A Response to the SDM Draft Round 1 Report Released June 6, 2024

Scott Hamilton, June 20, 2024

CSAMP employed a structured decision-making (SDM) process, led by Compass Resource Management (Compass) involving the evaluation of the effectiveness of alternative actions in improving the population growth of Delta Smelt while considering tradeoffs such as costs and effects on other species. The most promising of these candidate actions were grouped into portfolios. Using four different predictive quantitative models[1], the candidate actions and portfolios were evaluated for their likely contribution to Delta Smelt recovery while accounting for tradeoffs and the results were summarized in "consequences tables". Compass, working with a Technical Working Group (TWG), produced a "Round 1" Report. Different entities within the TWG had different perspectives on what information should be reported out to the Policy Group. To allow for a full presentation of perspectives, members of the TWG were provided an opportunity to develop and present "Response Documents". The document here represents one perspective of one member of the TWG. I have worked on quantitative modelling and simulation for 40 years with publications beginning in 1984[2]. I have been the lead author or coauthored seven manuscripts on Delta Smelt and this is my third involvement in an SDM process for Delta Smelt[3]. This document is intended to highlight management-relevant information for CSAMP and to facilitate discussion. It draws primarily from the consequences tables in the Round 1 Report, which are also provided at the end of this document.

This document was designed to minimize the need to continually cross-reference the Round 1 Report. Therefore It duplicates some material and notes similar findings. It contains an Appendix with a summary of the SDM process and some of the key tables.

[1] The four models were a simulation model (IBMR), two state-space models (LCM and Mauder-Deriso), and a Limiting Factor (LF) model. See Round 1 Report, Table 1 for a description of each model.

[2] Adams RM, Hamilton SA and McCarl BA (1984) The Economic Effects of Ozone on Agriculture, Washington, D.C.: Environmental Protection Agency, Office of Research and Development, Technical Report, EPA 600/3-84-090, September, 1984.

Hamilton SA, McCarl BA and Adams RM (1985) The Effects of Aggregate Response Assumptions on Environmental Impact Analyses, American Journal of Agricultural Economics, 67(2), May 1985, pp. 407-413.

[3] The two prior efforts were:

a) Compass Resource Management (2018) Structured Decision Making for Delta Smelt Demo Project, prepared for CSAMP/CAMT, and

b) Peterson J T. McCreless E, Duarte A, Wohner P, Hamilton S, Medellín-Azuara J, Escriva-Bou A. (2024) Prototyping structured decision making for water resource management in the San Francisco Bay-Delta. Environmental Science & Policy, 157, 103775.

1. What are the key findings?

1.1 All models predict that the implementation of certain management actions could lead to the recovery of Delta Smelt

The Round 1 Report presents a metric "λ" (lambda) which is calculated as the geometric mean of the projected Delta Smelt population in one year divided by the projected population in the previous year, averaged over the 20-year study period. A λ with a value greater than one indicates that the population is increasing, and less than one, that it is decreasing.

All models projected two food-focused portfolios would provide the greatest population growth rates for Delta Smelt – Portfolio 3d (the "Focus on Food" portfolio) and 3e ("Habitat Connectivity")[4]. The average of λ across 3 models was 1.63 for Portfolio 3d, and 1.61 for Portfolio 3e[1]. Portfolio 3d contained management actions for tidal wetland restoration, managed wetlands in Suisun Marsh, nutrient supplementation in the Sacramento Deep Water Ship Channel, aquatic weed control and contaminant reduction, in addition to some "current management" actions. Portfolio 3e contained management actions for tidal wetland restoration, aquatic weed control, contaminant reduction, restoration of Franks Tract, and sediment supplementation in addition to some "current management" actions. These portfolios had actions in common that **improved food availability and turbidity conditions and reduced contaminants and aquatic weeds[5].** Neither portfolio includes any new flow-augmentation actions[6] suggesting relatively large population increases could be possible without using expensive flow augmentation actions. To be effective, some food-focused actions will require implementation over a sustained period, for example, management of wetlands requires annual implementation to achieve benefits.

Given that adequate food supplies appear critical to improving abundances of Delta Smelt, it can be inferred that other management actions that also enhance food supplies in spring and summer could further increase recovery rates of delta smelt.

1.2 Some models showed a benefit to summer flow augmentation

Two of three models showed population benefits for "Full Year Flows" (Portfolio 2a.1), with λ= 1.21 & 1.15 for IBMR and LCME models respectively, with small benefits to salmon but no risks, and a cost in the range of $151 to $200 mill/year (Round 1 Report, Table ES-2). The results suggest some possible benefits to flow augmentation although it still needs to be determined if water operations are capable of this type of

[4] See Tables A-2 and A-3 for details of actions included in each portfolio.
[5] By incrementally adding and subtracting actions to portfolios it is possible to isolate the value of any individual action to a portfolio. That exercise was conducted using the LF model but the TWG did not have the time to review the results.

implementation and whether the realized effects being assumed by this portfolio are worth the costs in the face of other alternative portfolios.

1.3 Food-based actions are likely to be more cost-effective than flow augmentation actions

The costs to implement management actions vary significantly across portfolios[7]. Round 1 portfolios were not optimized to identify the most cost-effective portfolios. Despite the preliminary cost estimates, two of the portfolios appeared to be significantly more cost effective than others - Portfolios 2b and 2c. Portfolios 2b and 2c added actions to "Current Management" - a food action in the Deep Water Ship Channel, aquatic weed control in Yolo Bypass and Cache Slough, but no new flow actions. Portfolio 2c also added 2,000 ac of managed wetlands in Suisun Marsh and in doing so became the most cost-effective portfolio. That is, **Portfolio 2c showed the greatest predicted increase in the size of the Delta Smelt population per unit of cost** (Table 1)[8]. More cost-effective and efficient portfolios could be developed by optimizing the level of actions in Portfolio 3d (which already includes all of the actions in Portfolio 2c) and removing current management actions that have not shown benefits to Delta Smelt.

Table 1 *Cost effectiveness of portfolios modelled in Round 1 calculated from data in Table ES-2 of the Round 1 Report. Only the IBMR model results were used for this calculation because it was the only model that analyzed all the listed portfolios. The cost of actions in the SDM process were "coarse ballpark estimates" and were expressed as a range, thereby recognizing the uncertainty in the cost estimates. For simplicity, only the mid-point of the range is used here. See Table A-2 for more complete cost information.*

Portfolio	IBMR	Avg Cost	Cost per percent gain
	Lambda-1	$mill/yr	$mill/yr/1% gain
1b	0.00		
2a.1	0.21	175.5	8.36
2b	0.12	3.0	0.25
2c	0.25	3.0	0.12
3c.2	0.13	425.5	32.73
3c.4	0.10	125.5	12.55
3a	0.40	125.5	3.14
3d	0.96	175.5	1.83
3e	1.23	88.0	0.72

[7] It should be noted that costs for actions were estimated at a high level and were intended to be "ballpark estimates" and should not be interpreted to have precision.
[8] Table A-5 was derived from the Round 1 Report, Table ES-2.

2 Are the findings credible?

2.1 The findings are consistent with results from earlier studies showing flows during the first flush and availability of food largely determine population responses in Delta Smelt

Results from the Limiting Factors[9] model supported elements common in conceptual models – that the magnitude and timing of the first flush has a major bearing on hydrologic conditions and food-web status for the year with corresponding influences on flows across floodplains that increase nutrients and turbidity entering the Delta [10]. Flows in the summer and fall are correlated with flows in the winter and spring [11]. Numerous researchers have mischaracterized the correlation between flows in summer and food availability in summer as cause and effect. However, augmentation of flows via reservoir releases cannot replicate the benefits of extensive and persistent flows across floodplains in the spring. The primary cause of food availability in summer is due to the magnitude of the first flush and the associated introduction of nutrients and turbidity into habitat area supporting Delta Smelt [5]. Regardless of the research evaluating the relationship between specific actions like flow or habitat restoration on food supply, the results were clear across multiple models, more food resulted in greater population growth. While a first flush cannot be replicated artificially, it is possible to manage food production to benefit Delta Smelt.

2.2 Some findings are supported by time series data

Supporting the modelling conclusion, historic data suggests that a **shortage of food from June through August limits the population growth of Delta Smelt** (see Figure 1).

2.3 The findings related to synergism are consistent with the theory of limiting factors

An understanding of thresholds and limiting factors is fundamental to understanding the modeling results. Results of individual management actions are provided in Table

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[9] See also Hamilton and Murphy (2022) next footnote.

