract → Hydrodynamics around North side of Bethel Island → Navigation and Infrastructure on North shore of Bethel Island**<br><br>FT Restoration has the potential to change flow patterns and increase water velocities along the North side of Bethel Island, which has lots of waterfront residences with a marina and boat docks all along it. If water velocity is increased along this area, there could be impacts to the boat docks, levees and ease of navigation if you're having to fight stronger currents on the ebb and flood tides. | Input from C. Wilcox on magnitude of this effect (pers. comm., Aug. 10, 2017):<br>• This effect will have to be mitigated for the project to go ahead, either through design or through putting in a control structure like a weir. We want to minimize, or avoid redirection of the tidal force into these areas that could cause problem.<br>• As part of the feasibility study, we're looking at ways to minimize this potential impact on the North Side of Bethel Island. In the conceptual design, the weir at the North side is a potential way to control the tidal velocity along the north side of Bethel Island. |

| # | Effect Hypothesis | Effect Characterization |
|---|---|---|
| 13-5 | **Restoration of Franks Tract → Recreational Fishing**<br>Currently, Franks Tract is filled with aquatic weeds and is very good habitat for black bass. The Delta has become one of the top ten black bass tournament fishing areas in the country and a lot of this fishing happens in the Bethel Island / Oakley Area – so Franks Tract Restoration will have some effect on black bass fishing values.<br><br>Implementing Franks Tract restoration will change the routing for people going fishing. Currently, boats can cut straight across Franks Tract. Once restored, boats will have to go around, adding approximately ten minutes to their journey. | Input from C. Wilcox on magnitude of this effect (pers. comm., Aug. 10, 2017):<br>• There is the potential for high levels of opposition from the fishing community for restoring Franks Tract unless their interests are taken into consideration and managed. Not insurmountable levels of opposition.<br>• The extra ten minutes travel time around Franks Tract would not be a big deal for regular fisherman but may have an influence on the time-limited black bass tournament. |
| 13-5 | **Restoration of Franks Tract → Recreational Waterfowl Hunting**<br><br>Currently, Franks Tract is a State Recreation Area which provides waterfowl hunting opportunities. Once restored, the area would remain a State Recreation Area but the area available for waterfowl hunting would be reduced. Waterfowl hunters in Franks Tract use floating seasonal blinds and there's a lease/permit system to do this. Reducing the area would potentially affect the number of hunters and blinds that could be accommodated. | Input from C. Wilcox on magnitude of this effect (pers. comm., Aug. 10, 2017):<br>• Under the current design, the area available for waterfowl hunting would decrease by approximately 25%. Would have to speak to the manager of the Recreation Area (California Department of Parks and Recreation) about how this would affect the availability and quality of waterfowl hunting in the area. |
| 13-5 | **Restoration of Franks Tract → Improved non-consumptive recreational activities (bird watching, boating)** | |
| ***Resources Required*** | | |
| 13-7 | **Restoration of Franks Tract → Direct Management Costs**<br>**Upfront Costs:** \$80 to \$200 million (ball park estimate)<br>**Operating costs:** | Ball-park costs provided by Carl Wilcox (DFW, Aug. 10, 2017 and Jan. 2018). |

| # | Effect Hypothesis | Effect Characterization |
|---|---|---|
| ***Implementation*** | | |
| Time | Comments from C. Wilcox, March 29, 2016, Delta Smelt Symposium, 41 to 42 min: "To remedy the problems of Franks Tract, my idea would be to fill it up to tidal elevations, remove it as a bridge of salinity into Old River and get rid of the egeria. Maybe make it a more productive place for the kinds of species that we're interested in. **But those kind of things have huge hurdles to overcome from an institutional perspective**". | |

## 13.3 Original Action in Resiliency Strategy (July 2016) and Update (June 2017)

**Summary of Action:** Franks Tract is located near the confluence of the Sacramento and San Joaquin Rivers, and could support LSZ habitat. DFW will conduct a conceptual plan and feasibility study for restoring Franks Tract to reduce invasive aquatic weeds, reduce predation on Delta Smelt, increase turbidity, and improve food webs. The conceptual plan will be completed by the spring of 2017. If this management action is found to be feasible, the restoration of Franks Tract could begin as early as 2018.

**Update**: A conceptual restoration design has been prepared for evaluation. The conceptual plan would convert a portion of Franks Tract to inter-tidal marsh and modify hydraulic connections between False River and Old River through Franks Tract and associated channels. Contracts are in place with the Metropolitan Water District of Southern California to produce an engineering feasibility report for restoration construction. DWR will conduct three-dimensional hydrodynamic modeling to evaluate changes in circulation patterns and effects on turbidity and water quality. Additional two-dimensional modeling will assess the effects of the restoration in the context of other habitat restorations being implemented through California EcoRestore on water circulation and quality in the Delta. Outreach to the local community and affected recreational users will be conducted as a part of the study. A final report is expected by the end of November 2017.

**Linkage to Conceptual Models:** This management action would benefit all life stages. The primary Environmental Driver that would be affected is Food Production and Predators, which would affect two Habitat Attributes, Food Availability/Visibility and Predation Risk.

## 13.4 Background and Context

Franks Tract was originally reclaimed between 1902 and 1906 and given over to farming of potatoes, beans, asparagus, sugar beets, onions, seed crops, small grains, and corn. Levee breaches flooded Franks Tract in 1936, which was repaired, and again in 1938. The 1938 breach was never repaired, and thus the tract has been open water ever since. The entire 3,523-acre (1,426 ha) flooded tract area became officially designated state park in 1959 and took on the name of Franks Tract State Recreation Area (SRA) in 1963. The adjacent Little Franks Tract underwent a levee breach in 1981 and was then incorporated into the SRA. Since its permanent flooding a novel ecology has developed in Franks tract. Replacing the monocultural agricultural fields is a only slightly more diverse ecology, dominated by invasive aquatic vegetation, freshwater alien invertebrates, and other alien fishes (Milligan and Kraus-Polk, 2016).

## 13.5 References


Lucas, L.V., Cloern, J.E., Thompson, J.K., Monsen, N.E.. "Functional Variability of Habitats Within the Sacramento-San Joaquin Delta: Restoration Implications". *Ecological Applications,* 12 (5), 2002, pp. 1528-1547.

Milligan and Kraus-Polk, (2016). Brett Milligan and Alejo Kraus-Polk. *Human Use of Restored and Naturalized Delta Landscapes: Appendix.* Downloaded from: https://watershed.ucdavis.edu/library/human-use-restored-and-naturalized-delta-landscapes . Downloaded on: July 22, 2017.

# Appendix 2 - The Rose Bioenergetics Model in support of a CAMT Structured Decision Making for Delta Smelt Demo Project

William E. Smith, 5 January 2018

## Methods: the bioenergetics model

The Delta Smelt bioenergetics model described by Rose et al. (2013a) and length-based natural mortality model of Rose et al. (2013b) were combined with a model of movement based on observed Delta Smelt spatial distributions in order to simulate Delta Smelt feeding, growth, mortality, and movement in the Sacramento-San Joaquin Delta. The model described here differed from Rose's model in 3 critical aspects. Rose's model accounted for the entire life cycle, but only the June through January portion of the life cycle was modeled here. Rose's full life cycle model depended on a complex biophysical model of salinity-based movement and spatially-explicit spawning that was beyond the scope of this project. The movement model used here was based on observed smelt distributions rather than a biophysical model. Finally, Rose's model was programed using FORTRAN90; however, the model described here was programmed using R (R 2017).

*Starting weights and lengths.* Fish lengths on June 1st were simulated to approximate June observed lengths of juvenile Delta Smelt in the 20mm survey and Von Bertalanffy Growth Model predictions of average Delta Smelt length, assuming an April 15 birthday (26 mm fork length) (Fig. 1). The currency of the bioenergetics model was weight, so weights were generated from a lognormal distribution and converted to lengths using the length-weight equation derived by Kimmerer et al. (2005),

$$FL_{i,t} = \sqrt[3.82]{\frac{W_{i,t}}{1.8e^{-6}}}, \qquad \textbf{Equation 1.}$$

where $W_{i,t}$ was weight in grams and $FL_{i,t}$ was fork length in millimeters of individual *i* on day *t* of the simulation.

*Movement.* Fish were randomly assigned to strata based on observed spatial distributions in the 20mm, Midwater Trawl, and Spring Kodiak surveys. Monthly observed catch densities (catch/volume) for 1995–2005 were assigned to the 11 strata of the Rose model, and observed densities were expanded to abundance by multiplying by strata volume. Proportional abundance in each year *yr*, month *m*, and strata *str* $y_{yr,m,str}$ were then treated as observations in a Dirichlet regression model in order to smooth spatial distributions over months and avoid substantial (outlier) monthly shifts in spatial distributions. A parabolic functional form was assumed,

$$\begin{bmatrix} y_{yr,m,str=1} \\ \vdots \\ y_{yr,m,str=11} \end{bmatrix} \sim \text{Dirichlet} \begin{bmatrix} e^{\beta 0_{yr,s=1} + \beta 1_{yr,s=1} * m + \beta 2_{yr,str=1} * m^2} \\ \vdots \\ e^{\beta 0_{yr,s=11} + \beta 1_{yr,s=11} * m + \beta 2_{yr,str=11} * m^2} \end{bmatrix}. \qquad \textbf{Equation 2.}$$

Predicted proportions in each strata were then treated as data to inform randomized movement. At the beginning of June, each individual was randomly assigned to a stratum by drawing from a categorical distribution with probabilities equal to the Dirichlet regression predictions of spatial distributions. On the first day of subsequent months, categorical distribution probabilities to randomly assign strata were the product of predicted spatial distributions and a set of rules for movement. The rules for movement allowed residence in a strata or movement to adjacent strata from month to month but not movement to more distant strata.

*Growth*. The bioenergetics growth model described by Rose et al. (2013a) was a system of equations (Eq. 3–12) estimating daily Delta Smelt growth in weight as a function of rates of consumption $C_{i,t}$, metabolism $R_{i,t}$, egestion $F_{i,t}$, excretion $U_{i,t}$, activity $SDA_{i,t}$, and spawning (not modeled here). Parameters specific to each life-stage $s$ to model each rate were derived and listed in Rose et al. (2013a) (Fig. 2); henceforth, these fixed quantities are underlined to distinguish them from variable quantities. Time- and area-specific data to model each rate, prey density $PD_{p,str,t}$ of prey species $p$ and temperature $T_{str,t}$, were acquired from the authors.

