# Memo

To: CSAMP Policy Group

From: Sally Rudd, Brian Crawford and Dan Ohlson, Compass Resource Management

Date: May 30, 2023

**Re: Round 1 SDM Evaluation Summary**

This memo provides a concise summary of the CSAMP Delta Smelt Structured Decision Making (SDM) Project's "Round 1" evaluation. Section 1 summarizes the objectives and performance measures used in Round 1. Section 2 summarizes the alternatives, which are distinct combinations of Delta Smelt management actions that we called 'portfolios.' Section 3 provides the Consequence Table that shows the predicted effects of each alternative on each objective. Section 4 identifies key takeaways and limitations of the evaluation from the Delta Smelt Technical Working Group (TWG). The Round 1 evaluation drew on extensive resources and produced additional methods and results documentation. CSAMP Policy Group and CAMT members are encouraged to consult their TWG members who can provide further documents and interpretation of the Round 1 evaluation. Compass will be writing a comprehensive report on the analysis at the appropriate point.

As a reminder, the purpose of this project is to provide opportunities for analysis and dialogue on Delta Smelt management actions and science that could advance the CSAMP Management Goal for Delta Smelt. Compass provides facilitation and analytical support for the Project and has worked closely with the Delta Smelt TWG (composed of CAMT member organization staff) and the Policy Group SDM Steering Committee. CAMT co-chairs have also helped Compass set up and engage other technical groups for hydrology and salmon to support coarse analysis of Delta Smelt management actions with respect to water resource costs and salmon effects.

At the June 7 Policy Group meeting, Compass will provide an overview of the key activities and take-aways from the Round 1 evaluation. The Policy Group will then have an opportunity to ask questions, share your reactions and provide direction on the next steps for the Project. SDM is typically done in rounds of developing and evaluating alternatives to allow for iterative learning and improvement of the alternatives and analysis. In this Project, and similarly to other SDM processes, the "Round 1" evaluation was focused on exploring the possibilities for the focus objective (Delta Smelt population growth) and there was more coarse analysis on the other objectives (salmon, financial resources, water resources). Additional analysis could build on the portfolios evaluated in Round 1, refine performance measures and/or explore uncertainty and feasibility questions more deeply.

**CSAMP MANAGEMENT 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. To achieve this goal, CSAMP members will work collaboratively, and with urgency, to prioritize and implement management actions that are targeted at known or hypothesized stressors, habitat needs or other critical factors affecting the Delta Smelt population, and to learn through implementation.***

*Endorsed by Policy Group, Oct. 30, 2019.*

# 1 Objectives and Performance Measures

Table 1 provides the performance measures (PMs) that were used to evaluate the effects of management actions and portfolios on Delta Smelt, financial resources, water resources and salmon. The Delta Smelt TWG used various approaches (multiple population models, existing studies, expert judgment) to predict the relative performance of each portfolio for Delta Smelt. Because the Round 1 portfolios are wide ranging and are still at a more exploratory stage, other (non-Delta Smelt) objectives were evaluated more coarsely by engaging subject matter experts.