[10] Hamilton SA, Murphy DD (2022) *Identifying Environmental Factors Limiting Recovery of an Imperiled Estuarine Fish*. Frontiers in Ecology and Evolution 10:826025. doi: 10.3389/fevo.2022.826025

[11] The correlations (r) between seasonal X2 values from DWR's Dayflow database (1956-2022).

	Dec-Feb	*Mar-May*	*Jun-Aug*
Mar-May	0.69		
Jun-Aug	0.61	0.87	
Sep_Nov	0.78	0.80	0.73

A-5 (Table ES-3 of the Round 1 Report). While it is tempting to apply significance to the findings relating to individual actions, such results should be interpreted with great caution. In real-world ecosystems, more than one factor usually limits abundance. Hypothetically, if one factor limits recovery in summer and a different one would limit recovery in spring but for summer constraint, just looking at the spring action by itself will show no benefit because the summer constraint is limiting. If just the summer factor is addressed through an action, the action will show limited benefit because the spring constraint will be realized. Only when both limiting factors are addressed simultaneously are the potential benefits realized. Therefore, the results from the analysis of management portfolios have more relevance than those of individual actions.

2.4 The findings are consistent with an earlier SDM effort[12]

The Compass "SDM Demo" Project[13] identified a set of management actions that were "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." Those actions were: north Delta food web enhancement, reoperation of Suisun Marsh flood and drainage, tidal wetland restoration, establishment of a Rio Vista Research Station, reoperation of SMSCG, and Roaring River food production.

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[12] A "protype SDM process - Peterson JT et al. (2024) Prototyping structured decision making for water resource management in the San Francisco Bay-Delta. *Environmental Science & Policy*, *157*, 103775 - also showed benefits of enhancing food for Delta Smelt. That analysis utilized an earlier version of the LF Model - Hamilton SA and Murphy DD (2018) Analysis of Limiting Factors Across the Life Cycle of Delta Smelt (*Hypomesus transpacificus*) Environmental Management. Because of the similarities of the models utilized in Peterson et al. in the Round 1 report, consistencies of results does not provide corroboration of the Round 1 findings.

[13] Compass Resource Management (2018) Structured Decision Making for Delta Smelt Demo Project, prepared for CSAMP/CAMT.

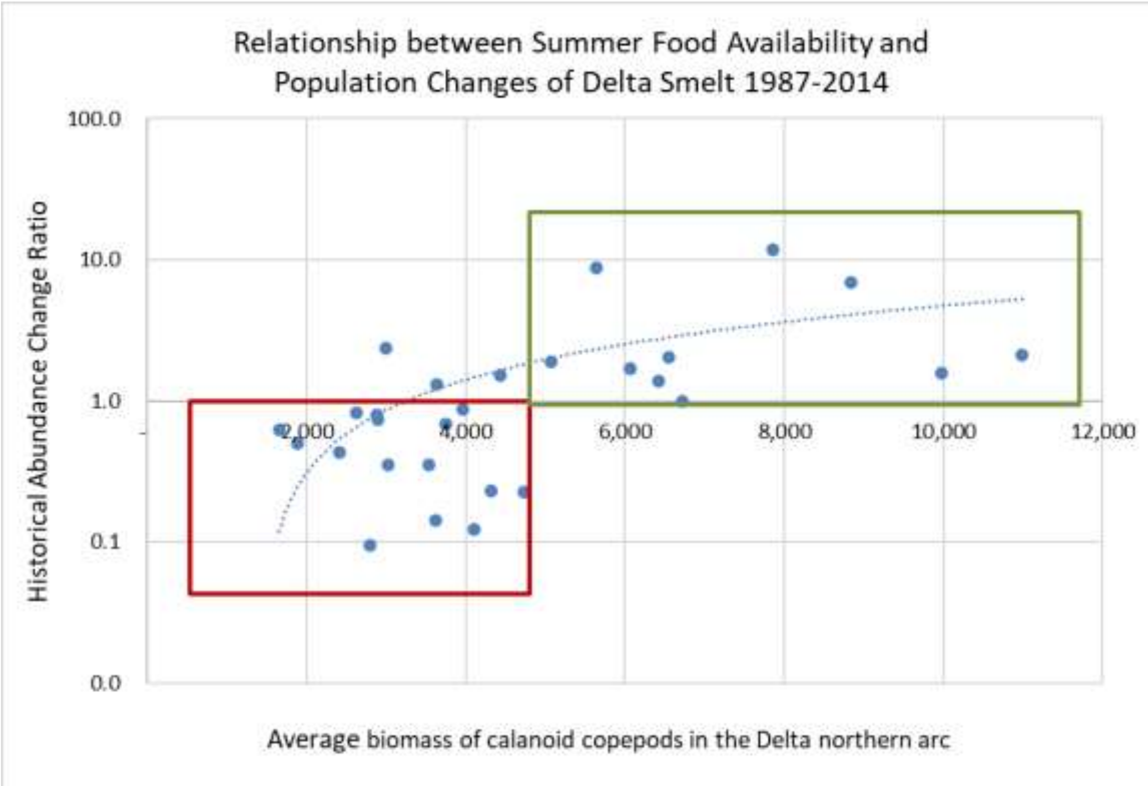

Figure 1. *The relationship between summer food availability and Delta Smelt population-size changes 1987-2014. A ratio greater than one indicates an increase in the population. Delta smelt abundances consistently increased when prey availability in the Delta northern arc exceeded an average of 5,000 µgC/m³ in the period from June through August. While univariate (one factor) analysis can be misleading, for example, if there is a more relevant covariate influencing the dependent variable, in this case, this figure helps to understand the findings in Table ES-2 of the Round 1 Report. (Note that the horizontal axis is the average biomass of adult calanoid copepods from June through August in the northern arc of Delta Smelt habitat [stations NZ028, NZ032, NZ054, NZ060, NZ064] from 1987 to 2014. The vertical axis is the FMWT Index in one year divided by the FMWT Index in the previous year).*

3. What are the implications of the findings for conservation management?

3.1 Implementing certain management actions is projected to lead to Delta Smelt recovery

It can be inferred from the results presented in the consequences tables that **certain management actions, implemented simultaneously, have the potential to have substantial benefits for Delta Smelt**, and could do so while still keeping implementation costs at moderate levels.

At least two "next-steps" options are available. One path forward would be to complete a full structured-decisio-making analysis to better refine and clarify the next steps. Other decision-support analyses, such as Value of Information (which estimates "worth" that will come from knowledge that leads to a decision), could be useful in determining whether any reduction in uncertainty of an action is worth the investment.

Another approach is to select some actions for implementation in a rigorous adaptive management framework. At the end of Round 1 of the SDM process, considerable uncertainty exists regarding the performance and likelihood of success of any of the actions. Adaptive management aims to reduce this uncertainty by setting objectives, defining success, implementing management alternatives, instituting a monitoring program sufficient to determine effectives of the implemented actions, analysis, and review and modification of actions, as needed. Rigorous implementation of that process facilitates learning and continual improvement of implemented actions for the benefit of the species.

Actions that might be considered for immediate implementation in an adaptive management framework include:

a) Implementation and **adaptive management of wetlands in Suisun Marsh** to produce food from May through November to increase spring and summer food supplies (~4,000 acres). This suggestion is consistent with Next Steps #1 in the Round 1 Report, p.ii.

b) Implementation and **adaptive management of flow-through wetlands systems** in wildlife refuges in Suisun Marsh and Yolo Bypass to evaluate effects on summer food supplies (~17,000 ac). While this action was not the subject of modeling, the apparent benefit of summer food together with a potential June food gap under managed wetlands action suggests the action is worth pursuing in an adaptive management framework.

c) **Reconnection of floodplains to rivers** upstream of the Delta to increase sediment and fuel food webs. While this action was not modeled, benefits of increased turbidity for Delta Smelt are likely. Adding sediment directly to the Delta has permitting challenges and funding for additional removal of aquatic weeds has been challenging. Reconnection of floodplains to rivers restores pertinent natural processes and can be implemented in an adaptive management framework, allowing improvements in turbidity to be assessed. This suggestion provides a more pragmatic alternative to Next Steps #5 in the Round 1 Report, p.ii, because direct addition of sediment to Delta water proposed in Next Steps #5 may be very difficult to permit and expensive to implement annually.

d) **Nutrient addition** to the Sacramento deep water ship channel.

e) **Construction of wetlands at a contaminant hot spot** to mitigate contaminant inputs to the Delta. To be feasible, such an action should take place in a location that meets the following criteria: (a) the location supports or potential supports Delta Smelt; (b) the location is a serious contaminant hot spot (enriched contaminant concentrations documented); (c) adverse effects of contaminants in the candidate location are documented by field evidence and/or advanced toxicity testing; and (d) the location is amenable to mitigation with available technology. Ulatis Creek in the Cache Slough Complex meets these criteria (see below) and could be an ideal candidate site for implementing and testing constructed wetlands for contaminant reduction. This suggestion is consistent with Next Steps #3 in the Round 1 Report, p.ii.