$$KA_{i,t} = \frac{\underline{CK1_s} * e^{\frac{1}{\underline{T0_s}-\underline{CQ_s}} * ln\left(\frac{0.98*\left(1-\underline{CK1_s}\right)}{0.02*\underline{CK1_s}}\right) * \left(T_{str,t}-\underline{CQ_s}\right)}}{1+\underline{CK1_{i,t}} * \left( e^{\frac{1}{\underline{T0_s}-\underline{CQ_s}} * ln\left(\frac{0.98*\left(1-\underline{CK1_s}\right)}{0.02*\underline{CK1_s}}\right) * \left(T_{str,t}-\underline{CQ_s}\right)} - 1\right)} \qquad \textbf{Equation 3.}$$

$$KB_{i,t} = \frac{\underline{CK4_s} * e^{\frac{1}{\underline{TL_s}-\underline{TM_s}} * ln\left(\frac{0.98*\left(1-\underline{CK4_s}\right)}{0.02*\underline{CK4_s}}\right) * \left(\underline{TL_s}-T_{str,t}\right)}}{1+\underline{CK4_{i,t}} * \left( e^{\frac{1}{\underline{TL_s}-\underline{TM_s}} * ln\left(\frac{0.98*\left(1-\underline{CK4_s}\right)}{0.02*\underline{CK4_s}}\right) * \left(\underline{TL_s}-T_{str,t}\right)} - 1\right)} \qquad \textbf{Equation 4.}$$

$$Cmax_{i,t} = \underline{ac_s} * W_{i,t}^{\underline{bc_s}} * KA_{i,t} * KB_{i,t} \qquad \textbf{Equation 5.}$$

$$C_{i,t} = \sum_{q=1}^{6} \frac{Cmax_{i,t} * \frac{PD_{q,str,t} * \underline{\underline{V_{q,s}}}}{\underline{K_{q,s}}}}{\sum_{r=1}^{6} \frac{PD_{r,str,t} * \underline{\underline{V_{r,s}}}}{\underline{K_{r,s}}}} \qquad \textbf{Equation 6.}$$

$$ep_{i,t} = \frac{\sum_{q=1}^{6} ed_q * \left( \frac{Cmax_{i,t} * \frac{PD_{q,str,t} * \underline{\underline{V_{q,s}}}}{\underline{K_{q,s}}}}{\sum_{r=1}^{6} \frac{PD_{r,str,t} * \underline{\underline{V_{r,s}}}}{\underline{K_{r,s}}}} \right)}{\sum_{q=1}^{6} \left( \frac{Cmax_{i,t} * \frac{PD_{q,str,t} * \underline{\underline{V_{q,s}}}}{\underline{K_{q,s}}}}{\sum_{r=1}^{6} \frac{PD_{r,str,t} * \underline{\underline{V_{r,s}}}}{\underline{K_{r,s}}}} \right)} \qquad \textbf{Equation 7.}$$

$$R_{i,t} = \underline{ar_s} * W_{i,t}^{\underline{br_s}} * e^{\underline{RQ_s} * T_{str,t}} \qquad \textbf{Equation 8.}$$

$$F_{i,t} = \underline{Fa_s} * C_{i,t} \qquad \textbf{Equation 9.}$$

$$U_{i,t} = \underline{Ua_s} * \left(C_{i,t} - F_{i,t}\right) \qquad \textbf{Equation 10.}$$

$$SDA_{i,t} = \underline{Sd_s} * \left(C_{i,t} - F_{i,t}\right) \qquad \textbf{Equation 11.}$$

$$W_{i,t+1} = W_{i,t} + W_{i,t} * \frac{ep_{i,t}}{\underline{es}} * \left(C_{i,t} - R_{i,t} - F_{i,t} - U_{i,t} - SDA_{i,t}\right) \qquad \textbf{Equation 12.}$$

*Mortality.* The length-based instantaneous natural mortality model described by Rose et al. (2013b) was used rather than the stage-based alternative, because this approach was consistent with the concept that predation declined with fish length. Some Resiliency Strategy Actions were hypothesized to influence predation.

$$M_{i,t} = -0.034 + 0.165 * FL_{i,t}^{-0.322}$$ **Equation 13.**

Daily instantaneous rate of entrainment mortality *F* of 0.02 was applied to fish located in the South Delta strata on days during December–June when Old and Middle River flows were negative. Fish located outside of the South Delta were assigned *F* = 0; all fish were assigned *F* = 0 during July–November. Total mortality was the sum of individual *M* and *F*, and survival *S* was equal to $e^{-(M+F)}$. Survival or death (1 or 0) was randomly assigned to each individual each day based on draws from a Bernoulli distribution with probability *S*. Additionally, any underweight individual less than half the weight expected given length died.

In order to capture effects of turbidity on Delta Smelt, estimates of mortality effects from Ferrari et al. (2014) were applied. A 67% linear decline in mortality was modeled when an individual was located in strata with secchi depths between 53 to 35 cm (Fig. 3), corresponding the 67% decline in mortality measured by Ferrari et al. (2014) in two laboratory treatments of clear water (<1 NTU) and turbid water (20 NTU or 34 cm secchi depth). . The full mortality described by Eq. 13 was applied above 53 cm secchi depth, and 67% of the full mortality was applied at secchi depths below 35 cm.

*Model calibration.* As described in the appendix to Rose et al. (2013a), the growth model parameters *K* for each prey species and life stage of Delta Smelt required calibration to expected growth rates. *K* represented the half-saturation constant for feeding rates. Rather than attempt to calibrate each *K* for all prey and Delta Smelt life-stage combinations, the matrix of $K_{p,s}$ was iteratively multiplied by a scalar until expected growth rates were achieved. Expected growth rates were derived from Von Bertalanffy Growth Model predictions at four equidistant points in the June 1 to January 31 time series, and a residual sum of squares function was minimized across those four points. A *K* scalar of 4 was required to achieve expected growth rates.

*Secchi data.* Secchi data obtained from Rose et al. appeared to be truncated, with few values greater than 70 cm (Fig. 4); therefore secchi depth data were interpolated from field observations, as described in the appendix to Rose et al. (2013a). Time series were summarized from all observed secchi depths recorded in 10 fish monitoring programs throughout the Sacramento-San Joaquin Delta, the 20 mm, Midwater Trawl, Spring Kodiak Trawl, Smelt Larval, TowNet, Early Warning, Prisoners Point, Mossdale Trawl, Sacramento Trawl, and Seine Surveys. Each observation was assigned to a day and one of the 11 spatial strata, multiple daily observations within a single strata were averaged, and missing data were linearly interpolated between the closest observed neighboring data.

*List of differences from original model developed by Rose et al.*

1. incomplete life cycle (only Jun-Jan)
2. no spawning or recruitment mechanism, including timing, therefore starting *W* and *L* do not vary

3. movement model
4. *K* calibration
5. length-weight equation (Rose Fortran code differs from article)
6. mortality was a function of secchi depth
7. entrainment mortality applied seasonally (Dec-Jun) rather than by life-stage as in Rose's formulation
8. unclear how bioenergetics parameter *e.p* was calculated in Rose's model. Here, it was calculated as mean energy density (J/g) consumed per unit prey consumed $e.p = \frac{\sum_{prey=1}^{6} C_{prey} * energy\ density_{prey}}{\sum_{prey=1}^{6} C_{prey}}$.

   This is likely related to the fact that *K* required calibration.
9. Re-summarized secchi data from a larger set of survey data.

**References**


Ferrari, M. C., Ranåker, L., Weinersmith, K. L., Young, M. J., Sih, A., & Conrad, J. L. (2014). Effects of turbidity and an invasive waterweed on predation by introduced largemouth bass. *Environmental biology of fishes*, *97*(1), 79-90. (Cited in USFWS, "Why Flow is a Necessary Element of Delta Smelt Habitat", June 29, 2016)

Kimmerer, W., S. R. Avent, S. M. Bollens, F. Feyrer, L. F. Grimaldo, P. B. Moyle, M. Nobriga, and T. Visintainer. 2005. Variability in length–weight relationships used to estimate biomass of estuarine fish from survey data. Transactions of the American Fisheries Society 134: 481–495.

R Core Team. 2017. R version 3.3.3: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL http://www.R-project.org/.

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

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

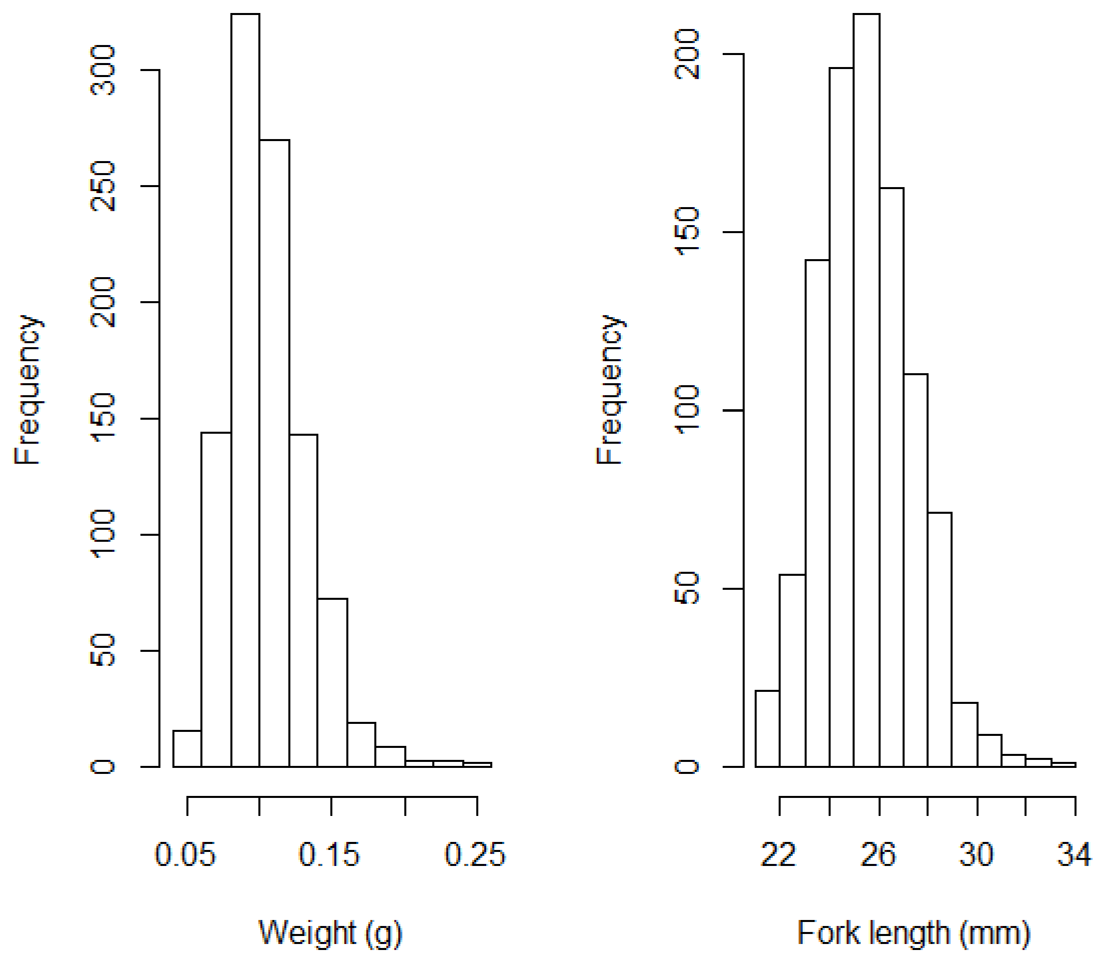



**Figure 1.** June 1st starting weight and length distributions used for all simulations.

TABLE 1. Parameter values for each Delta Smelt life stage in the bioenergetics model.

| Parameter | Description | Larvae | Postlarvae | Juveniles and adults |
|---|---|---|---|---|
| | **Maximum consumption ($C_{max}$)** | | | |
| $a_c$ | Weight multiplier | 0.18 | 0.18 | 0.1 |
| $b_c$ | Weight exponent | −0.275 | −0.275 | −0.54 |
| $CQ$ (°C) | Temperature at $CK_1$ of maximum | 7 | 10 | 10 |
| $T_O$ (°C) | Temperature at 0.98 of maximum | 17 | 20 | 20 |
| $T_M$ (°C) | Temperature at 0.98 of maximum | 20 | 23 | 23 |
| $T_L$ (°C) | Temperature at $CK_4$ of maximum | 28 | 27 | 27 |
| $CK_1$ | Effect at temperature $CQ$ | 0.4 | 0.4 | 0.4 |
| $CK_4$ | Effect at temperature $T_L$ | 0.01 | 0.01 | 0.01 |
| | **Metabolism ($R$)** | | | |
| $a_r$ | Weight multiplier | 0.0027 | 0.0027 | 0.0027 |
| $b_r$ | Weight exponent | −0.216 | −0.216 | −0.216 |
| $R_Q$ | Exponent for temperature effect | 0.036 | 0.036 | 0.036 |
| $S_d$ | Fraction of assimilated food lost to $SDA$ | 0.175 | 0.175 | 0.175 |
| | **Egestion ($F$) and excretion ($U$)** | | | |
| $F_a$ | Fraction of consumed food lost to egestion | 0.16 | 0.16 | 0.16 |
| $U_a$ | Fraction of assimilated food lost to excretion | 0.1 | 0.1 | 0.1 |

Table F.1. Calibrated values of the feeding parameters $K_{ij}$ (mg C/m$^3$) by delta smelt life stage.

| Zooplankton Group | Larvae | Post-larvae | Juveniles | Adults |
|---|---|---|---|---|
| Limnoithona spp. adult | 1.0 | 1.0 | 4.0 | 2.0 |
| Calanoid copepodid | 0.2 | 0.8 | 4.0 | 2.0 |
| Other Calanoid adult | NA | 1.5 | 0.6 | 0.07 |
| Eurytemora spp. adult | NA | 1.5 | 0.6 | 0.07 |
| A. vernalis adult | NA | 1.5 | 0.6 | 0.07 |
| Pseudodiaptomus adult | NA | 1.5 | 0.6 | 0.07 |

**Figure 2.** Tables from Rose et al. (2013a) (top) and supplemental table (bottom) showing fixed parameter values used to simulate Delta Smelt feeding and growth.