**Table 1. Performance Measures (PMs) for CSAMP Delta Smelt SDM Project.**

| Objective | Performance Measure | Description |
|---|---|---|
| Delta Smelt population | Population growth rate (lambda, λ) | Annual population growth rate (lambda) is summarized over the entire model period (20 years) by calculating the median population growth rate across model simulations. Separate estimates provided for three models. |
| | % change in population growth rate from baseline (baseline = observed conditions) | The % change is calculated as the median population growth rate (over 20 years) for a given portfolio divided by the median population growth rate (over 20 years) estimated for the baseline (no action) minus 1. Therefore, a % change greater than 0 indicates a portfolio increased population growth rate, relative to the baseline. Separate estimates provided for four models. |
| | % change in population growth rate from Reference Portfolio 1b | The % change is calculated as the median population growth rate (over 20 years) for a given portfolio divided by the median population growth rate (over 20 years) estimated for the Reference Portfolio (1b, current management approximation) minus 1. Therefore, a % change greater than 0 indicates a portfolio increased population growth rate, relative to the Reference Portfolio 1b. Separate estimates provided for three models. |
| | Dynamic Habitat Suitability Index (DHSI) | An index (between 0 and 100%) showing 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. The DHSI is calculated for each subregion but reported for the Yolo/Cache Slough subregion, the subregion with the maximum value in the Confluence and Lower Rivers, and the subregion with the maximum value in Suisun Marsh and Bay. |
| Financial resource cost | Ballpark cost estimate (above Reference Portfolio 1b) | Estimated ballpark cost of portfolios, represented as a range of annualized capital and operating costs over the 20-year modeling period ($ Million / yr). Provided for comparative purposes only. |
| Water resource cost | Annual average net additional water (above Reference Portfolio 1b) | Average net additional water TAF/yr (includes additional water needed and potential ‘water savings’), relative to water required for Portfolio 1b (approx. current management) for wetter (W and AN) and drier (BN, D, and C) water year types in the 20-year model period. Operations modeling was not available for Round 1. The PM is calculated based on a coarse hydrology analysis method and is suitable for comparative purposes only. For example, potential water savings might not actualize because of other constraints in the system. Annual results are available on request. |
| Salmon | Potential direct benefits | A group of salmon experts scored the effects of individual actions using a constructed scale (-3 [greatest risks] to +3 [greatest benefits]) based on the expected magnitude of effects and spatial/temporal extent of the action. Individual action scores were combined within a portfolio and rescaled from 0 (no benefits) to +5 (greatest benefits). Scores for individual actions deemed by experts as having any potential direct risk were summed within a portfolio and rescaled from -5 (greatest risks) to 0 (no risks). Indirect risks (e.g., the effects of flow actions on flows later in the year or in the next year) were not evaluated in Round 1. |
| | Potential direct risks | |

## 2 Round 1 Portfolios

Round 1 portfolios (Table 2) were developed by the TWG to test distinct, hypothesis-based approaches for advancing Delta Smelt recovery. Portfolios used different combinations of flow and/or non-flow actions, where "flow action" is defined as an action requiring additional water to the reference portfolio. Each portfolio is specified with details concerning the time (month), place (Delta subregion; see Figure 1), and intensity of management actions for Delta Smelt, as well as assumptions around the continuation or adjustment of existing management actions. Portfolios focused on different time periods related to when management actions could be implemented and produce benefits for Delta Smelt:

- Group 1 Reference/current: A reference portfolio including the management actions related to Delta Smelt in the 2020 Record of Decision (ROD)/Biological Opinions (BiOps) and Incidental Take Permit (ITP);
- Group 2 "Immediate/near-term": Portfolios with near-term actions that can be implemented within the next ~5 years. It is assumed that these actions will likely not be sufficient for recovery and would ultimately need to be coupled with additional actions; and,
- Group 3 "Near and long-term": Portfolios with near-term and one or more long-term actions that cannot be implemented within the next 10 or fewer years (2032 onwards), acknowledging that some planning, resourcing, research, implementation, etc. would likely begin sooner.