3.2 Some of the remaining uncertainty can be resolved through application of adaptive management

Uncertainties regarding Delta Smelt ecology, behavior, and resource needs and tolerances exist; they are the reason to undertake an SDM process. Findings from this process to date should be interpreted cautiously, with numbers in tables reflecting general indications rather than precise findings. That said, the final step in the SDM process is to implement, monitor, and review management actions that are likely to be most effective and affordable (see Figure A-1). In that step, much uncertainty that existed prior to SDM can be resolved by implementing actions in an adaptive framework and effectiveness (performance) monitoring. The SDM process does not require, nor would it be possible, for all uncertainties to be resolved prior to implementation of actions. Delaying implementation of actions in order to reduce uncertainties could have adverse impacts for the species.

3.3 The policy group might consider if possibly ineffective management actions should be continued

The abundance of Delta Smelt in long-running surveys has trended downwards since the implementation of the Biological Opinion of 2008 suggesting that current management actions, which were only intended to mitigate water project operations, are by themselves, ineffective in recovering the species. However, modelling of individual management actions showed that only one of the "Current Management" actions (OMR Management) predicted population benefits. **Modeling did not show population benefits for other actions currently being implemented**. Those were North Delta Food web enhancement, Fall X2 (flow augmentation in wetter years) and Suisun Marsh Salinity Control Gate reoperation. In determining the best use of available resources, the policy group may want to consider the value of continuing management actions that are not well supported by the modelling.

3.4 Some further research and directed studies would facilitate adaptive management and accelerate learning

Further research, new directed studies, and funding are needed to improve the effectiveness and reduce risks when implementing management actions such as:

a) Monitoring to quantify local and **system-wide contributions of restored tidal wetlands** to Delta Smelt food availability and diets, and the effects of tidal wetland restoration on water temperature. Alternative studies have provided different assessments of the level of food production from tidal wetlands. Because tidal wetlands are expensive to restore, it would be worthwhile to confirm their expected benefits before expending more resources on such restoration. This suggestion is consistent within Next Steps #7 in the Round 1 Report, p.ii.

b) Identifying **cost-effective means of restoring tidal wetlands**. Creating extensive areas of inter-tidal wetlands can be expensive. But given sea level rise, highly engineered tidal wetlands may not be optimal. Evaluating alternative design concepts for tidal marsh restoration may lead to better use of existing resources and increasing long-term benefits for Delta Smelt.

c) **Increasing funding for aquatic weed control.** Fund different spatial and temporal aquatic weed control applications in an effort to scale up and increase effectiveness. This suggestion differs from Next Steps 2 in the Round 1 Report, p.ii, by suggesting that funding and permitting, and not the need for further assessment, is limiting expanded use of aquatic weed control

d) Reviewing and carrying out further studies of the effects of **predation by silversides.** Several studies have identified silversides as being a predator of importance on Delta Smelt eggs and larvae[14] but none of the four models in the current SDM process identified population level effects of predation by silversides. A review of more recent studies and DNA data may help resolve this discrepancy and, if appropriate, may lead to consideration of protective actions, for example, a program to establish propagated eggs in a nursery protective from silversides. This could help overcome constraints at propagation facilities.

e) Developing more efficient **alternatives to protect Delta Smelt from entrainment** in the short and long term. The modeling determined that entrainment management improved survival but at cost to water supply. Finding ways to reduce both entertainment and cost would provide dual benefits. This suggestion differs from Next Steps 6 in the Round 1 Report, p.ii, because small and late first flushes are associated with low levels of entrainment (delta smelt do not disperse to areas near the pumps under these circumstances) and supplementing first flush under these circumstances, as proposed in next Steps #6 is unlikely to have much influence on entrainment). Rather, preliminary investigations suggest risk based OMR management is likely to be more effective in reducing entrainment in the short term[15] and strategically located fish friendly diversions are likely to be more effective in the long term.

f) Assessing the **effectiveness of actions that contribute to habitat connectivity**. Modeling showed benefits for the portfolio that focused on habitat connectivity. Another way to achieve that would be to connect Cache Slough to Suisun Marsh via a northern waterway and similar in design to the deep water ship channel, thereby allowing Delta Smelt to move between these two productive areas. However, such a radical change to the waterways may have unintended consequences. A preliminary step may be to utilize expert elicitation to analyze the concept.

Noteworthy, there is no science study proposed here that is consistent with Next Steps #4 in the Round 1 Report (p.ii) which proposes studying the feasibility of additional outflow actions. Several concerns reported in this document indicate that further study of flow augmentation may not be an appropriate next step. Those concerns include: the need to resolve differences in food modeling that may be

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[14] See Mahardja B. et al. (2016). Abundance Trends, Distribution, and Habitat Associations of the Invasive Mississippi Silverside (Menidia audens) in the Sacramento–San Joaquin Delta, California, USA. San Francisco Estuary and Watershed Science, 14(1).
Baerwald et al (2012), Contents of the Invasive Mississippi Silverside in the San Francisco Estuary Using TaqMan Assays, Transactions of the American Fisheries Society, 141:6, 1600-1607.
Hamilton SA and Murphy DD (2018) Analysis of Limiting Factors Across the Life Cycle of Delta Smelt (*Hypomesus transpacificus*) Environmental Management.
[15] Hamilton and Murphy (2024), Using predictive models to manage risk of entrainment for Delta Smelt, an imperiled estuarine fish. In review.

overestimating the benefits of flow actions, the cost effectiveness of flow actions relative to food actions, and the finding that recovery can likely be achieved without the need for expensive flow actions. Also, the impacts of flow action are difficult to analyze because of the potential impacts to cold water flows for salmon.

3.5 The SDM effort is not complete

The SDM effort was intended to be conducted in two rounds -- the first is completed. In Round 1, candidate actions were identified and evaluated and the most promising of these were grouped into portfolios that reflected different strategies. The actions and portfolios were evaluated using four different predictive quantitative models. The modeling focus in Round 1 was population growth of Delta Smelt. The consequences of candidate actions to salmonids and water supply were also estimated and the costs of candidate actions were tabulated. Compass took direction on study scope from the Steering Committee for Round 1. Effort was directed to investigating the sensitivity of outcomes to different levels (intensities) of summer/fall habitat actions, tidal wetland restoration, and aquatic weed control. Effort was also dedicated to documenting relative levels of uncertainty that accompany predicted management outcomes. It was not the intent in Round 1 to determine the "best" combinations of actions that would maximize the benefits to Delta Smelt while minimizing costs, nonetheless useful inferences can be drawn from the SDM consequences tables and some omitted information is noteworthy.

a) **The Round 1 Report does not consider or calculate the costs of current regulations.** The Steering Committee felt that a full financial analysis was not necessary in Round 1 if the analysis was structured to contrast the proposed actions against a baseline cost. The cost estimates of the portfolios in the report are compared to Portfolio 1b "Current Management." As such, the costs for Portfolio 1b are not reported in Table ES-2 although some of the actions may be costly. For example, DWR estimated that the cost of the Fall X2 action in 2023 was on the order of 600,000 af[16]. At $815/af[17] that equates to $489 million. **If the Fall X2 action occurs in 30% of years[18], the average annual cost is around $147 million per year**.

b) **The Round 1 Report does not consider employment and other economic impacts**. Water can be used to meet many beneficial uses such as in-stream flow requirements for salmonids or to enhance water quality, or diverted for

[16] J. Leahigh (2023) Presentation at ACWA Committee Meeting, November 2023.

[17] See Round 1 Report, Appendix 3 – Water Resources Methods – Monetized water cost.