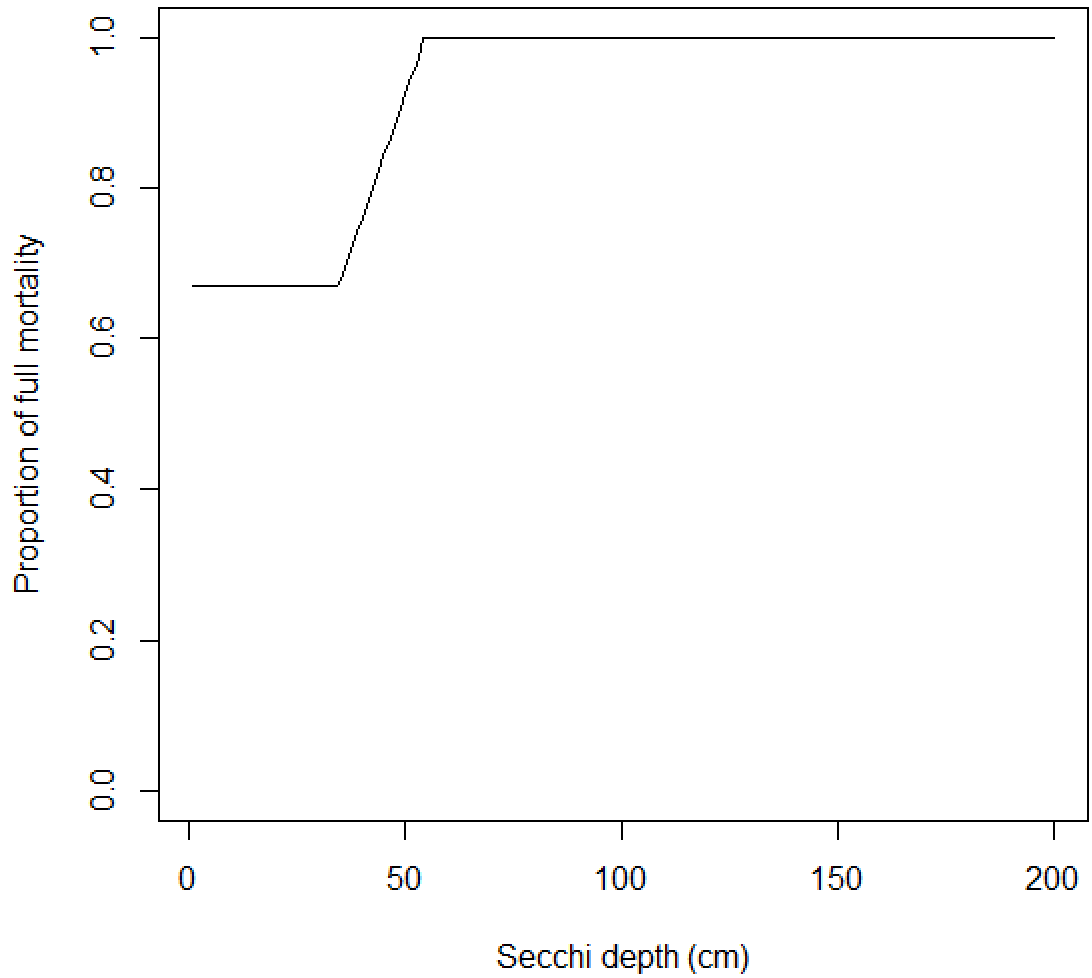



**Figure 3.** Modeled effect of secchi depth on mortality.

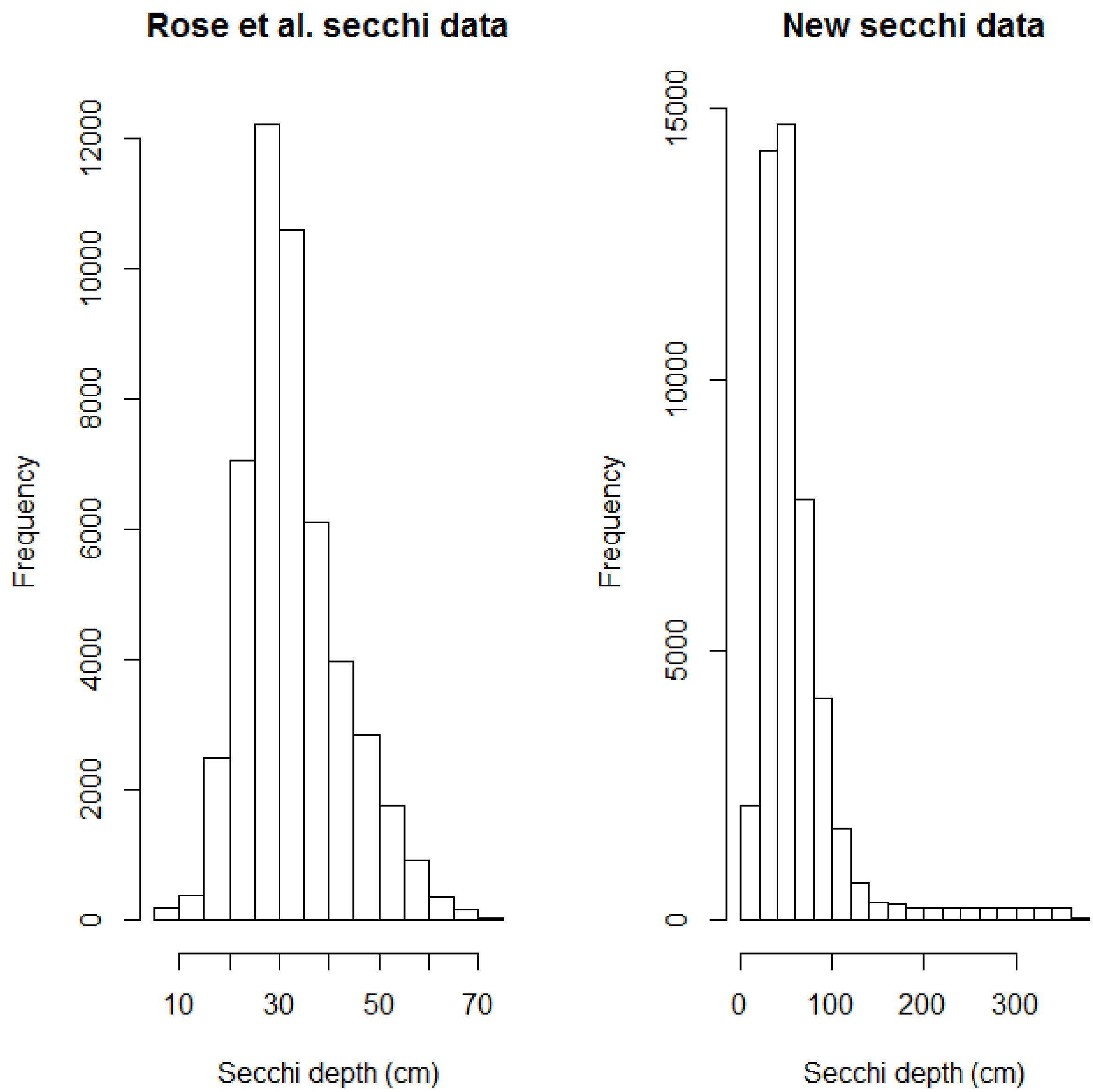
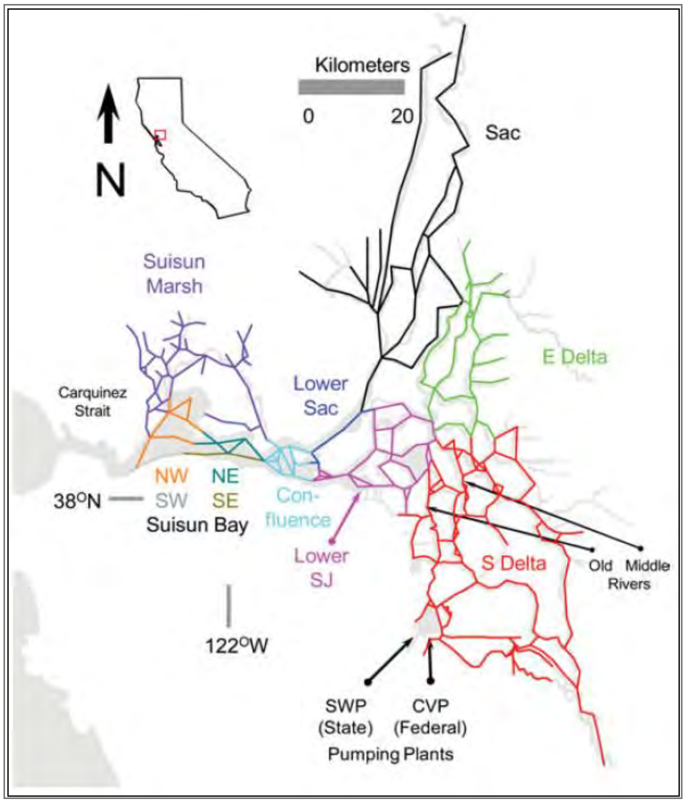



**Figure 4.** Histograms of secchi depth datasets.

**Figure 37: Spatial grid and boxes used in the Rose et al. (2013) Delta Smelt Simulation Model. Gray represents the outline of the estuary. The 11 boxes are color coded and refer to (in numerical order): (1) Sacramento River region (Sac) of the Sacramento-San Joaquin Delta; (2) eastern Delta (E Delta); (3) southern Delta (S Delta); (4) lower Sacramento River region (Lower Sac); (5) lower San Joaquin River region (Lower SJ); (6) confluence (westernmost box in the Delta); (7) southeast Suisun Bay (SE); (8) northeast Suisun Bay (NE); (9) Suisun Marsh; (10) southwest Suisun Bay (SW); and (11) northwest Suisun Bay (NW).**



# Appendix 3 – Cost Estimates

Ball-park cost estimates for the full build out scale scenario of each Resiliency Strategy action were gathered from multiple sources as per advice from the TWG. The first table below provides a summary of cost estimates followed by more detailed tables with cost break-downs and references.