**Figure 1. Spatial extent of the Delta Smelt SDM evaluation, including 12 subregions used by the IBMR.**

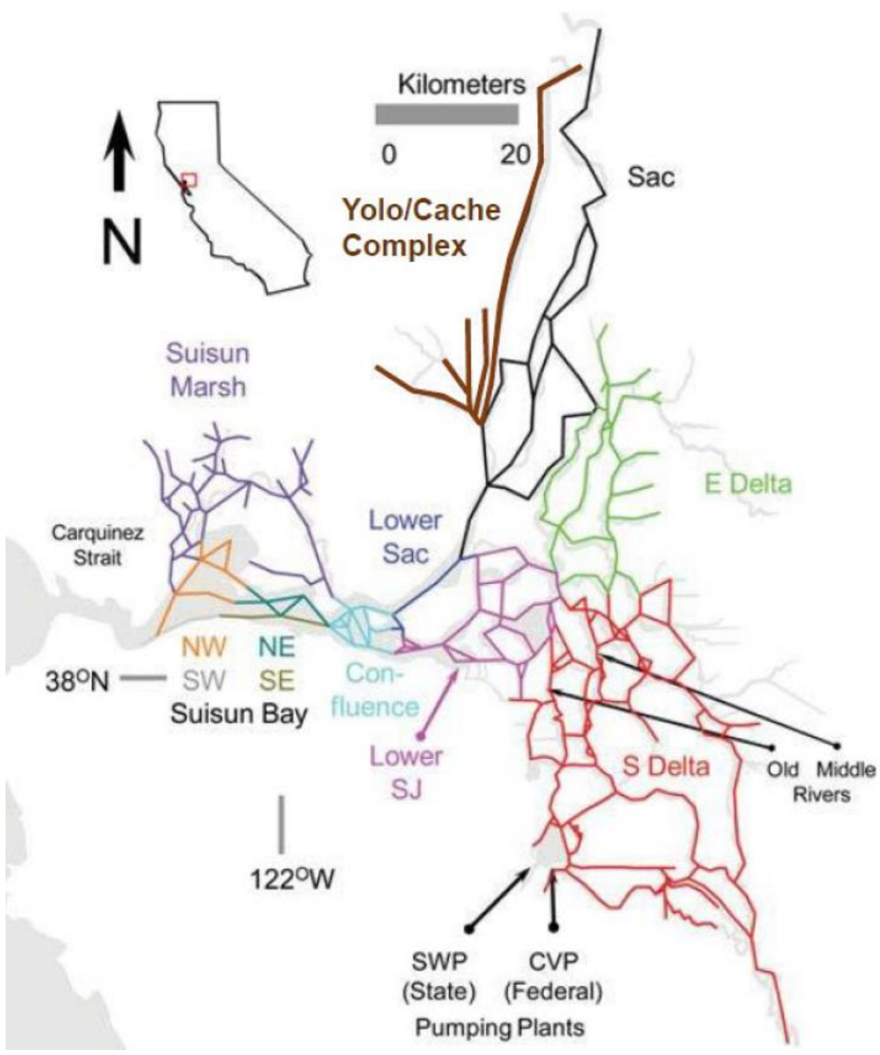

**Table 2. Summary of management portfolios developed by the Technical Working Group for Round 1 of the CSAMP Delta Smelt SDM evaluation.**

| Short ID & name | Category (time to implementation & action type) | Description | Actions included |
|---|---|---|---|
| 1b: Current management (approximation) | Current (reference); | Includes actions/regulations targeted at delta smelt that are currently being implemented under the State's Incidental Take Permit (ITP) and the 2020 federal ROD and BiOp for the long-term operation of the Projects. **All subsequent portfolios are additive to this reference portfolio unless otherwise specified.** | • Fall X2 ≤ 80 km<br>• OMR flows under the 2008/09 BiOp<br>• Suisun Marsh Salinity Control Gates (SMSCG)<br>• North Delta Food Subsidies (NDFS) |
| 2a: Full-year flows | Near-term; flow actions | Deploys flow actions, which could be implemented immediately (i.e., beginning in 2022/23), across a year that reactively mitigate poor conditions to create full good years for Delta Smelt (i.e., target the predicted bottleneck for each life stage in each year). Two versions of the portfolio tested different annual water budgets: (1) No annual water budget (flows necessary to meet minimum thresholds year-round); (2) Annual water budget of 700 TAF. | • Actions from Portfolio 1b<br>• Engineered First Flush<br>• Additional Spring/Summer outflow when minimum flow thresholds are triggered:<br>  ○ Mar-May: < 25,000 cfs in W or AN yrs; <11,700 cfs in BN, D, and C<br>  ○ Jun: < 12,400 cfs in W yrs; < 11,400 cfs in AN or BN<br>  ○ Jul-Aug: < 7,500 cfs in W, AN, or BN yrs |
| 2b: Cache Slough | Near-term; non-flow actions | Deploys actions in the short-term to create year-round refuges in Cache Slough – especially in the Deep Water Ship Channel (DWSC), where significant numbers of Delta Smelt adults and larvae have been found in more recent years. The DWSC is hydrodynamically isolated, relative to other areas, which may increase success of mgmt (e.g., invasive predators and SAV removal). | • Actions from Portfolio 1b<br>• Sacramento Deep Water Ship Channel (DWSC) Food Transport & Production<br>• Aquatic weed control (AWC) + sediment agitation (Yolo/Cache Slough) |
| 2c: Cache Slough & Suisun Marsh | Near-term; non-flow actions | Builds on Portfolio 2b: includes all the same actions in DWSC plus short-term actions in Suisun Marsh (Montezuma Slough). These two areas are hypothesized to have the best conditions for growth and survival of Delta Smelt and should be maintained and enhanced to reduce extinction risk. | • Actions from Portfolio 1b<br>• Sacramento Deep Water Ship Channel (DWSC) Food Transport & Production<br>• Aquatic weed control (AWC) + sediment agitation (Yolo/Cache Slough)<br>• Managed wetlands in Suisun Marsh / Roaring River Distribution System (2,000 ac) |