[18] DWR data (http://cdec.water.ca.gov/cgi-progs/iodir/wsihist) indicate that wet years have historically occurred in a third of all years, and above-normal years in an eighth of all years. In some of those years Fall X2 requirements would be met without flow augmentation.

human use to produce food or meet health and human safety needs. Appropriate allocation of water resources involves evaluating challenging tradeoffs. Without being aware of these tradeoffs, policy makers are at a disadvantage. For example, Professor David Sunding, at UC Berkeley, estimated the consequences of water shortages in the San Joaquin Valley[19]. Interpolating his results, each 1,000 af reduction in water supply results in a loss of 17.5 FTE agricultural jobs, 9.8 FTE in indirect jobs in the San Joaquin Valley and 8 FTE jobs outside of the San Joaquin Valley for a total of 35.3 jobs lost per 1,000 acre-feet. The summer flows action in Portfolio 3c.2 is estimated to cost 495,000 af/year, which may equate to more than 17,000 jobs lost statewide. Many of the people that would be impacted are Hispanic workers in disadvantaged communities. Whether that is important or not is a value judgement. The Steering Committee directed Compass not to consider such impacts in Round 1. However, without a more complete consequences table, policy makers are not fully informed.

c) **An iterative review of the Round 1 results would have highlighted the potential for additional actions to further aid recovery of Delta Smelt.** Due to direction from the Policy Group to stop further iterations and report on the results, necessary analyses were not fully completed. The analyses that were performed did include grouping individual management actions into portfolios and the consequences of different levels of implementation of some management actions. These steps further refined actions but there were much larger potentials for optimization. For example, modeling suggested that increases in managed wetlands are likely to benefit Delta Smelt, but the action as proposed does not produce food for Delta Smelt in June. That one month gap in food production could potentially be overcome by combining the action with management of water in wildlife refuges, **supplementing June food supplies, and providing sustained food production through the spring and summer, thereby further increasing the projected recovery rates for Delta Smelt**.

d) Optimizing portfolios similarly could have led to increased projected population rates at decreased costs. Conservation managers have limited budgets and limited expert staff, requiring agencies to direct available resources to the areas where they are likely to be most effective. Because the portfolios in Round 1 were not optimized, that is, the implementation level of each action within a portfolio was not optimized, **realistic costs for management-action portfolios were not calculated**. For example, Portfolio 3d (Focus on Food) had aquatic weed control being implemented in 5 regions and contaminant reduction in 12 regions[20]. Likely both of those actions achieve most of the benefit if implemented in just a few

[19] Microsoft Word - Blueprint.EIA.PhaseOne.2.28.docx (waterblueprintca.com)
[20] See Table A-2, a reproduction of Round 1 Report Table ES-1 .

regions. Implementing those actions in fewer regions would have reduced the cost with little difference in benefits to Delta Smelt.

e) **Key technical issues were not resolved with the likelihood that certain benefits to Delta Smelt were overestimated**

One of the major factors influencing the predicted benefits of certain management actions was **the choice of the food models** used to inform the effects of flow augmentation. The SDM process did not resolve which of the alternative predictive food models represents the best available scientific information. The Flow/Food model used to provide inputs to the IBMR model was based on changes in salinity and only modelled conditions from the Confluence westward, ignoring changes in food in half of the subregions. Prey availability east of the Confluence can change substantially with seasons and inflows, while changes in salinity are small. Therefore, while this food model is good for some tasks, it may not be well suited to providing estimates of changes in food supply across the entire Delta or for some parts of the year when flow actions are applied. The differences in estimated population growth rates between the IBMR model and the LCME model when conducting sensitivity analyses were relatively small (less than 10%) suggesting that the bias, if there is any, may be small. The flow/food model and the flow/distribution model **led to the benefits of flow augmentation in the IBMR model which were not detected by the LF model for the same action in the Fall.** An alternative flow-food model[21] using 12 subregions covering the entire upper estuary, modeled the influence of flows directly. Other statistically significant covariates in that model included previous and upstream biomass, water temperature and the historic presence of the Asian clam. The use of this alternative model identified the benefits of flows to food production, which varied by season and region. Although, this model only considers one category of the prey for Delta Smelt (calanoid copepods), they are a preferred prey category. With two alternative models providing differing results important for evaluating flow actions, CSAMP might consider requesting this scientific discrepancy be resolved prior to proceeding with flow augmentation actions.

Two USFWS models (IBMR and LCME) offered differing predictions for benefits of turbidity. The turbidity response in the IBMR model, which showed a greater response to turbidity, was an assumed relationship. In contrast, the LCME

[21] Hamilton S, Bartell S, Pierson J, Murphy D (2020). *Factors Controlling Calanoid Copepod Biomass and Distribution in the Upper San Francisco Estuary and Implications for Managing the Imperiled Delta Smelt* (*Hypomesus transpacificus*). Environmental Management 65: 587–601. https://doi.org/10.1007/s00267-020-01267-8

relationship was empirically based. Because the turbidity relationship in the LCME model was empirically based, **it is likely that the assumed relationship between turbidity and Delta Smelt population responses in the IBMR model overestimates the importance of turbidity in that model.** Modelling suggested the benefits to Delta Smelt were sensitive to the turbidity responses, and addressing the difference may help reduce uncertainty.

Appendix A

Summary of the SDM Process and Findings

Introduction

The primary purpose of structured decision making is to aid and inform decision makers in an informed, defensible and transparent manner, rather than to prescribe a preferred solution. It's founded on the idea that good decisions are based on an in-depth understanding of both values (what's important) and consequences (likely outcomes)[22]. The process recognizes that the context is fuzzy, the science is uncertain, stakeholders are emotional and values are entrenched.[23]

CSAMP has initiated a Structured Decision Making (SDM) Process to identify sets of actions that might lead to recovery delta smelt

Figure A-1. The standard SDM process follows a six step process, with iterations as necessary. The structure of this Appendix follows the SDM steps through to evaluation of tradeoff in step 5. Because the participating agencies, and not CSAMP itself, have the authority to implement projects, the "select, implement, monitor and review" components of the SDM process are not addressed here.

1. The Decision Context

The CSAMP Policy Group adopted the following recovery goal for delta smelt:

"Reverse the trajectory of the Delta Smelt population from one in decline to one experiencing overall increases within 5-10 generations with the long-term aim of establishing a self-sustaining population." [24]

[22] Gregory et al. (2012) p. 2,6.
[23] Gregory et al. (2012) p. 2.
[24] Round 1 Report Ver. 2.4, p.2.

The aim of the SDM process is to identify a portfolio of management and science actions that CSAMP members can support that are likely to improve the abundance of delta smelt [25]

2. Objectives and Measures

Objectives

Objectives were identified in the SDM process are summarized in (Table A-1)[26].

Table A-1. *SDM Objectives for Delta Smelt*

Objective	General Description of Metrics
Grow the Delta Smelt population	Metrics generated from the model outputs include: population growth rate (average population change from one year to the next), percent change in population growth rate from observed conditions) percent change in population growth rate from a Reference Portfolio, effect uncertainty (subjective qualitative score)
Protect Salmon	Potential direct benefits and risks to salmon derived from salmon expert elicitation (score -3 to +3 for management actions and 0 to 3 for portfolios).
Keep capital and operating costs o acceptable levels	Estimates of "ballpark" costs for each management action over a 20-year period, including upfront capital costs, ongoing operating costs (e.g., staff time, annual monitoring), and water costs.
Avoid unnecessary impacts to water supply	Estimated changes in water supply resulting from a management action.
Meet Iin-Delta water quality standards	Estimated changes to water quality from an action that would impact in-Delta diversions for municipal and agricultural uses (e.g., increasing/decreasing salinity levels).

Measures

The following performance measures were developed to help evaluate tradeoffs between management actions an between portfolios in the Structured Decision Making Process.

Delta Smelt[27]

Population growth rate (lambda, λ) – calculated as the estimated population in one year divided by the estimated population in the previous year. A number above one means the population is increasing and conversely a number less than one is decreasing. Lambda for the period 1995 to 2014 was 0.86 indicating that values higher than this represent an improvement over historic conditions. Annual population growth rates are summarized over the entire model period (20 years) by calculating the median and/or average population growth rate across model simulations.

[25] Compass (2021) Process Guidelines, CSAMP Delta Smelt Structured Decision Making Project, p.7.
[26] See Round 1 Report , Table 11, for the full description.
[27] Adapted from Compass (2013) Delta Smelt PM Inf Sheet March 2023 on SharePoint

Change in population growth rate from reference - the estimated median population growth rate (over 20 years) for a given action divided by the historical median population growth rate (over 20 years) minus one. Therefore, a percentage change greater than zero indicates an action increased population growth rate from historical.

Effect uncertainty - Score between 1 (low uncertainty) and 3 (high uncertainty) indicating the degree of uncertainty of an actions' effects, based on the amount and level of agreement of existing data/models/evidence.

Physical [28]Feasibility - Score between 1 (low feasibility) and 3 (high feasibility) indicating the expected level of physical feasibility of implementing a management action without being burdened by needing to account for logistical, financial, and policy barriers.

Time to Implementation – a range in years of the expected time to implement the action and realize expected benefits, assuming normal permitting requirements and no litigation.