| Action | Units | 1<br>Aquatic Weed Control | 2<br>North Delta Food Web | 3<br>Outflow Augmentation | 4<br>Reoperation of the Suisun Marsh Salinity | 5<br>Sediment Supplementation | 7<br>Roaring River Distribution System | 8<br>Coordinate Managed Wetlands | 9<br>Adjust Fish Salvage Operations | 10<br>Stormwater Discharge Management | 11<br>Rio Vista Fish Technology Center | 12<br>Near-term Delta Smelt Habitat Restoration | 13<br>Franks Tract Restoration |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Initial Costs** | | | | | | | | | | | | | |
| High | | 36,000,000 | 0 | 0 | 0 | 0 | 1,000,000 | 10,000,000 | 5,000,000 | 267,752,306 | 0 | 330,000,000 | 375,000,000 |
| Low | | 24,000,000 | 0 | 0 | 0 | 0 | 1,000,000 | 10,000,000 | 2,500,000 | 1,270,598 | 0 | 220,000,000 | 300,000,000 |
| **Annual Operating Costs** | | | | | | | | | | | | | |
| High | per year | 1,200,000 | 210,000 | 2,650,000 | 117,000 | 4,240,000 | 200,000 | 2,862,500 | 1,000,000 | 375,650 | 7,500,000 | 5,500,000 | 734,250 |
| Low | per year | 400,000 | 70,000 | 0 | 39,000 | 3,392,000 | 125,000 | 1,147,500 | 500,000 | 127,060 | 5,500,000 | 2,750,000 | 489,500 |
| **Water Costs** | | | | | | | | | | | | | |
| High | per year | | 6,689,605 | 65,616,056 | 13,468,605 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Low | per year | | 1,486,579 | 27,285,291 | 5,836,395 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Undiscounted Average Annual Costs (20 years)** | | | | | | | | | | | | | |
| Hi | per year | 3,000,000 | 6,899,605 | 65,616,056 | 13,585,605 | 4,240,000 | 250,000 | 3,362,500 | 1,250,000 | 13,763,265 | 7,500,000 | 22,000,000 | 19,484,250 |
| Moderate (Average of high and low) | per year | 2,300,000 | 4,228,092 | 46,450,673 | 9,730,500 | 3,816,000 | 212,500 | 2,505,000 | 937,500 | 6,976,927 | 6,500,000 | 17,875,000 | 17,486,875 |
| Low | per year | 1,600,000 | 1,556,579 | 27,285,291 | 5,875,395 | 3,392,000 | 175,000 | 1,647,500 | 625,000 | 190,590 | 5,500,000 | 13,750,000 | 15,489,500 |

**Table 48: Cost estimate for Action #1: Aquatic Weed Control**

| Component | | Notes | Area | | Unit Cost | | Duration | | Total | |
|---|---|---|---|---|---|---|---|---|---|---|
| Initial costs to establish control | | | | | | | | | | |
| | High | [a] | 10,000 | ac @ | $1,200 | /ac/year for | 3 | years | 36,000,000 | |
| | Low | [b] | 10,000 | ac @ | $800 | /ac/year for | 3 | years | 24,000,000 | |
| Annual Operating Costs | | | | | | | | | | |
| | High | [c] | 2,000 | ac @ | $600 | | | | 1,200,000 | /yr |
| | Low | [d] | 1,000 | ac @ | $400 | | | | 400,000 | /yr |
| | | | | | | | | | | |
| **Undiscounted annual costs** | | | 20 | years | | | | | | |
| High | | | | | | | | | 3,000,000 | /yr |
| Average of high and low | | | | | | | | | 2,300,000 | /yr |
| Low | | | | | | | | | 1,600,000 | /yr |
| | | | | | | | | | | |
| **Notes** | | | | | | | | | | |
| [a],[b] | 10,000 acre target provided by C. Wilcox (DFW, July 18, 2017) | | | | | | | | | |
| [a],[b] | DBW (E. Hard) provided ball park estimate for upfront SAV control costs of $2,500-$3,500 for three years (following up with him to confirm this cost is over three years and not annual cost every year for 3 years). Note control FAV is easier than SAV, so by using SAV cost for estimate we have overestimated cost if some of the 10,000 acres is FAV. | | | | | | | | | |
| [c] | Assume area to be sprayed to maintain weed free area (after control phase is complete) is 20% of initial area and sprayed half as often (Compass/Hamilton assumption - following up with DBW for better | | | | | | | | | |
| [d] | Assume area to be sprayed is 10% of initial area and sprayed half as often (Compass/Hamilton assumption - following up with DBW for further input). | | | | | | | | | |

**Table 49: Cost estimate for Action #2: North Delta Food Web AM Projects**

| Component | | Notes | Quantity | | Unit Cost | | Frequency | | Total | |
|---|---|---|---|---|---|---|---|---|---|---|
| Initial Costs | | | | | | | | | | |
| | High | [a] | | | | | | | | |
| | Low | [b] | | | | | | | | |
| Annual Operating Costs | | | | | | | | | | |
| | High | [c] | | | $300,000 | /year for | 70% | of years | 210,000 | /yr |
| | Low | [d] | | | $100,000 | /year for | 70% | of years | 70,000 | /yr |
| Water Costs | | | 24,000 | af/pulse flow and 2 pulse flows each year with September free water | | | | | | |
| | High | [e] | 24,000 | af @ | $398 | /af | 70% | of years | 6,689,605 | /yr |
| | Medium | [f] | 24,000 | af @ | $265 | /af | 70% | of years | 4,459,737 | /yr |
| | Low | [g] | 8,000 | af @ | $265 | /af | 70% | of years | 1,486,579 | /yr |
| | | | | | | | | | | |
| **Undiscounted average annual costs** | | | | | | | | | | |
| High | | | | | | | | | 6,899,605 | /yr |
| Average of high and low | | | | | | | | | 4,228,092 | /yr |
| Low | | | | | | | | | 1,556,579 | /yr |

**Notes**

Table RAC-2a Frequency of Water Year Types & Assumed Water Prices

Assumed water prices from CAMT, Aug. 11, 2017 meeting discussion.

Source: Table DFL-5b

| Year Type | Historic Frequency | Project Frequency | | Water Price ($/af) |
|---|---|---|---|---|
| W | 33% | 17% | | $100 |
| AN | 14% | 14% | | $125 |
| BN | 18% | 18% | | $250 |
| D | 21% | 21% | | $500 |
| C | 14% | 0% | | |
| Total | 100% | 70% | Avg: | $265 |

[a]

[b]

[c] For staff time & monitoring (estimate from T. Sommer)

[d] For staff time. Assumes monitoring conducted through existing programs. (Compass/S. Hamilton assumptio

[e] 150% of medium cost (S. Hamilton assumption)

[f] See Table RAC-2a for calculation of water cost

[g] Assumes only consumptively used water needs to be purchased.

**Possible Improvements**

Confirm if only consumed water needs to be purchased

Confirm if water is free in September

**Table 50: Cost estimate for Action #3: Spring/Summer Outflow Augmentation**

| Component | | Notes | Quantity | | Unit Cost | | Frequency | | Total | |
|---|---|---|---|---|---|---|---|---|---|---|
| Initial Costs | | | | | | | | | | |
| | High | [a] | | | | | | | | |
| | Low | [b] | | | | | | | | |
| Annual Operating Costs | | | | | | | | | | |
| | High | [c] | | | $5,000,000 | /year for | 53% | of years | 2,650,000 | /yr |
| | Low | [d] | | | $0 | /year for | 53% | of years | - | /yr |
| Water Costs | | | | | | | | | | |
| | High | [e] | 250,000 | af @ | $475 | /af | 53% | of years | 62,966,056 | /yr |
| | Medium | [f] | 250,000 | af @ | $317 | /af | 53% | of years | 41,977,371 | /yr |
| | Low | [g] | 250,000 | af @ | $206 | /af | 53% | of years | 27,285,291 | /yr |
| | | | | | | | | | | |
| **Undiscounted average annual costs** | | | | | | | | | | |
| High | | | | | | | | | 65,616,056 | /yr |
| Average of high and low | | | | | | | | | 46,450,673 | /yr |
| Low | | | | | | | | | 27,285,291 | /yr |

**Notes**

Table RAC-3a Frequency of Water Year Types & Assumed Water Prices

Assumed water prices from CAMT, Aug. 11, 2017 meeting discussion.

Source: Table DFL-5b

| Year Type | Historic Frequency | Project Frequency | | Water Price ($/af) |
|---|---|---|---|---|
| W | 33% | 0% | | $100 |
| AN | 14% | 14% | | $125 |
| BN | 18% | 18% | | $250 |
| D | 21% | 21% | | $500 |
| C | 14% | 0% | | |
| Total | 100% | 53% | Avg: | $317 |

[a]

[b]

[c] Monitoring Costs (ball park estimate from C. Wilcox)

[d] Assumes all monitoring can be conducted through existing monitoring programs (S. Hamilton assumption)

[e] Assumes 150% of average cost (S. Hamilton assumption)

[f] See Table RAC-3a for calculation of water cost

[g] Assumes 65% of average cost (S. Hamilton assumption)

**Table 51: Cost estimate for Action #4: Suisun Marsh Salinity Control Gates**

| Component | | Notes | Quantity | | Unit Cost | | Frequency | | Total | |
|---|---|---|---|---|---|---|---|---|---|---|
| Initial Costs | | | | | | | | | | |
| | High | [a] | | | | | | | | |
| | Low | [b] | | | | | | | | |
| Annual Operating Costs | | | | | | | | | | |
| | High | [c] | | | $300,000 | /year for | 39% | of years | 117,000 | /yr |
| | Low | [d] | | | $100,000 | /year for | 39% | of years | 39,000 | /yr |
| Water Costs | | | | | | | | | | |
| | High | [e] | 60,000 | af @ | $576 | /af | 39% | of years | 13,468,605 | /yr |
| | Medium | [f] | 60,000 | af @ | $384 | /af | 39% | of years | 8,979,070 | /yr |
| | Low | [g] | 60,000 | af @ | $249 | /af | 39% | of years | 5,836,395 | /yr |
| | | | | | | | | | | |
| Undiscounted average annual costs | | | | | | | | | | |
| High | | | | | | | | | 13,585,605 | /yr |
| Average of high and low | | | | | | | | | 9,730,500 | /yr |
| Low | | | | | | | | | 5,875,395 | /yr |

**Notes**

Table RAC-4a Frequency of Water Year Types & Assumed Water Prices

Assumed water prices from CAMT, Aug. 11, 2017 meeting discussion.

Source: Table DFL-5b

| Year Type | Historic Frequency | Project Frequency | | Water Price ($/af) |
|---|---|---|---|---|
| W | 33% | 0% | | $100 |
| AN | 14% | 0% | | $125 |
| BN | 18% | 18% | | $250 |
| D | 21% | 21% | | $500 |
| C | 14% | 0% | | |
| Total | 100% | 39% | Avg: | $384 |

| | |
|---|---|
| [a] | |
| [b] | |
| [c] | For staff time & monitoring (estimate from T. Sommer) |
| | See Table RAC-4a for calculation of frequency of action |
| [d] | For staff time. Assumes all monitoring can be conducted through existing monitoring programs (S. Hamilton assumption) |
| [e] | Assumes 150% of average cost (S. Hamilton assumption) |
| [f] | See Table RAC-4a for calculation of water cost |
| [g] | Assumes 65% of average cost (S. Hamilton assumption) |

**Possible Improvements**

Discuss if 60 TAF of water is really needed to offset salinity increases in the Delta with this action - i.e. do analysis on whether any water users would be impacted by this level of salinity increase.