| Short ID & name | Category (time to implementation & action type) | Description | Actions included (in addition to 1b) |
|---|---|---|---|
| 3a: Self-sustaining/ permanent mgmt | Long-term; non-flow actions | Deploys actions aimed to benefit all life stages that could be implemented in the long-term and are more self-sustaining or permanent in nature and thus require less oversight and continual intervention. | • Actions from Portfolio 1b<br>• Tidal wetland restoration (~9,000 ac)<br>• Franks Tract restoration<br>• Physical point source contaminant restoration (Delta-wide; 12 subregions) |
| 3c: Summer flow & tidal wetlands | Near-term; flow + non-flow actions | Building on important factors identified in recent work using the Life Cycle Model (Polansky et al. 2020, Smith et al. 2021), focuses on actions to promote good conditions for spawning and larval survival, with additional flow actions during summer and fall. Hypothesizes that mgmt resources allocated to spawning/larvae stages may produce largest population benefits. | • Actions from Portfolio 1b (with variations in Fall X2 as noted below)<br>• Tidal wetland restoration (~9,000 ac)<br>• X2/outflow management (4 versions):<br>**3c1:** Lower Summer X2 (65km in Jul, 70km in Aug), relaxed Fall X2<br>**3c2:** Lower Summer X2 (65km in Jul, 70km in Aug), current Fall X2<br>**3c3:** Low Summer X2 (70km in Jul, 75km in Aug), relaxed Fall X2<br>**3c4:** Low Summer X2 (70km in Jul, 75km in Aug), current Fall X2 |
| 3d: Focus on food | Near and Long-term; non-flow actions | 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. | • Actions from Portfolio 1b<br>• Tidal wetland restoration (~30,000 ac)<br>• Sacramento Deep Water Ship Channel (DWSC) Food Transport & Production<br>• Managed wetlands in Suisun Marsh / Roaring River Distribution System (4,000 ac)<br>• Aquatic weed control (AWC) (5 subregions)<br>• Physical point source contaminant restoration (Delta-wide; 12 subregions)<br>• X2/outflow management: either current or relaxed Fall X2 (2 versions) |
| 3e: Habitat connectivity | Near and Long-term; non-flow actions | Specifies restoration and other non-flow actions to improve and connect habitat in the Confluence and Lower Rivers, between areas that currently have relatively good habitat (Suisun Marsh and DWSC). | • Actions from Portfolio 1b<br>• Tidal wetland restoration (~2,000 ac)<br>• Franks Tract restoration<br>• Aquatic weed control (AWC) (3 subregions)<br>• Sediment supplementation<br>• Physical point source contaminant restoration (8 subregions) |