Salmon

Salmon effects from management actions - The metric describes the expected level of risks or benefits of each action to salmonids. A constructed scale was developed and scored by a group of Central Valley salmonid experts in workshops conducted in March and April 2023. The levels in the constructed scale range from -3 (highest expected risk) to 0 (no expected risks or benefits) to +3 (highest expected benefits). For each action, the magnitude of its effects (e.g., the % change in food) and the temporal and spatial overlap between the action and salmonids was considered in scoring and the average was reported.

Salmon benefits from portfolios – Score (group average, minimum, and maximum). Potential benefits of a portfolio were calculated by taking the average, minimum, or maximum scores for each action, summing all scores for actions included in the portfolio, and rescaling the final value to be between 0 (no benefits to salmon) and +5 (greatest benefits to salmon). Actions with potential risks (SMSCG, relaxed Fall X2 management, and aquatic weed control) were not included when calculating benefits scores. Scores for each action were modified to account for the spatial and temporal extent the action was applied, if it varied by portfolio.

Salmon risks from portfolios - Score (group average, minimum). Potential risks were calculated by taking the average or minimum scores for each action that had any potential risk (SMSCG, relaxed Fall X2 management, and aquatic weed control), summing all scores for actions included in the portfolio, and rescaling the final value to be between -5 (greatest risks to salmon) and 0 (no risks to salmon). A performance measure for potential risk using the maximum action scores was not calculated because all portfolios would have received a score of 0.

Water supply

Water resource costs are expressed in change in average annual exports (in thousands of acre feet/year) over the 20 year study period compared to the no-action case (Portfolio 1B). Historical

[28] Also referred to as "Technical Feasibility"

hydrology (X2 location and average OMR) was modified to simulate the influence of current regulations on historical hydrology to generate Portfolio 1B flow conditions.

Financial Costs

Financial costs are comprised of three items – capital costs or one time implementation costs that occur when the action is first implemented, annual operating costs, and water costs, although not every action incurs all three components. Initial implementation costs are averaged over 20 years and added to annual operating costs and water costs to provide an annual cost per year. The unit water cost was set at $815/af per the decision of the Policy Group on December 6, 2023. The other costs were estimated and reported by Compass on SharePoint[29].

Cost per 1% average increase in abundance – while this metric was not in the original list of performance measures, it provides a means of accounting for benefits to Delta Smelt and annual costs simultaneously. It is calculated by applying the estimated population growth rate percentages from model estimates averaged over the 20 year study period and dividing by the average annual financial costs of the portfolio.

3. Management Alternatives[30]

The Delta Smelt Technical Work Group (TWG) reviewed available evidence of Delta Smelt population bottlenecks or limiting factors and brainstormed around 40 candidate management actions. Functionally, these were grouped into four categories: candidate actions for evaluation in the SDM process, management actions where the decision to implement had already been made , candidate actions requiring more research to enable evaluation at a later time, and candidate actions to park indefinitely because they were considered infeasible or impractical. All of the candidate actions are described briefly below.

Candidate Management Actions for Evaluation

1 **North Delta Food Subsidies** - Re-direct 1) agricultural drainage or 2) Sacramento River water through the Yolo Bypass Toe Drain as a flow-pulse to increase food web productivity and transport of food to downstream regions (Cache Slough Complex and lower Sacramento River).

2 **Sacramento Deep Water Ship Channel –** Add nitrogen to the Sacramento Deep Water Ship Channel to stimulate plankton growth and abundance.

3 **Managed Wetlands Food Production** - Manage wetland flood and drain operations to promote food export from the managed wetlands to adjacent tidal sloughs and bays.

[29] Compass SharePoint>Documents>7. PM Info Sheets > 4. Financial Resource Costs
[30] Descriptions of actions were obtained primarily from Compass (2021) Structured Decision Making for Delta Smelt, Phase 2 Report. Some listed actions were omitted from this summary because they were very similar to listed actions and were not subsequently considered.

4 **Tidal Wetland Restoration** - Restore tidal wetlands in areas hat are likely to benefit Delta Smelt (primarily Suisun Marsh, Grizzly Bay, and adjacent areas.

5 **Suisun Marsh Salinity Control Gate Reoperations** - Operate Suisun Marsh Salinity Control Gates during dry summer months to improve salinity and attract more delta smelt to Suisun Marsh and adjacent areas. 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 action 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.

6 **Summer and Fall Outflow Actions** - Modify project operations to maintain lower salinity conditions in Suisun Marsh and Grizzly Bay in Wet and Above-Normal water-year types. This action is expected to increase the areal extent of suitable salinity, turbidity and possibly prey availability conditions and establish a contiguous range of suitable conditions from the Cache Slough Complex to Suisun Marsh.

7 **Sediment Supplementation**– Physically add sediment to the estuary to increase turbidity.

8 **Aquatic Weed Control** - Chemically treat or physically remove aquatic weeds in the Delta.

9 **Franks Tract Restoration** - Restore Frank's Tract Bay, and adjacent areas to create large open water areas connected by tidal wetlands and navigable channels to improve conditions for Delta Smelt

10 **OMR Management** - Manage OMR flows to reduce entrainment risk.

11 **Full-year flows** - Additional spring/summer/fall outflow when minimum flow thresholds are triggered.

12 **Engineered Fist Flush** - Modify project operations to provide flows to approximate a 'first flush' in years that otherwise would not reach a flow threshold.

13 **Contaminants Reduction** - Construct wetlands designed to reduce contaminants entering the Delta.

Actions Already Being Implemented or Evaluated by Others

Yolo Bypass Big Notch – Constrcut an enlarged "notch" next to the Freemont Weir to allow more frequent and larger volumes of Sacramento River flows to enter the Bypass.

Target **zero entrainment via real-time monitoring** of fish movement - Reduce entrainment of delta smelt by reducing exports to achieve positive OMR flows when more Intensly fish monitor in Old River, turbidity at USGS stations, and modeling of fish distribution indicate heightened risk. A modified version of this is included in the CDFW's ITP.

Move intakes to the Sacramento River - Construct new water project intakes in the north Delta out of the normal range of the distribution of delta smelt. Delta Conveyance Project DWR has initiated the preparation of an Environmental Impact Report (EIR) for the Delta Conveyance Project, involving new intake facilities as points of diversion that would be located in the north Delta along the Sacramento River between Freeport and the confluence with Sutter Slough.

Sacramento Waste-Water Treatment Plant upgrade - Construct a tertiary wastewater treatment plant in Sacramento to reduce certain contaminants entering the Delta. This project is under construction.

Hatchery supplementation - Supplement the Delta population of delta smelt with propagated fish. As part of the 2019 BiOP, Reclamation proposed to fund annual supplementation of Delta Smelt. Supplementation began in 2022.

Roaring River Distribution System food production - Construct interconnections between the Roaring River distribution system and adjacent bays to enhance prey availability for delta smelt in open water adjacent to the distribution system. Construction of interconnections began in 2019.

Actions Requiring Further Research Prior to Evaluation

Silverside Predation Management - Construct a protected nursery in a natural setting in Suisun Marsh, free of predatory fish, in which propagated eggs would be distributed. The area of around 50 to 100 acres of marshes and waterways would be drained prior to operation, to remove any resident predators. The facility would have a constant inflow and outflow, serviced by screens to prevent entry by predators f and to retain young delta.

Partial reconnection of floodplains to rivers - Remove levees or divert water from selected rivers to restore flows across floodplains and partially restore natural sediment transport and food web processes.

Increase turbidity in Delta Smelt habitat - A number of ways for increasing turbidity were identified by the TWG including (1) altering the timing and deposition of regular dredging operations (2) develop infrastructure to transport sediment over/through dams, (3) encourage bank erosion and channel migration below dams (4) supplement erodible sediments below dams.

Encourage channel migration and bank erosion below dams **–** Construct setback levees on river reaches below dams and then encourage the river to cut new channels through existing sediment deposits.

Barker Slough – Nurse Slough fish passageway - Construct a new channel, similar is design to the Sacramento Deep Water Ship Channel to connect Barker Slough to Nurse Slough to provide habitat connectivity between Susin Marsh and the Cache Slough complex - two of the best areas for delta smelt.

Develop infrastructure to transport sediment over/through dams - Employ any of a variety of technologies (e.g. on-stream or off-stream bypassing, sluicing or drawdown routing, dredging and flushing) to move sediment through or around dams.

Spawning habitat augmentation (restoring beaches taken over by invasive species) - Remove invasive *Arundo Donax* from the beaches on the Sacramento River to increase spawning substrates for Delta Smelt in suitable locations.

Salinity control devices - Place operable salinity control devices to limit the intrusion of high salinity water to the Delta (e.g., inflatable salinity sill at the bottom of Carquinez Strait to limit seawater intrusion) .