**Table 52: Cost estimate for Action #5: Sediment supplementation**

| Component | | Notes | Quantity | | Unit Cost | | Frequency | | Total | |
|---|---|---|---|---|---|---|---|---|---|---|
| Initial Costs | | | | | | | | | | |
| | High | [a] | | | | | | | | |
| | Low | [b] | | | | | | | | |
| Annual Operating Costs | | | | | | | | | | |
| | High | [c] | 500,000 | cu yds | $8,000,000 | /year for | 53% | of years | 4,240,000 | /yr |
| | Low | [d] | 400,000 | cu yds | $6,400,000 | /year for | 53% | of years | 3,392,000 | /yr |
| Undiscounted average annual costs | | | | | | | | | | |
| High | | | | | | | | | 4,240,000 | /yr |
| Average of high and low | | | | | | | | | 3,816,000 | /yr |
| Low | | | | | | | | | 3,392,000 | /yr |

**Notes**

Table RAC-5a Frequency of Water Year Types & Assumed Water Prices

Source: Table DFL-5b

| Year Type | Historic Frequency | Project Frequency |
|---|---|---|
| W | 33% | 0% |
| AN | 14% | 0% |
| BN | 18% | 18% |
| D | 21% | 21% |
| C | 14% | 14% |
| Total | 100% | 53% |

[a]

[b]

[c] MacWilliams and Bever (2017) - Sediment Supplementation Initial Evaluation on increasing turbidity by 10 NTU in LSZ

See Table RAC-5a for calculation of frequency of action

[d] MacWilliams and Bever (2017) - Sediment Supplementation Initial Evaluation - using opinion that the amount of sediment could be reduced by 20% to achieve objective of increasing turbidity by 10 NTU on average

**Possible Improvements**

Consider scaled down action by just putting enough sediment in to reach 10-12 NTU in LSZ (current definition is to increase turbidity by NTU)

**Table 53: Cost estimate for Action #7: Roaring River Distribution System Food Production**

| Component | | Notes | Quantity | | Total | |
|---|---|---|---|---|---|---|
| Initial Costs | | | | | | |
| | High | [a] | | | 1,000,000 | |
| | Low | [b] | | | | |
| Annual Operating Costs | | | | | | |
| | High | [c] | | | 200,000 | /yr |
| | Low | [d] | | | 125,000 | /yr |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| Undiscounted annual costs | | | 20 | years | | |
| High | | | | | 250,000 | /yr |
| Average of high and low | | | | | 212,500 | /yr |
| Low | | | | | 175,000 | /yr |
| | | | | | | |
| **Notes** | | | | | | |
| [a] | Capital costs: $1 million for new drain gate on western side (already in State budget) | | | | | |
| [b] | | | | | | |
| [c] | $100,000 for O&M (compass assumption based on 10% of capital), 1 FTE @ 100,000/year (Compass/S.Hamilton estimate) | | | | | |
| [d] | $100,000 for O&M (compass assumption based on 10% of capital), $25,000 for staff time (E. Loboschefsky estimate) | | | | | |

## Table 54: Cost estimate for Action #8: Coordinate Managed Wetland Flood and Drain Operations

| Component | | Notes | Quantity | | Unit Cost | | Frequency | | Total | |
|---|---|---|---|---|---|---|---|---|---|---|
| Initial Costs | | | | | | | | | | |
| | High | [a] | | | $10,000,000 | | | | 10,000,000 | |
| | Low | [b] | | | | | | | | |
| Annual Operating Costs | | | | | | | | | | |
| High | Staff | [c] | | | $125,000 | /year for | 100% | of years | 125,000 | /yr |
| | O&M | [d] | 7,500 | ac @ | 360 | /ac/year for | 100% | of years | 2,700,000 | /yr |
| | Incentives | [e] | 7,500 | ac @ | $5 | /ac | | | 37,500 | /yr |
| | Subtotal | | | | | | | | 2,862,500 | |
| | | | | | | | | | | |
| Low | Staff | [f] | | | $125,000 | /year for | 100% | of years | 125,000 | /yr |
| | O&M | [g] | 7,500 | ac @ | $133 | /ac/year for | 100% | of years | 1,000,000 | /yr |
| | Incentives | [h] | 7,500 | ac @ | $3 | /ac | | | 22,500 | /yr |
| | Subtotal | | | | | | | | 1,147,500 | |
| | | | | | | | | | | |
| Undiscounted annual costs | | | 20 | years | | | | | | |
| High | | | | | | | | | 3,362,500 | /yr |
| Average of high and low | | | | | | | | | 2,505,000 | /yr |
| Low | | | | | | | | | 1,647,500 | /yr |

**Notes**

Table RAC-8a Frequency of Water Year Types & Assumed Water Prices

Source: Table DFL-5b

| Year Type | Historic Frequency | Project Frequency | | Water Price ($/af) |
|---|---|---|---|---|
| W | 33% | 33% | | $100 |
| AN | 14% | 14% | | $125 |
| BN | 18% | 18% | | $250 |
| D | 21% | 21% | | $500 |
| C | 14% | 14% | | |
| Total | 100% | 100% | Avg: | $202 |

[a] Assume an upfront investment of $10m (Compass assumption based on cost of drain gate in RRDS and input that infrastructure upgrades would be desirable to enable flooding/draining for this action)

[b]

[c] Assume 1 FTE to co-ordinate =$100,000/year (Compass assumption)
Assume outreach costs =$25,000/year (Compass assumption)

[d] Incremental changes & maintenance
Hamilton assumption: $15/af for 7,500 ac * 1 af/ac cycled 24 times = 2,700,000

[e] E. Loboschefsky guess for incentive amount

[f] Assume 1 FTE to co-ordinate =$100,000/year (Compass assumption)
Assume outreach costs =$25,000/year (Compass assumption)

[g] Incremental changes & maintenance 10% of initial cost (Compass assumption)

[h] E. Loboschefsky guess for incentive amount

**Possible Improvements**

Get more input on upfront capital costs

Get O&M information from duck clubs (esp. for flushing flows in Jan-Feb period) - Suisun Marsh Conservation District is a possible contact

**Table 55: Cost estimate for Action #9: Adjust Fish Salvage Operations during Summer and Fall**

| Component | | Notes | Quantity | | Total | |
|---|---|---|---|---|---|---|
| Initial Costs | | | | | | |
| | High | [a] | | | 5,000,000 | |
| | Low | [b] | | | 2,500,000 | |
| Annual Operating Costs | | | | | | |
| | High | [c] | | | 1,000,000 | /yr |
| | Low | [d] | | | 500,000 | /yr |
| | | | | | | |
| Undiscounted annual costs | | | 20 | years | | |
| High | | | | | 1,250,000 | /yr |
| Average of high and low | | | | | 937,500 | /yr |
| Low | | | | | 625,000 | /yr |
| | | | | | | |
| **Notes** | | | | | | |
| [a] | Assume an upfront investment of $5m (guess from T. Sommer) | | | | | |
| [b] | Assumes upfront investment could be half (guess by S Hamilton) | | | | | |
| [c] | Guess from T.Sommer | | | | | |
| [d] | Assumes O&M could be half (guess by S Hamilton) | | | | | |

**Table 56: Cost estimate for Action #10: Stormwater Discharge Management in Ulatis Creek Watershed**

| Component | | Notes | Quantity | | Total | |
|---|---|---|---|---|---|---|
| Initial Costs | | | | | | |
| | High | [a] | | | 267,752,306 | |
| | Low | [b] | | | 1,270,598 | |
| Annual Operating Costs | | | | | | |
| | High | [c] | | | 375,650 | /yr |
| | Low | [d] | | | 127,060 | /yr |
| | | | | | | |
| Undiscounted annual costs | | | 20 | years | | |
| High | | | | | 13,763,265 | /yr |
| Average of high and low | | | | | 6,976,927 | /yr |
| Low | | | | | 190,590 | /yr |
| | | | | | | |
| **Notes** | | | | | | |
| [a] | High estimate include land purchase and low efficiency of stormwater mgmt. | | | | | |
| [b] | Low estimate includes no land purchase and high efficiency of stormwater mgmt. | | | | | |
| [c],[d] | O&M - Shawn found: 4% - 14.1%. Compass assumes 10% of high construction cost and 10% of low construction cost to get range of operating costs | | | | | |
| | | | | | | |
| **Possible Improvements** | | | | | | |
| | The assumed land cost is making the high estimate very high. Could get more information on what type of land would be needed to do this action and the market value of that land (e.g. land in the flood zone might be less costly than what is assumed here) | | | | | |

**Table 57: Cost estimate for Action #11: Rio Vista Research Station and Fish Technology Center**

| Component | | Notes | Quantity | Interest | Total | |
|---|---|---|---|---|---|---|
| Initial Costs | | | | | | |
| | High | [a] | | | - | |
| | Low | [b] | | | - | |
| Annual Operating Costs | | | | | | |
| | High | [c] | 20-yr lease to purchase agreement (high) minus rental | | 7,500,000 | /yr |
| | Low | [d] | 20-yr lease to purchase agreement (low) minus rental | | 5,500,000 | /yr |
| | | | | | | |
| **Undiscounted annual costs** | | | 20 years | | | |
| High | | | | | 7,500,000 | /yr |
| Average of high and low | | | | | 6,500,000 | /yr |
| Low | | | | | 5,500,000 | /yr |
| | | | | | | |
| **Notes** | | | | | | |
| [a],[b] | No upfront cost because research station is financed through a 20-yr lease to purchase agreement | | | | | |
| [c] | Economic Analysis for IEP Facility Options. High estimate of annual lease cost is $9,000,000 per year. Rental savings is 1.5 M per year on average. | | | | | |
| [d] | Economic Analysis for IEP Facility Options. Low estimate of annual lease cost is 7,000,000 per year. Rental savings is 1.5 M per year on average. | | | | | |

**Table 58: Cost estimate for Action #12: Near-term Delta Smelt Habitat Restoration**

| Component | | Notes | Quantity | | Unit Cost | | Total | |
|---|---|---|---|---|---|---|---|---|
| Initial Cost | | | | | | | | |
| | High | [a] | 11,000 | ac | $30,000 | /ac | 330,000,000 | |
| | Low | [b] | 11,000 | ac | $20,000 | /ac | 220,000,000 | |
| Annual Operating Costs | | | | | | | | |
| | High | [c] | 11,000 | ac | $500 | /ac | 5,500,000 | /yr |
| | Low | [d] | 11,000 | ac | $250 | /ac | 2,750,000 | /yr |
| | | | | | | | | |
| **Undiscounted annual costs** | | | 20 | years | | | | |
| High | | | | | | | 22,000,000 | /yr |
| Average of high and low | | | | | | | 17,875,000 | /yr |
| Low | | | | | | | 13,750,000 | /yr |
| | | | | | | | | |
| **Notes** | | | | | | | | |
| [a],[b] | Rule of thumb: Upfront costs: 20,000-30,000 per acre to restore tidal wetland (C. Wilcox, Jan. 2018) | | | | | | | |
| [c],[d] | If no levee then ongoing costs are low; some policing and veg. If levee then costs are higher. (C. Wilcox comment) | | | | | | | |
| [c] | High estimate from C. Wilcox (Jan. 2018) | | | | | | | |
| [d] | Low estimate from C. Wilcox (Jan. 2018) | | | | | | | |

**Table 59: Cost estimate for Action #13: Franks Tract**

| Component | | Notes | Quantity | | | Total | |
|---|---|---|---|---|---|---|---|
| Initial Cost | | | | | | | |
| | High | [a] | | | | 375,000,000 | |
| | Low | [b] | | | | 300,000,000 | |
| Annual Operating Costs | | | | | | | |
| | High | [c] | 979 | 750 | per acre | 734,250 | /yr |
| | Low | [d] | 979 | 500 | per acre | 489,500 | /yr |
| | | | | | | | |
| **Undiscounted annual costs** | | | 20 | years | | | |
| High | | | | | | 19,484,250 | /yr |
| Average of high and low | | | | | | 17,486,875 | /yr |
| Low | | | | | | 15,489,500 | /yr |
| | | | | | | | |
| **Notes** | | | | | | | |
| [a],[b] | C. Wilcox provided ball park upfront costs. | | | | | | |
| [c] | High estimate from C. Wilcox (Jan. 2018) | | | | | | |
| [d] | Low estimate from C. Wilcox (Jan. 2018) | | | | | | |

## Appendix 4 - Qualitative Scoring for Ecological Objectives

### Delta Smelt Spawning/Recruitment

This sub-objective was scored by TWG members. Each TWG member scored each action independently according to the directions below and then discussed scoring on a conference call. Scores were adjusted by TWG members based on new information and considerations from discussion.

**Directions provided to participants:**

- Enter numbers -3 to +3 to communicate your view on how each of the full build-out actions described in the accompanying presentation might affect this issue. Use the scoring key (Figure 38) to aid in scoring. Note considerations that are not captured by the scoring key for group discussion (we may choose to over-ride scoring key fora given action if an additional consideration is significant and the group wants it included).
- Consider only life stages during the period that we have not modeled (Feb. 1 to May 30). Life stages include: Spawning, egg (survival), larvae. Juveniles are excluded as their growth and survival is modelled from June 1 onwards.
- For 'geographic extent affected', consider overlap between the spatial influence of the action and the spatial distribution of delta smelt during this time period.