# 3 Predicted consequences

**Table 3. Consequence table of predicted outcomes for portfolios and objectives/performance metrics in Round 1 of the CSAMP Delta Smelt SDM evaluation. Green cells indicate performance metrics where higher values (darker shades) are preferred. Orange cells indicate metrics where lower values (lighter shades) are preferred.**

| Objective | Less Preferred – More Preferred (green); Less Preferred – More Preferred (orange) | Performance Measure | Unit | 1b Current mgmt (approximation) | 2a.2 Full-year flows - 700 TAF water budget | 2b Cache Slough | 2c Cache Slough & Suisun Marsh | 3c.2 Summer flow & tidal wetlands (X2: Summer 65/70km; Fall current) | 3c.4 Summer flow & tidal wetlands (X2: Summer 70/75km; Fall current) | 3a Self-sustaining/permai management | 3d Focus on food | 3d.2 Focus on food - Fall X2 < 88km | 3e Habitat connectivity |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Delta Smelt Population** | | | | | | | | | | | | | |
| Population growth rate | | | | | | | | | | | | | |
| IBMR | Low TW food effect | Avg. population growth | # | 1.00 | 1.21 | 1.12 | 1.25 | 1.13 | 1.10 | 1.40 | 1.96 | 1.98 | 2.23 |
| LCME | Low TW food effect | Avg. population growth | # | 1.09 | 1.15 | | | 1.25 | 1.19 | 1.21 | 1.50 | 1.50 | 1.31 |
| LF | Low TW food effect | Avg. population growth | # | 0.91 | 0.92 | 1.05 | 1.27 | 1.07 | 1.06 | 1.11 | 1.43 | 1.57 | 1.29 |
| Change in population growth (from baseline) | | | | | | | | | | | | | |
| IBMR | Low TW food effect | Avg. % change in population growth | % | 1 | 23 | 14 | 27 | 15 | 12 | 42 | 99 | 101 | 126 |
| LCME | Low TW food effect | Avg. % change in population growth | % | 20 | 25 | | | 33 | 27 | 27 | 58 | 58 | 38 |
| MDR | Low TW food effect | Avg. % change in population growth | % | 29 | 15 | | | 24 | 17 | 13 | 33 | | 90 |
| LF | Low TW food effect | Avg. % change in population growth | % | 5 | 7 | 22 | 47 | 22 | 21 | 29 | 64 | 81 | 48 |
| Dynamic Habitat Suitability Index (overlap) | | | | | | | | | | | | | |
| Yolo/Cache Slough | Low food effect | DHSI | % | 20 | 20 | 32 | 32 | 21 | 21 | 21 | 33 | 33 | 20 |
| Confluence & Lower Rivers | Low food effect | DHSI (max of subregion) | % | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 12 | 12 | 30 |
| Suisun Marsh & Bay | Low food effect | DHSI (max of subregion) | % | 20 | 23 | 20 | 21 | 23 | 23 | 21 | 21 | 18 | 21 |
| **Financial resources (above Portfolio 1b)** | | | | | | | | | | | | | |
| Ball-park cost estimate (for comparative purposes only) | | Annualized capital and operating cost (range) | $ million / yr | None | None | $1-$5 | $1-$5 | $21-$30 | $21-$30 | $101-$150 | $151-$200 | $151-$200 | $76-$100 |
| **Water resources (above Portfolio 1b)** | | | | | | | | | | | | | |
| Net additional water (for comparative purposes only): W, AN | ^ | Annual average | TAF / yr | 0 | 165 | 0 | 0 | 1100 | 283 | 0 | 0 | -129 | 0 |
| Net additional water (for comparative purposes only): BN, D, C | ^ | Annual average | TAF / yr | 0 | 195 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Salmon Population (relative to Portfolio 1b)** | | | | | | | | | | | | | |
| Potential direct benefits | Avg | Constructed scale (0 to 5) | 0 to 5 | 0 | 1 | 1 | 1 | 1 | 1 | 2 | 3 | 3 | 1 |
| Potential direct risks | Min | Constructed scale (-5 to 0) | -5 to 0 | 0 | -1 | 0 | 0 | 0 | 0 | 0 | -2 | -5 | -1 |

Notes for interpreting consequences:

- Delta Smelt population growth rate: MDR results were only available for % change from baseline. The LCME, LF, and MDR models used different versions to evaluate different portfolios, which leads to variation in % change from baseline.
- Water resource costs: water balancing within or across years has not been done in Round 1.
- Salmon: results for potential benefits are shown using the average expert scores; results for potential risks are shown using the minimum expert scores to highlight the worst-case estimates of risk.