Actions thought to be Infeasible or Ineffective

Other actions were not analyzed because, after preliminary review they were considered infeasible or ineffective:

Releases from Oroville to extend spawning season - Release a block of water from Oroville dam to cool water during the spawning window in the hope that this creates further time for an additional spawning event.

Cooling devices in key habitats - Some form of large engineering infrastructure (geothermal heat pumps?) could theoretically reduce the temperature in localized areas of hypothesized high spawning activity during the critical months of February and March to extend the spawning season.

Predator Host Spot Removal – removal of salvaged predators from tanks at salvage facilities prior to returning native fish to the Delta**.**

Evaluation of Management Alternatives

The CSAMP Delta Smelt Technical Working Group (TWG) predicted the relative performance for Delta Smelt across management options in two steps. First, existing studies, new analytical tools, and expert judgment were used to quantify 1) the effects of candidate management actions on environmental conditions relevant for delta smelt (e.g., salinity, turbidity, food), 2) Delta Smelt spatial distribution, and 3) Delta Smelt survival for specific life stages (e.g., larvae, juvenile, adult survival). Second, the predicted proximate effects of management actions were used as inputs into four quantitative Delta Smelt population models to estimate a percent change in mean population growth. Other (non-Delta Smelt) objectives were evaluated more coarsely by engaging subject matter experts, due to the wide-ranging and exploratory nature of the management options.

This "Round 1" of the SDM process evaluated outcomes of several management options, beginning with 12 candidate management actions with intended increases in flow, food, turbidity and survival and 8 management portfolios, which were distinct combinations of actions. Additional exploratory and sensitivity analyses were conducted that predicted outcomes under varying intensities and timings of an action (e.g., outflow management) or under varying assumptions about an action's effects to capture uncertainty.

Portfolios – Round 1

In round 1, after specifying two reference portfolios against which other portfolios could be compared, the TWG developed portfolios around diverse themes[31]. It was typical to analyze a range of responses and implementation levels within each portfolio. Often the group was interested in the bookends – the highest and lowest values at which to implement actions - because if the highest value had no benefit there was little point in pursuing the action. If there was little

[31] Adapted from Compass SharePoint > Documents > 4. Portfolios > 2_DS Portfolio Dev-May2022_v3.0, pp:7-9

difference in benefits resulting from the highest and lowest levels of action implementation, other objectives could be given more consideration. The Round 1 modeling was focused on benefits for Delta Smelt and was completed without any real consideration of costs. The portfolios analyzed in round 1 are listed below. The actions comprising those portfolios are listed in Table A-2 and a high level summary of those actions are listed in Table A-3.

1a. **Reference: Post-2008 BiOp -** Includes all actions/regulations that were being implemented after the 2008 federal Record of Decision (ROD) and Biological Opinion (BiOp) for the long-term operation of the Projects.

1b. **Preference: Post-2020 BiOp/ITP -** This portfolio ncludes actions and regulations that are being implemented under the State's Incidental Take Permit (ITP) and the 2020 federal ROD and BiOp for the long-term operation of the water projects: SMSCG operations, OMR Management, north Delta food web subsidies and flow augmentation in the fall of wetter years All subsequent portfolios are additive to this reference portfolio unless otherwise specified.

2a. **Immediate and intensive management** - This portfolio employs the strategical use of a range of flow actions combined with intensive monitoring with the intent of reactively mitigating the earliest predicted bottleneck in each year.

2b. **Cache Slough/DWSC focus –** This portfolio includes short term actions to improve food availability and reduce aquatic vegetation in Cache Slough and the Deep Water Ship Channel (DWSC), where higher numbers of Delta Smelt have been sampled, relative to other regions, in recent years. The DWSC is hydrodynamically isolated, relative to other areas, which may increase success of the proposed management action.

2c. **Cache Slough and Suisun Marsh focus** - This portfolio ubilds on Portfolio 2b by adding managed wetlands in Suisun Marsh. These two areas are hypothesized to have the best conditions for growth and survival of Delta Smelt and could function as core refuge from which to build the population of delta smelt.

3a. **Self-sustaining/permanent management** - In this portfolio a set of actions are proposed that are intended to be more self-sustaining or permanent in nature and thus require less oversight and continual intervention. It builds on Portfolio 2b by adding tidal wetland restoration, contaminant reduction at multiple sites and restoration of Franks Tract).

3c. **Summer Flow and Tidal Wetlands –** This portfolio builds on Portfolio 1b by adding tidal wetland restoration and summer flow actions. It is intended to improve conditions for juvenile survival, building on important factors identified in recent work using the Life Cycle Model (Polansky et al. 2020, Smith et al. 2021), with additional flow actions during summer.

3d. **Focus on food -** Building on recent research using a limiting factor analysis (Hamilton & Murphy 2018, 2021, 2022), this portfolio focuses on food actions to address hypothesized limiting factors to the Delta Smelt population.

3e. **Improve habitat connectivity** - Specifies restoration and other non-flow actions to improve and connect habitat in the Confluence and Lower Rivers, between Suisun Marsh and DWSC that have relatively good habitat (Suisun Marsh and DWSC).

Table A-2[32]**.** *Summary of management actions included in 8 portfolios modeled in the Round 1 evaluation. Actions in grey are the same as actions included in the Reference Portfolio (1b, current management approximation). Actions in blue were adjusted or additional to the Reference Portfolio. Different scales or timings are noted for some actions that differed across portfolios.*

Action name	1b Current mgmt (approx.)	2a Full-year flows	2b Cache Slough	2c Cache Slough & Suisun Marsh	3c Summer flow & tidal wetlands[1]	3a Self-sustaining/ permanent mgmt	3d Focus on food	3e Habitat connectivity
NDFS	✓	✓	✓	✓	✓	✓	✓	✓
DWSC Food			✓	✓			✓	
Managed wetlands				✓ 2K ac			✓ 4K ac	
Tidal wetlands					✓ 9K ac	✓ 9K ac	✓ 30K ac	✓ 2K ac
SMSCG	✓	✓	✓	✓	✓	✓	✓	✓
X2/outflow	Fall (W,AN)	All seasons / yrs	Fall (W,AN)	Fall (W,AN)	Sum-Fall (W,AN)	Fall (W,AN)	Fall (W,AN)	Fall (W,AN)
Sediment supp								✓
Aquatic Weed Control			✓ 1 sub-region	✓ 1 sub-region			✓ 5 sub-regions	✓ 3 sub-regions
Franks Tract						✓		✓
OMR mgmt	✓	✓	✓	✓	✓	✓	✓	✓
Engineered First Flush		✓						
Contaminant reduction						✓ 12 sub-regions	✓ 12 sub-regions	✓ 8 sub-regions

[1] Portfolio 3c included multiple versions/model runs that varied X2 targets in summer and fall. Specific X2 targets are given when presenting and discussing results in subsequent sections of the report.

[32] Table A-2 is Table ES-1 from Round 1 Report.

Table A-3. *Details of actions included in Round 1 portfolios.*

	Action	Level	Response Assumption	Timing	Years to Implement[33]
1.1	North Delta Food Subsidies	25,000 af	Food	Aug-Oct	1
2.2	DWSC Food + Nutrients		Food		1-3
3.4	Managed Wetlands Spring to Fall – high response	4,000 af	Food	Mar-Apr, Jul-Oct	1-3
3.5	Managed Wetlands Spring to Fall – medium response	2,000 af	Food	Mar-Apr, Jul-Oct	1-3
4.1	Tidal wetlands	8,900 ac	Low food response	Perennial	1-3
4.2	Tidal wetlands	8,900 ac	High food response	Perennial	1-3
4.3	Tidal wetlands	20,000 ac	Low food response	Perennial	1-3
4.4	Tidal wetlands	20,000 ac	High food response	Perennial	1-3
5.2	Suisun Marsh Salinity Control Gate Reoperation		No food response	Jun-Oct	1
6.26	Flow Augmentation [a]		Medium food, fish distribution	Jul-Aug	1-3
6.31	Flow Augmentation [b]		Medium food, fish distribution	Sep-Oct	1-3
6.33	Flow Augmentation [c]		Size of LSZ	Mar-May, Aug-Oct	1-3
7.1*	Sediment Supplementation: Lower Sacramento to Suisun Bay	450,000 cu yd	Turbidity	May-Dec ’95-’97, ’04-‘14	3-5
8.1	Aquatic Weed Control – Yolo	600 ac	Turbidity & Food	All year	3-5
8.4	Aquatic Weed Control – North Delta	1,430 ac	Turbidity & Food	All year	3-5
8.5	Aquatic Weed Control – North Delta + Lower SJR	3,470 ac	Turbidity & Food	All year	3-5
9.2	Franks Tract Restoration		Low bookend		5-10
10.2	OMR Management 2008/09 BiOps plus OMR protection during first flush		Entrainment	Dec-Jun	1
11.2	Engineered First Flush	25,000 cfs	Low bookend	January	1-3
12.2	Contaminants Reduction – Yolo & Sacramento River	3 Sites	Survival	Perennial	5-10
13	Risk -Based OMR		Entrainment	Dec-Jun	1-3
14	Fish Friendly Diversions	15,000 cfs	Entrainment	Dec-Jun	5-10

[a] X2<70km in Jul, 75 km in Aug, in W, AN years

[b] X2<80km in Sep & Oct in W, AN years

[c] [a] +700 taf in Mar, Apr or May (2004, 2008, 2013, 2014). X2<75km in Aug 2002, 2010, X2<80km in Sep & Oct in W, AN years

[33] This metric does not include factors such as time for permitting and legislative changes in order to implement.