**Figure 38: Scoring key for Delta Smelt Spawning/Recruitment**

| | | | | | |
|---|---|---|---|---|---|
| If net benefit | | | Geographic Extent Affected | | |
| | # Life stages | | Lo | Hi | |
| | | >1 life stage | 2 | 3 | |
| | | One life stage | 1 | 2 | |
| If no net benefit or adverse effect | | | | | |
| | | | 0 | 0 | |
| If net adverse effect | | | | | |
| | # Life stages | | Lo | Hi | |
| | | >1 life stage | -2 | -3 | |
| | | One life stage | -1 | -2 | |

**Table 60: Group results for Delta Smelt Spawning/Recruitment**

| | | Person | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Resiliency Strategy Action - Full Build-out Scale Scenario** | **Max-Min** | 1 | 2 | 3 | 4 | 5 | | Ave |
| 1. Aquatic Weed Control | 1 | 3 | 2 | 2 | 3 | 2 | | 2.4 |
| 2. North Delta Food Web Adaptive Management Projects | 0 | 0 | 0 | 0 | 0 | 0 | | 0 |
| 3. Outflow Augmentation | 1 | 1 | 1 | 0 | 1 | 0 | | 0.6 |
| 4. Reoperation of the Suisun Marsh Salinity Control Gates | 1 | 0 | 0 | 1 | 0 | 1 | | 0.4 |
| 5. Sediment Supplementation in the Low Salinity Zone | 1 | 1 | 1 | 1 | 0 | 1 | | 0.8 |
| 7. Roaring River Distribution System Food Production | 1 | 1 | 0 | 1 | 1 | 1 | | 0.8 |
| 8. Coordinate Managed Wetland Flood and Drain Operations in Suisun Mars | 1 | 2 | 1 | 2 | 1 | 2 | | 1.6 |
| 9. Adjust Fish Salvage Operations during Summer and Fall | 0 | 0 | 0 | 0 | 0 | 0 | | 0 |
| 10. Stormwater Discharge Management | 1.5 | 1 | 2 | 2 | 2 | 0.5 | | 1.5 |
| 11. Rio Vista Research Station and Fish Technology Center | 0 | 0 | 0 | 0 | 0 | 0 | | 0 |
| 12. Near-term Delta Smelt Habitat Restoration | 1 | 2 | 3 | 2 | 3 | 2 | | 2.4 |
| 13. Franks Tract Restoration Feasibility Study | 1 | 1 | 1 | 1 | 2 | 1 | | 1.2 |

**Table 61: Rationales/Discussion for Scores**

| Action (Full build-out scale) | Average Score | Rationale/Discussion |
|---|---|---|
| Aquatic Weed Control | 2.4 | • May open up both spawning and rearing habitat |
| North Delta Food Web Adaptive Management Projects | 0 | • This action occurs outside the effect window of concern here (Feb. 1 to May 30)<br>• Food web benefits are covered through the Rose BEM modeling |
| Spring/Summer Outflow Augmentation | 0.6 | • May have benefit to larval survival but many of the relationships are due to indirect benefits that have not been well quantified<br>• Effect limited by small scale of action (250 TAF)<br>• This action will only sometimes occur within the window of concern here (Feb. 1 to May 30) |
| Reoperation of the Suisun Marsh Salinity Control Gates | 0.4 | • This action occurs outside the effect window of concern here (Feb. 1 to May 30) but there may be some indirect benefits |
| Sediment Supplementation in the Low Salinity Zone | 0.8 | • Limited effects period overlap<br>• Will help delta smelt larvae avoid predation and will improve food visibility for delta smelt larvae |
| Roaring River Distribution System Food Production | 0.8 | • Good overlap with effects window, rapid dilution effect of small volume of enriched water |
| Coordinate Managed Wetland Flood and Drain Operations in Suisun Marsh | 1.6 | • Good effects period overlap and enhanced food in key area<br>• Multiple lifestages influenced in Suisun Marsh and assuming optimal DO management this has the potential to directly improve prey availability for growth and survival. Also the diffuse nature of using multiple outflow points will reduce the direct impacts of contaminants and reduced DO. |

| Action (Full build-out scale) | Average Score | Rationale/Discussion |
|---|---|---|
| Adjust Fish Salvage Operations during Summer and Fall | 0 | • No overlap with effects period, small proportion of predator population, dynamic predator situation at release sites, small predators<br>• This action does not directly overlap therefore it is through indirect effects that it can be judged. The action is unlikely to have lasting impacts that could translate into improved adult/larvae relationship |
| Stormwater Discharge Management | 1.5 | • Good effects period overlap<br>• Assuming impacts of all stormawater everywhere else is background mortality than there will be benefits to adults and subsequent larvae in a limited area |
| Rio Vista Research Station and Fish Technology Center | 0 | • No effect |
| Near-term Delta Smelt Habitat Restoration | 2.4 | • Large area and multiple life stages will benefit through improved food and increased turbidity |
| Franks Tract Restoration | 1.2 | • Could improve habitat quality and reduce fish entrainment but geographically localized |

### Delta Smelt Resiliency to Random Events

This sub-objective was scored by all TWG members. Each TWG member scored each action independently according to the directions below and then discussed scoring on a conference call. Scores were adjusted by TWG members based on new information and considerations from discussion.

**Directions provided to participants:**

- Enter numbers -3 to +3 to communicate your view on how each of the full build-out actions described in the accompanying presentation might affect this issue. Use the scoring key (Figure 39) to aid in scoring. Note considerations that are not captured by the scoring key for group discussion (we may choose to over-ride scoring key fora given action if an additional consideration is significant and the group wants it included).
- Consider effects over the whole year.
- Score reflects the degree to which the action in helping to minimize the overall probability of extinction by improving life history.
- For ‘geographic extent affected’, consider overlap between the spatial/temporal influence of the action and the spatial/temporal distribution of delta smelt.

**Figure 39: Scoring key for Delta Smelt Resiliency to Random Events**

| If net benefit | | | Geographic Extent Affected | |
|---|---|---|---|---|
| | # Life stages | | Lo | Hi |
| | | >1 life stage | 2 | 3 |
| | | One life stage | 1 | 2 |
| If no net benefit or adverse effect | | | | |
| | | | 0 | 0 |
| If net adverse effect | | | | |
| | # Life stages | | Lo | Hi |
| | | >1 life stage | -2 | -3 |
| | | One life stage | -1 | -2 |

**Table 62: Group results for Delta Smelt Resiliency to Random Events**

| | | Person | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Resiliency Strategy Action - Full Build-out Scale Scenario** | **Max-Min** | 1 | 2 | 3 | 4 | 5 | | Average |
| 1. Aquatic Weed Control | 1 | 3 | 3 | 2 | 3 | 3 | | 2.8 |
| 2. North Delta Food Web Adaptive Management Projects | 1 | 1 | 2 | 2 | 2 | 1 | | 1.6 |
| 3. Outflow Augmentation | 2 | 1 | 1.5 | 0 | 1.5 | 2 | | 1.2 |
| 4. Reoperation of the Suisun Marsh Salinity Control Gates | 1 | 1 | 2 | 2 | 1 | 1 | | 1.4 |
| 5. Sediment Supplementation in the Low Salinity Zone | 1 | 3 | 2 | 2 | 2 | 2 | | 2.2 |
| 7. Roaring River Distribution System Food Production | 1 | 1 | 0 | 1 | 1 | 1 | | 0.8 |
| 8. Coordinate Managed Wetland Flood and Drain Operations in Suisun Mars | 1 | 2 | 1 | 2 | 1 | 1 | | 1.4 |
| 9. Adjust Fish Salvage Operations during Summer and Fall | 1 | 0 | 1 | 0 | 0 | 0 | | 0.2 |
| 10. Stormwater Discharge Management | 0.5 | 1 | 1 | 1 | 1 | 0.5 | | 0.9 |
| 11. Rio Vista Research Station and Fish Technology Center | 1 | 1 | 1 | 1.5 | 2 | 1 | | 1.3 |
| 12. Near-term Delta Smelt Habitat Restoration | 1 | 3 | 3 | 3 | 3 | 2 | | 2.8 |
| 13. Franks Tract Restoration Feasibility Study | 1 | 1 | 1 | 1 | 2 | 1 | | 1.2 |

**Table 63: Rationales/Discussion for Scores**

| **Action (Full build-out scale)** | **Average Score** | **Rationale/Discussion** |
|---|---|---|
| Aquatic Weed Control | 2.8 | • Improves distribution and perhaps life history diversity<br>• Large geographic and life stage effect |
| North Delta Food Web Adaptive Management Projects | 1.6 | • Improves distribution and perhaps life history diversity<br>• Benefits juveniles and sub-adults<br>• High benefit in North Delta region<br>• Some effect in downstream areas during summer |
| Spring/Summer Outflow Augmentation | 1.2 | • Improves distribution and perhaps life history diversity<br>• Effects one life stage but large geographic area<br>• Expands low salinity zone and moves it away from Delta hazards (entrainment, high temps, etc.) |

| Action (Full build-out scale) | Average Score | Rationale/Discussion |
|---|---|---|
| Reoperation of the Suisun Marsh Salinity Control Gates | 1.4 | • Improves distribution and perhaps life history diversity<br>• High benefit in Suisun region<br>• Possible negative confluence area effects, risks of 'ruining a good thing' |
| Sediment Supplementation in the Low Salinity Zone | 2.2 | • Improves distribution and perhaps life history diversity (improves overlap of turbidity and food availability)<br>• Influences a large area and at least two life stages (juveniles, sub-adults) |
| Roaring River Distribution System Food Production | 0.8 | • Improves distribution and perhaps life history diversity<br>• Modest benefit in Suisun region<br>• Potential for multiple life stages to benefit |
| Coordinate Managed Wetland Flood and Drain Operations in Suisun Marsh | 1.4 | • Improves distribution and perhaps life history diversity<br>• Potential for multiple life stages to benefit in Suisun region<br>• Assumes optimal dissolved oxygen management |
| Adjust Fish Salvage Operations during Summer and Fall | 0.2 | • Provides a very small benefit to juveniles over a discrete range around the confluence – this benefit is sufficiently covered through the Rose BEM modeling |
| Stormwater Discharge Management | 0.9 | • Improves distribution and perhaps life history diversity<br>• Modest benefit to multiple life stages in North Delta |
| Rio Vista Research Station and Fish Technology Center | 1.3 | • Refuge population acts as "life boat" for population |
| Near-term Delta Smelt Habitat Restoration | 2.8 | • Improves distribution and perhaps life history diversity (expands area of higher quality habitat)<br>• Large geographic and life stage influence |

| Action (Full build-out scale) | Average Score | Rationale/Discussion |
|---|---|---|
| Franks Tract Restoration | 1.2 | • Improves distribution and perhaps life history diversity<br>• Influences several life stages<br>• Localized geographic effect |

### Delta Smelt Learning

This sub-objective was scored by all TWG members. Each TWG member scored each action independently according to the directions below and then discussed scoring on a conference call. Scores were adjusted by TWG members based on new information and considerations from discussion.