# 4 Takeaways & limitations

***Takeaways***

To date, the Delta Smelt TWG has been the primary CSAMP group reviewing the consequence table. Over several TWG meetings to discuss the Round 1 results, the following key takeaways were formulated. The June 7 presentation to the Policy Group will provide additional information on these key takeaways.

1. Current management (approximated in Portfolio 1b) is not sufficient to achieve Delta Smelt population growth in the long-term in the absence of consecutive wet years.
2. Recovery is possible through multiple, additional actions with synergistic effects; there's no silver bullet.
3. Actions and portfolios that improved food and turbidity showed greatest benefits to Delta Smelt across models.
4. Strategically increasing flow could grow the population in the near-term.
5. Portfolios that showed greater benefits to Delta Smelt included actions that have substantial financial costs and feasibility challenges.
6. Exploring more portfolios could inform how to combine types of actions (flow, food, turbidity) and balance financial costs, water resources, and feasibility concerns.

***Limitations***

While this project is the most comprehensive effort at modeling alternative Delta Smelt recovery strategies, the following are some important limitations/disclaimers:

1. ***Be careful about over-interpreting results.***
   Broad questions are better addressed through this Round 1 analysis than specific questions on management action effectiveness (e.g., we shouldn't over-emphasize small differences in lambdas or make implementation decisions on these results).
2. ***Round 1 actions vary in their physical feasibility & effect uncertainty.***
   Actions with high potential benefits but low feasibility or high uncertainty could be priorities for further R&D; We generally used best estimates for effects or sensitivity analyses when uncertainty is high (e.g., tidal wetland restoration). Degree of optimism varies across effects assumptions.
3. ***Water balancing has not been done for flow actions.***
   A hydrology/operations model was not available for Round 1. While a coarse estimate for change in water quantity was completed, trade-offs for fish could not be estimated (e.g., effects of having less water in non-action periods because additional water is used in action periods).

# 5 Key References

**Table 4. Delta Smelt population model references (peer-reviewed publications and technical documents).**

| Model | References |
|---|---|
| **Individual-based model in R (IBMR)** | Rose, K.A., Kimmerer, W.J., Edwards, K.P., Bennett, W.A., 2013. 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. https://doi.org/10.1080/00028487.2013.799518<br><br>Smith, W.E., 2022. A Delta Smelt Individual-Based Life Cycle Model in the R statistical environment (Technical Note). Prepared for CSAMP Delta Smelt SDM Technical Working Group (TWG). 15 Jul 2022. |
| **Limiting Factors (LF) model** | Hamilton, S.A., Murphy, D.D., 2022. Identifying Environmental Factors Limiting Recovery of an Imperiled Estuarine Fish. Frontiers in Ecology and Evolution. June 3, 2022. https://doi.org/10.3389/fevo.2022.826025 |
| **Life Cycle Model with Entrainment (LCME)** | Smith, W.E., Polansky, L., Nobriga, M.L., 2021. Disentangling risks to an endangered fish: using a state-space life cycle model to separate natural mortality from anthropogenic losses. Canadian Journal of Fisheries and Aquatic Sciences 78, 1008–1029. https://doi.org/10.1139/cjfas-2020-0251 |
| **Maunder and Deriso model in R (MDR)** | Maunder, M.N., Deriso, R.B., 2011. A state–space multistage life cycle model to evaluate population impacts in the presence of density dependence: Illustrated with application to Delta Smelt (*Hyposmesus transpacificus*). Canadian Journal of Fisheries and Aquatic Sciences 68, 1285–1306. https://doi.org/10.1139/f2011-071 |