4. Estimated Consequences

The estimated consequences for each of the Round 1 portfolios are presented in Table A-4 (a condensed version of Table ES-2 from the Round 1 Report) for specified performance measures (see section 2). The possible ranges of scores, where relevant, are included in the first column. The original actions in each portfolio in round 1 are listed in Table A-2.

Table A-4. *Consequence Table of predicted outcomes for portfolios and objectives/performance measures in the CSAMP Delta Smelt Round 1 evaluation. Green cells indicate performance measures where higher values (darker shades) are preferred. Orange cells indicate metrics where lower values (lighter shades) are preferred. Grey cells indicate water/cost metrics that are components of aggregated totals in the top water/cost row. This table is a condensed version of Table ES-2 in the Round 1s Report.*

Objective & Performance Measure	1b Current manag.	2a.1 Full-year flows	2b Cache Slough	2c Cache Slough & Suisun Marsh	3c.2 Summer flow & tidal wetlands	3c.4 Summer flow & tidal wetlands	3a Self-sustaining	3d Focus on food	3e Habitat connectivity
Delta Smelt Population									
Population Growth rate[1] (average lambda: 1995-2014)									
IBMR	1.00	1.21	1.12	1.25	1.13	1.10	1.40	1.96	2.23
LCME	1.09	1.15	-	-	1.25	1.19	1.21	1.50	1.31
LF	0.91	0.93	1.05	1.27	1.07	1.06	1.11	1.43	1.29
Dynamic Habitat Suitability Index[3] (overlap)									
Yolo/Cache Slough	20%	20%	32%	32%	21%	21%	21%	33%	20%
Confluence & Lower Rivers	7%	7%	7%	7%	7%	7%	7%	12%	30%
Suisun Marsh & Bay	20%	23%	20%	21%	23%	23%	21%	21%	21%
Uncertainty[4] (TWG group scores)									
Confidence in action effect assumptions: TWG avg (range of actions; scale: 1 to 5)	3.0 (food) to 4.0 (OMR)	2.4 (distribution) to 4.0 (OMR)	2.4 (food) to 4.0 (OMR)	2.4 (food) to 4.0 (OMR)	2.3 (food) to 4.0 (OMR)	2.3 (food) to 4.0 (OMR)	2.3 (food) to 4.0 (OMR)	2.3 (food) to 4.0 (OMR)	2.3 (food) to 4.0 (OMR)
Time to implementation[5] (TWG group scores)									
# actions < 5 yrs	-	1	1	2	1	1	0	0	1
# actions > 5 yrs	-	0	1	1	1	1	3	5	4
Salmon effects[6] (expert group scores)									
Benefits: (scale: 0 to 3)	0	1	1	1	1	1	2	3	1

Objective & Performance Measure		1b Current manag.	2a.1 Full-year flows	2b Cache Slough	2c Cache Slough & Suisun Marsh	3c.2 Summer flow & tidal wetlands	3c.4 Summer flow & tidal wetlands	3a Self-sustaining	3d Focus on food	3e Habitat connectivity
Risks:[3] (scale: -3 to 0)		0	-1	-1	0	0	0	0	-2	-1
Water / Resource Costs[7] (ballpark estimates, relative to Reference Portfolio 1b, for comparative purposes only)										
Water[4,5] (TAF/yr)	All yrs	-	212	0	0	495	127	0	0	0
Costs[4] ($ million / yr)	Total[9]	None	$151-$200	$1-$5	$1-$5	$401-$450	$101-$150	$101-$150	$151-$200	$76-$100
	Water[10]	-	$173	$0	$0	$404	$104	$0	$0	$0
	Capital & Operating[11]	-	None	$1-$5	$1-$5	$21-$30	$21-$30	$101-$150	$151-$200	$76-$100

[1] Delta Smelt population metrics were calculated in three ways: (1) annual predicted population growth rate (lambda) from the portfolio, (2) the percent change in annual population growth from the portfolio relative to baseline, historical conditions between 1995-2014, where values > 0% indicate increased population growth relative to baseline, and (3) the percent change in annual population growth from the portfolio relative to Reference Portfolio 1b (current management approx.). Metrics were averaged over the 20-yr period.

[3] Dynamic Habitat Suitability Index (between 0 and 100%) was calculated as the percentage of months (over the 20-year model period) when all four dynamic habitat attributes (temperature, turbidity, salinity, and prey) are in "suitable" ranges (i.e., suitable conditions overlap), defined by existing studies and the TWG.

[4] Effect uncertainty was scored by TWG members to indicate their level of confidence in the assumed/quantified proximate effects (e.g., on food, turbidity) of each management action using a constructed scale (1 [lowest confidence] to 5 [greatest confidence]). Reported as the range of actions in a portfolio with the lowest and highest average TWG score.

[5] Time to implementation is defined in this process as how long it will take to achieve full implementation, including research of technical aspects of the action and generation of expected benefits for Delta Smelt, while not considering time needed for permitting. Time to implementation was scored by TWG members. Values in different time to implementation categories reflect the number of actions in a portfolio additional to actions included in Reference Portfolio 1b, based on average TWG scores.

[6] Salmon effects of actions (sometimes at different scales) were scored by subject matter experts from -3 (greatest risks) to +3 (greatest benefits). Individual action scores were summed within a portfolio and rescaled from 0 (no benefits) to +3 (greatest benefits). Scores for individual actions deemed by experts as having any potential direct risk were summed within a portfolio and rescaled from -3 (greatest risks) to 0 (no risks). Potential benefits are reported as average scores; potential risks are reported as minimum scores to represent any degree of risk to salmonids expressed by experts. Salmon experts noted potential negative risks to juvenile Chinook from AWC, as there is some evidence that higher turbidity can decrease foraging rates, and juveniles can use submerged aquatic vegetation to avoid predation. There is also the potential for direct mortality from mechanical (or chemical) removal. Effects to salmon of flow actions reflect potential direct, within-year benefits/risks of changing flow in a given season. Experts did not consider carry-over effects of flow actions, and modeling how operations would achieve flow actions is needed to better estimate effects to salmon.

[7] All water and resource costs: Water resources and capital and operating costs of portfolios were calculated relative to Reference Portfolio 1b (current management approx.). Costs for individual management actions are reported relative to baseline, historical conditions – not Reference Portfolio 1b. Therefore, water volumes and resource costs are slightly different between the tables. Ballpark values were estimated through coarse methods and meant for comparative purposes only.

[8] Additional water (relative to outflow under Reference Portfolio 1b) is averaged across all 20 years and is presented for comparative purposes only. The source of water needed to implement flow actions was not identified and water was not balanced within or among years in Round 1. The water resource volume represents the net volume of water necessary to move X2 from its position in Reference Portfolio 1b to a target condition, based on equations in Monismith et al. (2002) and Denton (1993).
[9] Total cost was calculated as the sum of monetized water and capital & operating costs, annualized over the 20-yr period without a discount rate.
[10] Monetization of water used $815 per acre foot of water, annualized over the 20-yr period, as discussed and agreed to by the CSAMP Policy Group Steering Committee. See Appendix 3 – Water Resources Methods – Monetized water cost.
[11] Includes ballpark estimates of capital & operating costs, annualized without a discount rate.

Table A-5. *The consequences of management actions evaluated in Round 1 against the specified performance measures (see section 2). The possible ranges of scores, where relevant are included in the first column.*

Table ES-3. Consequence Table of predicted outcomes for individual management actions and objectives/performance measures in the CSAMP Delta Smelt SDM evaluation. Actions are grouped by expected time to implementation. **Green cells indicate performance measures where higher values (darker shades) are preferred. Orange cells indicate metrics where lower values (lighter shades) are preferred.** Management action names are shaded by their primary effect: blue = flow and food, green = food, orange = turbidity, and purple = survival/other.