**Directions provided to participants:**

- Enter numbers -3 to +3 to communicate your view on how each of the full build-out actions described in the accompanying presentation might affect this issue. Use the scoring key (Figure 40) to aid in scoring. Note considerations that are not captured by the scoring key for group discussion (we may choose to over-ride scoring key fora given action if an additional consideration is significant and the group wants it included).
- Concerns our ability to learn about 1) Action effectiveness and 2) fundamental science about DS
    - o For (1), consider ability to meaningfully detect the hypothesized effect and confirm cause-effect relationship with management action
    - o For (2), consider general applicability of the learning for other Delta Smelt applications

**Figure 40: Scoring key for Delta Smelt Learning**

| | | | | | | |
|---|---|---|---|---|---|---|
| If net benefit | | | | Learning about transferrable DS science | | |
| | | | | Lo | Hi | |
| | Ability to learn | | Hi | 2 | 3 | |
| | about action | | Lo | 1 | 2 | |
| | | | | | | |
| | No meaningful ability to learn | | | | | |
| | | 0 | | | | |

**Table 64: Group results for Delta Smelt Learning**

| | | Person | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Resiliency Strategy Action - Full Build-out Scale Scenario** | **Max-Min** | 1 | 2 | 3 | 4 | 5 | | Average |
| 1. Aquatic Weed Control | 1 | 3 | 2 | 2 | 2 | 2 | | 2.2 |
| 2. North Delta Food Web Adaptive Management Projects | 1.5 | 2 | 2 | 3 | 2 | 1.5 | | 2.1 |
| 3. Outflow Augmentation | 1 | 1 | 2 | 1 | 1 | 2 | | 1.4 |
| 4. Reoperation of the Suisun Marsh Salinity Control Gates | 1.5 | 3 | 2 | 2 | 2 | 1.5 | | 2.1 |
| 5. Sediment Supplementation in the Low Salinity Zone | 1 | 3 | 2 | 2 | 2 | 2 | | 2.2 |
| 7. Roaring River Distribution System Food Production | 1 | 1 | 2 | 1 | 2 | 1 | | 1.4 |
| 8. Coordinate Managed Wetland Flood and Drain Operations in Suisun Mars | 1 | 2 | 2 | 2.5 | 2 | 1.5 | | 2 |
| 9. Adjust Fish Salvage Operations during Summer and Fall | 1 | 0 | 1 | 1 | 1 | 0 | | 0.6 |
| 10. Stormwater Discharge Management | 1 | 1 | 2 | 2 | 2 | 1 | | 1.6 |
| 11. Rio Vista Research Station and Fish Technology Center | 0 | 3 | 3 | 3 | 3 | 3 | | 3 |
| 12. Near-term Delta Smelt Habitat Restoration | 1 | 3 | 3 | 3 | 2 | 2 | | 2.6 |
| 13. Franks Tract Restoration Feasibility Study | 1 | 2 | 2 | 1 | 2 | 1 | | 1.6 |

**Table 65: Rationales/Discussion for Scores**

| Action (Full build-out scale) | Average Score | Rationale/Discussion |
|---|---|---|
| Aquatic Weed Control | 2.2 | • Allows substantial learning, assuming we have sufficient monitoring and evaluation<br>• Full build out scale is dispersed among regions/habitats |
| North Delta Food Web Adaptive Management Projects | 2.1 | • Allows substantial learning, assuming we have sufficient monitoring and evaluation<br>• Valuable insights into DS trophic relationships |
| Spring/Summer Outflow Augmentation | 1.4 | • One of the hardest to detect change from action |
| Reoperation of the Suisun Marsh Salinity Control Gates | 2.1 | • Allows substantial learning, assuming we have sufficient monitoring and evaluation<br>• High experimental manipulation ability<br>• Valuable learning of species' response in key area |
| Sediment Supplementation in the Low Salinity Zone | 2.2 | • Allows substantial learning, assuming we have sufficient monitoring and evaluation<br>• Potentially large effect in broad area, some manipulation possible, turbidity is easily measured |
| Roaring River Distribution System Food Production | 1.4 | • Allows substantial learning, assuming we have sufficient monitoring and evaluation<br>• Good potential for lower trophic level effect measurement, not so for delta smelt (small sample size) |
| Coordinate Managed Wetland Flood and Drain Operations in Suisun Marsh | 2 | • Allows substantial learning, assuming we have sufficient monitoring and evaluation<br>• Larger scale than Roaring River Distribution System action<br>• Good potential for lower trophic level effect measurement, not so for delta smelt (small sample size) |
| Adjust Fish Salvage Operations during Summer and Fall | 0.6 | • One of the hardest to detect change from action |

| Action (Full build-out scale) | Average Score | Rationale/Discussion |
|---|---|---|
| Stormwater Discharge Management | 1.6 | • Allows substantial learning, assuming we have sufficient monitoring and evaluation<br>• Messy "experimental " circumstances (scale, duration, loadings in time) |
| Rio Vista Research Station and Fish Technology Center | 3 | • Project is focused on supporting learning |
| Near-term Delta Smelt Habitat Restoration | 2.6 | • Allows substantial learning, assuming we have sufficient monitoring and evaluation<br>• Many opportunities for manipulation and species studies |
| Franks Tract Restoration | 1.6 | • Allows substantial learning, assuming we have sufficient monitoring and evaluation |

### Salmon

This sub-objective was scored by two TWG members (Shawn Acuña and Ted Sommer), Brett Harvey and Brad Cavallo. Each participant scored each action independently. Only TWG members discussed scores via conference call and had opportunity to adjust based on new information and considerations from discussion.

**Directions provided to participants:**

- Enter numbers -3 to +3 to communicate your view on how each of the full build-out actions described in the accompanying presentation might affect this issue. Use the scoring key (Figure 41Figure 40) to aid in scoring. Note considerations that are not captured by the scoring key for group discussion (we may choose to over-ride scoring key fora given action if an additional consideration is significant and the group wants it included).
- Score reflects net effect across all salmon species and runs in aggregate.
- For ‘geographic extent affected’, consider overlap between the spatial/temporal influence of the action and the spatial/temporal distribution of salmon.

**Figure 41: Scoring key for Salmon**

| If net benefit | | Geographic Extent Affected | |
|---|---|---|---|
| | Migrations affected | Lo | Hi |
| | Up AND Down | 2 | 3 |
| | Up OR Down | 1 | 2 |
| If no net benefit or adverse effect | | | |
| | | 0 | 0 |
| If net adverse effect | | | |
| | Migrations affected | Lo | Hi |
| | Up AND Down | -2 | -3 |
| | Up OR Down | -1 | -2 |
| | | | |
| Consider all salmon species | | | |
| | Up migration | Fall and Spring (Sep - Jun) | |
| | Down migration | Winter and Spring (Dec - Jun) | |

**Table 66: Group results for Salmon**

| | | Person | | | | | |
|---|---|---|---|---|---|---|---|
| **Resiliency Strategy Action - Full Build-out Scale Scenario** | **Max-Min** | 1 | 2 | 3 | 4 | | Average |
| 1. Aquatic Weed Control | 1 | 2 | 2 | 2 | 3 | | 2.3 |
| 2. North Delta Food Web Adaptive Management Projects | 0.5 | 0 | 0 | 0.5 | 0 | | 0.1 |
| 3. Outflow Augmentation | 2 | 1 | 1 | 2 | 0 | | 1.0 |
| 4. Reoperation of the Suisun Marsh Salinity Control Gates | 0 | 0 | 0 | 0 | 0 | | 0.0 |
| 5. Sediment Supplementation in the Low Salinity Zone | 1 | 0 | 0 | 0 | 1 | | 0.3 |
| 7. Roaring River Distribution System Food Production | 1 | 0 | 1 | 1 | 1 | | 0.8 |
| 8. Coordinate Managed Wetland Flood and Drain Operations in Suisun Mars | 0 | 1 | 1 | 1 | 1 | | 1.0 |
| 9. Adjust Fish Salvage Operations during Summer and Fall | 0 | 0 | 0 | 0 | 0 | | 0.0 |
| 10. Stormwater Discharge Management | 1 | 2 | 2 | 2 | 1 | | 1.8 |
| 11. Rio Vista Research Station and Fish Technology Center | 0 | 0 | 0 | 0 | 0 | | 0.0 |
| 12. Near-term Delta Smelt Habitat Restoration | 1 | 2 | 2 | 2 | 3 | | 2.3 |
| 13. Franks Tract Restoration Feasibility Study | 1 | 1 | 1 | 1 | 2 | | 1.3 |

**Table 67: Rationales/Discussion for Scores**

| **Action (Full build-out scale)** | **Average Score** | **Rationale/Discussion** |
|---|---|---|
| Aquatic Weed Control | 2.3 | • Will open up rearing habitat<br>• Potentially substantial benefits to juvenile salmonids - particularly shoals and channel margins. No basis for aquatic weeds or weed control to influence adults salmonids migrating upstream.<br>• Aquatic weeds hypothesized to have multiple negative pathway effects on Salmon, but primarily via predator recruitment, but no direct test of this to date, and will be difficult to quantify response except by density and duration of salmon lingering in treated areas. Also, area is small for a highly mobile creature. |
| North Delta Food Web Adaptive Management Projects | 0 | • Time period does not overlap with presence of juvenile salmonids in the Delta. Adults unaffected except for potential risk of increased straying of hatchery origin fall run Chinook into the Cache Slough complex. |

| **Action (Full build-out scale)** | **Average Score** | **Rationale/Discussion** |
|---|---|---|
| Spring/Summer Outflow Augmentation | 1.0 | The difference in scores for this one was greater than 1. Explanations for this difference follow:<br>• Rationale for score of 2: Portion of outflow in March-May benefits juvenile migration multiple runs over a broad geographic area.<br>• Rationale for score of 1: Outflow if managed in pulses has been shown to correlate with improving fish passage and seems to cue out-migration behavior but only the spring action seems to have any potential to do that.<br>• Rationale for score of 0: No benefit for salmon if done in July or August. Smalll benefit to salmon in rivers (not the tidal Delta) if flows increased by 3,000cfs for the month of April (179TAF = 3,000cfs for one month). If increased outflow is achieved by decreasing exports, then very little benefit to juvenile salmonids-even in April or May. |
| Reoperation of the Suisun Marsh Salinity Control Gates | 0 | • Summer operations don't affect adult or juvenile salmon |
| Sediment Supplementation in the Low Salinity Zone | 0.3 | • If the action were implemented in May, could have small benefit to juvenile salmonids by reducing predation risk. No effects to adult Chinook passing through the Delta in May or in September. |
| Roaring River Distribution System Food Production | 0.8 | • Potentially beneficial to juvenile salmonids by supplementing natural food in Suisun Bay, because of location may principally benefit non-salmonids.<br>• Large potential to create hotspot of improved food availability in both existing and soon to be restored habitat in Grizzly Bay, Tule Red area during periods when salmon are rearing in Delta. However, relatively limited geographic extent of effect. |
| Coordinate Managed Wetland Flood and Drain Operations in Suisun Marsh | 1.0 | • Potentially beneficial to juvenile salmonids by supplementing natural food in Suisun Marsh, because of location may principally benefit non-salmonids.<br>• Large potential to create hotspot of improved food availability in existing habitat throughout Suisun Marsh during periods when salmon are rearing in Delta. However, relatively limited geographic extent of effect. |

| Action (Full build-out scale) | Average Score | Rationale/Discussion |
|---|---|---|
| Adjust Fish Salvage Operations during Summer and Fall | 0 | • May reduce competitor and predator recruitment at very local vicinity of pumps, but limited effect over larger time and space scales due to mobility from other regions. |
| Stormwater Discharge Management | 1.8 | • Could impact multiple runs adult and juvenile, but over limited geographic extent (North Delta only). |
| Rio Vista Research Station and Fish Technology Center | 0 | • No effect |
| Near-term Delta Smelt Habitat Restoration | 2.3 | • Large scale habitat enhancements which should yield substantial benefits to juvenile salmonids. No effect to adult salmon. |
| Franks Tract Restoration | 1.3 | • Could substantially improve habitat conditions in the Central Delta for juvenile salmonids.<br>• Location makes it less useful/accessible to Sacramento basin salmon. |

### Other native estuarine species

This sub-objective was scored by three TWG members (Pat Coulston, Shawn Acuña, and Ted Sommer). Each TWG member scored each action independently according to the directions below and then discussed scoring on a conference call. Scores were adjusted by TWG members based on new information and considerations from discussion.

**Directions provided to participants:**

- Enter numbers -3 to +3 to communicate your view on how each of the full build-out actions described in the accompanying presentation might affect this issue. Use the scoring key (Figure 42) to aid in scoring. Note considerations that are not captured by the scoring key for group discussion (we may choose to over-ride scoring key fora given action if an additional consideration is significant and the group wants it included).
- Consider effects over the whole year.
- The score reflects any benefits or adverse impacts to native estuarine species that have not been included in scores for delta smelt and salmon.
- Interpret "species" at the broader species category level, for e.g. "zooplankton species" counts as one species.

- For "geographic extent affected" consider overlap between the spatial/temporal influence of the action and the spatial/temporal distribution of species.

**Figure 42: Scoring key for Other Native Estuarine Species**

| | | | | Geographic Extent Affected | |
|---|---|---|---|---|---|
| If net benefit | | | | | |
| | # species affected | | Lo | Hi | |
| | | Many | 2 | 3 | |
| | | Few | 1 | 2 | |
| If no net benefit or adverse effect | | | | | |
| | | | 0 | 0 | |
| If net adverse effect | | | | | |
| | # species affected | | Lo | Hi | |
| | | Many | -2 | -3 | |
| | | Few | -1 | -2 | |

**Table 68: Group results for Other Native Estuarine Species**

| | | Person | | | | |
|---|---|---|---|---|---|---|
| **Resiliency Strategy Action - Full Build-out Scale Scenario** | **Max-I** | 1 | 2 | 3 | | Average |
| 1. Aquatic Weed Control | 1 | 2 | 3 | 3 | | 2.7 |
| 2. North Delta Food Web Adaptive Management Projects | 0 | 2 | 2 | 2 | | 2.0 |
| 3. Outflow Augmentation | 1 | 2 | 1 | 2 | | 1.7 |
| 4. Reoperation of the Suisun Marsh Salinity Control Gates | 1 | 1 | 1 | 2 | | 1.3 |
| 5. Sediment Supplementation in the Low Salinity Zone | 0 | 1 | 1 | 1 | | 1.0 |
| 7. Roaring River Distribution System Food Production | 1 | 1 | 0 | 1 | | 0.7 |
| 8. Coordinate Managed Wetland Flood and Drain Operations in Suisun Mars | 0 | 1 | 1 | 1 | | 1.0 |
| 9. Adjust Fish Salvage Operations during Summer and Fall | 1 | 0 | 1 | 0 | | 0.3 |
| 10. Stormwater Discharge Management | 1 | 1 | 2 | 2 | | 1.7 |
| 11. Rio Vista Research Station and Fish Technology Center | 0 | 0 | 0 | 0 | | 0.0 |
| 12. Near-term Delta Smelt Habitat Restoration | 0 | 3 | 3 | 3 | | 3.0 |
| 13. Franks Tract Restoration Feasibility Study | 1 | 1 | 1 | 2 | | 1.3 |

**Table 69: Rationales/Discussion for Scores**

| **Action (Full build-out scale)** | **Average Score** | **Rationale/Discussion** |
|---|---|---|
| Aquatic Weed Control | 2.7 | • Will open up rearing habitat, reduce predator levels.<br>• Species that will benefit include: splittail, tule perch, hitch, longfin smelt, pikeminnow, sac sucker |
| North Delta Food Web Adaptive Management Projects | 2.0 | • Benefit for resident species like splittail, hitch, tule perch.<br>• Influences N. Delta and some downstream areas.<br>• Note that little food limitation data is available for other native species |

| Action (Full build-out scale) | Average Score | Rationale/Discussion |
|---|---|---|
| Spring/Summer Outflow Augmentation | 1.7 | • Could benefit some native species, e.g. longfin smelt, crangon, eurtemoa, starry flounder |
| Reoperation of the Suisun Marsh Salinity Control Gates | 1.3 | • Benefit for resident species like splittail, sac sucker, tule perch.<br>• Influences small range of Suisun/Delta region |
| Sediment Supplementation in the Low Salinity Zone | 1.0 | • Some other native species like longfin smelt also benefit from turbidity<br>• Presumably invasive species are less adapted to turbidity and there may be direct and indirect benefits to impairing invasive competitors and predators |
| Roaring River Distribution System Food Production | .7 | • Possible enhancement of food during rearing season for longfin smelt. Regionally localized. |
| Coordinate Managed Wetland Flood and Drain Operations in Suisun Marsh | 1.0 | • Possible enhancement of food during rearing season for longfin smelt.<br>• Regionally localized. |
| Adjust Fish Salvage Operations during Summer and Fall | 0.3 | • Slight benefit due to modest change in predators for splittail, sac sucker, tule perch.<br>• Low regional effect. |
| Stormwater Discharge Management | 1.7 | • Assuming impacts of all stormwater everywhere else is background mortality than there will be benefits to multiple species in a limited area. |
| Rio Vista Research Station and Fish Technology Center | 0 | • No effect |
| Near-term Delta Smelt Habitat Restoration | 3.0 | • Could substantially improve Delta habitat conditions for most native fishes. |
| Franks Tract Restoration | 1.3 | • Could substantially improve Central Delta habitat conditions for most native fishes and reduce entrainment. |

## Other native estuarine species

This sub-objective was scored by three TWG members (Pat Coulston, Ted Sommer, and Will Smith). Each TWG member scored each action independently according to the directions below and then discussed scoring on a conference call. Scores were adjusted by TWG members based on new information and considerations from discussion.

**Directions provided to participants:**

- Enter numbers -3 to +3 to communicate your view on how each of the full build-out actions described in the accompanying presentation might affect this issue. Use the scoring key (Figure 43) to aid in scoring. Note considerations that are not captured by the scoring key for group discussion (we may choose to over-ride scoring key fora given action if an additional consideration is significant and the group wants it included).
- Consider effects over the whole year.
- This score reflects any other ecological benefits or adverse impacts that have not been captured in scores for delta smelt, salmon and other native estuarine species.
- "Community" refers to different ecological habitats and communities of species within these habitats

**Figure 43: Scoring key for Other Ecological Endpoints**

| | | | | |
|---|---|---|---|---|
| If net benefit | | Geographic Extent Affected | | |
| | # Communities | Lo | Hi | |
| | > 1 community | 2 | 3 | |
| | One community | 1 | 2 | |
| If no net benefit or adverse effect | | | | |
| | | 0 | 0 | |
| If net adverse effect | | | | |
| | # Communities | Lo | Hi | |
| | > 1 community | -2 | -3 | |
| | One community | -1 | -2 | |

Table 70: Group results for Other Ecological Endpoints

| | | Person | | | | |
|---|---|---|---|---|---|---|
| **Resiliency Strategy Action - Full Build-out Scale Scenario** | **Max-Mi** | 1 | 2 | 3 | | Average |
| 1. Aquatic Weed Control | 0 | 3 | 3 | 3 | | 3.0 |
| 2. North Delta Food Web Adaptive Management Projects | 1 | 1 | 2 | 1 | | 1.3 |
| 3. Outflow Augmentation | 1 | 1 | 2 | 2 | | 1.7 |
| 4. Reoperation of the Suisun Marsh Salinity Control Gates | 1 | 1 | 1 | 2 | | 1.3 |
| 5. Sediment Supplementation in the Low Salinity Zone | 1 | 1 | 0 | 1 | | 0.7 |
| 7. Roaring River Distribution System Food Production | 0 | 1 | 1 | 1 | | 1.0 |
| 8. Coordinate Managed Wetland Flood and Drain Operations in Suisun Mars | 1 | 2 | 1 | 2 | | 1.7 |
| 9. Adjust Fish Salvage Operations during Summer and Fall | 1 | 0 | 0 | 1 | | 0.3 |
| 10. Stormwater Discharge Management | 1 | 2 | 2 | 1 | | 1.7 |
| 11. Rio Vista Research Station and Fish Technology Center | 0 | 0 | 0 | 0 | | 0.0 |
| 12. Near-term Delta Smelt Habitat Restoration | 0 | 3 | 3 | 3 | | 3.0 |
| 13. Franks Tract Restoration Feasibility Study | 1 | 2 | 2 | 1 | | 1.7 |

Table 71: Rationales/Discussion for Scores

| Action (Full build-out scale) | Average Score | Rationale/Discussion |
|---|---|---|
| Aquatic Weed Control | 3.0 | • Improves overall wetland functions in Delta for terrestrial and wetland species<br>• Improves circulation/water quality (if no adverse effects from herbicides) |
| North Delta Food Web Adaptive Management Projects | 1.3 | • Greater productivity in a portion of the upper estuary<br>• Enhanced food web effects also benefits riparian, wetland species, but only in summer |
| Spring/Summer Outflow Augmentation | 1.7 | • Higher flows have modest benefit to several communities.<br>• Broad geographic influence |
| Reoperation of the Suisun Marsh Salinity Control Gates | 1.3 | • Enhanced water quality and food web also benefits wetland species |
| Sediment Supplementation in the Low Salinity Zone | 0.7 | • Sedimentation can impact aquatic weeds, CHABs, and to lesser extent benthic invertebrates |
| Roaring River Distribution System Food Production | 1.0 | • Enhanced food web also benefits wetland species |

| Action (Full build-out scale) | Average Score | Rationale/Discussion |
|---|---|---|
| Coordinate Managed Wetland Flood and Drain Operations in Suisun Marsh | 1.7 | • Enhanced food web also benefits wetland species |
| Adjust Fish Salvage Operations during Summer and Fall | 0.3 | • Unlikely to have a lasting impact on the region as the timing is too short and limited to the area around the Confluence or the south Delta |
| Stormwater Discharge Management | 1.7 | • Enhanced water quality also benefits wetlands, terrestrial, riparian species. N. Delta only<br>• Could potentially improve benthic invertebrates and indirectly avian species that prey on vertebrates |
| Rio Vista Research Station and Fish Technology Center | 0 | • No effect |
| Near-term Delta Smelt Habitat Restoration | 3.0 | • Enhanced habitat quality for wetlands, riparian, terrestrial species<br>• Broad geographic influence |
| Franks Tract Restoration | 1.7 | • Improved overall wetland functions for wetland and riparian species in the Central Delta |

## Glossary

| Key Term | Definition for the purposes of the Delta Smelt SDM Analysis |
|---|---|
| **cfs** | Cubic feet/second |
| **Fall** | Sept.1 to Nov. 30 |
| **Low Salinity Zone** | Region with salinity between 0.5 and 6 psu. |
| **NTU** | Nephelometric turbidity units |
| **Spring** | March 1 to May 31 |
| **Summer** | June 1 to Aug. 31 |
| **TAF** | Thousand acre-feet |
| **Winter** | Dec. 1 to Feb. 28 |
| **X2** | X2 is the location of the 2 parts per thousand salinity contour (isohaline), one meter off the bottom of the estuary, as measured in kilometers upstream from the Golden Gate Bridge. |

## Contacts for Actions

Green indicates people provided direct input on this action for this project.

TWG (Technical Working Group) – Ted Sommer, Shawn Acuña, Scott Hamilton, Pat Coulston, Will Smith

| Action | Contacts |
|---|---|
| 1. Aquatic Weed Control | TWG, Louise Conrad (DWR), Eddie Hard (Division of Boating and Waterways) |
| 2. North Delta Food Web Adaptive Management Projects | TWG, Ted Sommer (DWR) |
| 3. Outflow Augmentation | TWG, Carl Wilcox (DFW) |
| 4. Reoperation of the Suisun Marsh Salinity Control Gates | Ted Sommer, TWG |
| 5. Sediment Supplementation in the Low Salinity Zone | TWG |
| 6. Spawning Habitat Augmentation | Scott Brandl (mapping), Senior Environmental Scientist, Delta Science Program/Delta Stewardship Council, 916-445-0513, Scott.Brandl@deltacouncil.ca.gov<br>Lauren Damon<br>Jim Hobbs |
| 7. Roaring River Distribution System Food Production | Eric Loboschefsky, Cliff Feldheim (DWR) |
| 8. Coordinate Managed Wetland Flood and Drain Operations in Suisun Marsh | Cliff Feldheim (DWR), Eric Loboschefsky, John Durand |
| 9. Adjust Fish Salvage Operations during Summer and Fall | Ted Sommer (DWR)<br>Brendan Lehman (NOAA) brendan.lehman@noaa.gov |
| 10. Stormwater Discharge Management | Shawn Acuña<br>Kris Tjernell, Water Resources Agency |
| 11. Rio Vista Research Station and Fish Technology Center | Ted Sommer (DWR) |
| 12. Near-term Delta Smelt Habitat Restoration | Carl Wilcox (DFW), Eric Loboschefsky, John Durand, Dennis McEwan (DWR) |
| 13. Franks Tract Restoration Feasibility Study | Carl Wilcox (DFW) |