Objective & Performance Measure	Management Actions[1]																			
	Current management				Can implement in < 5 yrs[2]					May be able to implement in > 5 yrs[2]										
	North Delta Food Subsidies[3]	Fall X2/Outflow (X2 ≤ 80 for Sept/Oct)[4]	Suisun Marsh Salinity Control Gates (SMSCG)[4]	Old & Middle River Management (2008/2009/ 2019 BiOps)	Managed Wetlands Food Production[3]	Summer Outflow (X2 ≤ 70/75 for July/Aug)[4]		Full-year Flow[4]	Engin-eered First Flush	Aquatic weed control	Tidal Wetland Restoration in North Delta Arc		Managed Wetlands Food Production[3]	DWSC Food[3]	Franks Tract Restora-tion	Aquatic weed control		Sediment supple-mentation	Contaminant reduction	
		W/AN			1K ac in SM	W/AN	W/AN/ BN	W/AN/ BN/D/C		600 ac in CS	9K ac	30K ac	4K ac			1.4K ac	3.5K ac		Yolo / CS	Delta-wide
Delta Smelt Population																				
Delta Smelt Population Growth[5] (average lambda 1995-2014)																				
IBMR	0.98	0.98	0.98	1.00	0.98	1.04	1.09	1.15	1.05	1.04	1.04	1.12	0.98	0.98	1.14	1.28	1.47	1.70	1.00	1.14
LCME	-	0.94	-	1.09	-	0.99	1.05	0.99	-	-	1.00	1.14	-	-	-	-	1.00	1.01	-	-
LF	0.87	-	-	-	-	-	-	-	-	0.87	0.98	1.10	1.15	0.97	0.98	-	-	1.00	-	-
Delta Smelt Population Growth[5] (% change from 1995-2014 baseline)																				
IBMR	0%	0%	0%	2%	0%	6%	11%	17%	7%	6%	5%	13%	0%	0%	16%	30%	49%	73%	1%	16%
LCME[6]	-	0%	-	16%	-	5%	12%	5%	-	-	5%	20%	-	-	-	-	4%	11%	-	-
MDR[6]	-	0%	-	29%	-	-	-	-	-	-	8%	17%	-	-	-	-	-	-	-	-
LF	0%	-	-	-	-	-	-	-	-	2%	16%	30%	36%	14%	16%	-	-	15%	-	-
Uncertainty[7] (TWG group scores)																				
Confidence in action effect assumptions: TWG avg score (scale: 1 [low] to 5 [high] confidence)	Food: 3.0	IBMR salinity-zoop model: 3.0; LF flow-zoop model: 2.0	IBMR salinity-zoop model: 3.1; LF flow-zoop model: 2.3	OMR flows: 4.4	Food: 3.0	IBMR salinity-zoop model: 3.0; LF flow-zoop model: 2.0			IBMR distrib: 2.4	Turbidity: 3.3	Food: 2.3	Food: 2.3	Food: 3.0	Food: 2.4	Food: 2.3	Turbidity: 3.3		Turbidity: 2.5	Contaminants: 3.1	
Salmon effects[8] (expert group scores)																				
Potential benefits: Salmon expert avg score (scale: 0 to 3)	0	Not assessed	0	Not assessed	2	0	0	3	2	0	2	2	2	2	1	0	0	1	2	2
Potential risks: Salmon expert min score (scale: -3 to 0)	0	Not assessed	-1	Not assessed	0	0	0	0	0	-1	0	0	0	0	0	-1	-1	0	0	0
Water / Resource Costs[9] (ballpark estimates for comparative purposes only)																				
Water[10] (TAF/yr): All yrs	Financial and water costs were only evaluated for actions additional to current management, per agreement by the SDM Policy Group Steering Committee.				-	157	319	248	23	-	-	-	-	-	-	-	-	-	-	-
Water[10] (TAF/yr): W / AN					-	350	350	361	-	-	-	-	-	-	-	-	-	-	-	-
Water[10] (TAF/yr): BN					-	-	810	300	38	-	-	-	-	-	-	-	-	-	-	-
Water[10] (TAF/yr): D / C					-	-	-	72	43	-	-	-	-	-	-	-	-	-	-	-
Costs ($ million / yr): Total[11]					$1	$128	$260	$192	$18	$2	$22	$63	$2	$1	$29	$5	$13	$5	$7	$84
Costs ($ million / yr): Water[12]					-	$128	$260	$192	$18	-	-	-	-	-	-	-	-	-	-	-
Costs ($ million / yr): Capital & operating[13]					$1	-	-	-	-	$2	$22	$63	$2	$1	$29	$5	$13	$5	$7	$84

[1] The management action effect assumptions used in the Delta Smelt modeling are summarized in Table 2.

[2] Actions are grouped by relative time to implementation. Time to implementation is defined in this process as how long it will take to achieve full implementation, including research of technical aspects of the action and generation of expected benefits for Delta Smelt, while not considering time needed for permitting. Time to implementation was scored by TWG members, and average scores were used to group actions in implementation categories.

[3] Small-scale actions that are predicted to have a 0% population growth when modeled individually with the IBMR contribute to positive population growth when modeled with other actions in a portfolio (see Sections 4.4 and 5).

[4] There were 9 W/AN years, 4 BN years, and 7 D/C years in the 20-yr model period. Fall X2 action: X2 was set to 80 km in Sept/Oct in W and AN water year types when historical X2 locations were > 80 km (this occurred in 10 months out of the 18 applicable months across the 20-yr model period). Summer X2 action: X2 was set to targets in July/Aug only for months when historical X2 locations were > 70/75, respectively. This occurred in 12 of the 18 applicable months for the W/AN action and 20 of the 26 months for the W/AN/BN action (across the 20-yr model period). For the Full-year Flow action, X2 was set to month-specific targets in 30 months across the 20-yr model period.

[5] Delta Smelt population metrics were calculated in two ways: (1) annual predicted population growth rate (lambda) from the action, and (2) the percent change in annual population growth from the portfolio relative to baseline, historical conditions between 1995-2014, where values > 0% indicate increased population growth relative to baseline. Metrics were averaged over the 20-yr period.

[6] The LCME and MDR models used different versions (with different sets of covariates) to evaluate different actions, which leads to variation in % change from baseline. These models often could only include effects of an action for a portion of months even if it was specified to have year-round effects.

[7] Effect uncertainty was scored by TWG members to indicate their level of confidence in the assumed/quantified proximate effects (e.g., on food, turbidity) of each management action using a constructed scale (1 [lowest confidence] to 5 [greatest confidence]). Reported as the average TWG score.

[8] Salmon effects of actions (sometimes at different scales) were scored by subject matter experts from -3 (greatest risks) to +3 (greatest benefits). Individual action scores were summed within a portfolio and rescaled from 0 (no benefits) to +3 (greatest benefits). Scores for individual actions deemed by experts as having any potential direct risk were summed within a portfolio and rescaled from -3 (greatest risks) to 0 (no risks). Potential benefits are reported as average scores; potential risks are reported as minimum scores to represent any degree of risk to salmonids expressed by experts. Salmon experts noted potential negative risks to juvenile Chinook from AWC, as there is some evidence that higher turbidity can decrease foraging rates, and juveniles can use submerged aquatic vegetation to avoid predation. There is also the potential for direct mortality from mechanical (or chemical) removal. Effects to salmon of flow actions reflect potential direct, within-year benefits/risks of changing flow in a given season. Experts did not consider carry-over effects of flow actions, and modeling how operations would achieve flow actions is needed to better estimate effects to salmon.

[9] All water and resource costs: Water resources and capital and operating costs of actions were calculated relative to baseline, historical conditions. Ballpark values were estimated through coarse methods and meant for comparative purposes only.

[10] Additional water (relative to outflow under baseline, historical conditions between 1995-2014) is averaged across all 20 years and is presented for comparative purposes only. The source of water needed to implement flow actions was not identified in this SDM process. The water resource volume represents the estimated net volume of water necessary to move X2 from its historical monthly position to a target condition, based on equations in Monismith et al. (2002) and Denton (1993).

[11] Total cost was calculated as the sum of monetized water and capital & operating costs, annualized over the 20-yr period without a discount rate.

[12] Monetization of water used $815 per acre foot of water, annualized over the 20-yr period, as discussed and agreed to by the CSAMP Policy Group Steering Committee. See Appendix 3 – Water Resources Methods – Monetized water cost.

[13] Includes ballpark estimates of capital & operating costs, annualized without a discount rate, for comparative purposes only.

5. Evaluation of Tradeoffs

Findings

Findings of management relevance are reported in the body of this document (pages 2 to 14)