Delta Coordination Group SDM Decision Process Document (DRAFT)

WY 2022

Introduction

This Structured Decision Making (SDM) Decision Process Document describes the decision scope, process, and outcomes for the water year 2022 decision facing the Delta Coordination Group (DCG) related to the Delta Smelt Summer Fall Habitat Action (SFHA) under the Incidental Take Permit (ITP) and Biological Opinion (BiOp). This is a living document that will be revised as the process evolves, as some considerations become less important and as others emerge.

This SDM Decision Process builds on existing work, and several documents have been produced that may provide background and context for this process:

1. Reclamation strawman consequence table
2. Reclamation PM memo
3. SDM appendix
4. Reclamation DCG Guidance doc
5. DWR draft DCG process document
6. RMA report

Decision Scope and Context

Given the continued decline of Delta Smelt (DS) and regulatory requirements, the DCG was formed to provide a collaborative forum among federal, state, and water agencies to develop a multi-year science and monitoring plan and on an annual basis to review existing information, evaluate proposed summer-fall habitat actions, and inform the development of the annual Summer Fall Action Plan. The DCG is required to use a structured decision making process with the intent of making transparent decisions informed by current scientific knowledge.

The regulatory documents establishing the membership and function of the DCG include United States Bureau of Reclamation (USBR)'s Final Biological Assessment (BA; October 2019), the United States Fish and Wildlife Service (USFWS) Biological Opinion (BiOp; October 2019), National Marine Fisheries Service (NMFS) BiOp (October 2019), and California Department of Water Resources (DWR)'s Incidental Take Permit (ITP; March 2020). Per these documents, DCG members consist of the California Department of Fish and Wildlife (CDFW), DWR, USBR, USFWS, NMFS, and state and federal water contractors (Public Water Agencies; PWAs).

For the purposes of this year's SDM process, the DCG has decided to focus on the following decision:

> What suite of actions should the DCG recommend for the next SFHA period (June to October), given the likely water year types? This includes not just broad categories of action, but how we implement them. We anticipate using between 90% and 10% as our definition of likely; we will cover as many WYTs as feasible given time and data.

This decision could address both management actions (those intended primarily to get a positive response for DS) and science actions (those intended primarily to fill gaps in information and understanding).

Constraints:

The action options are currently constrained by regulatory requirements (e.g., ITP), lack of infrastructure (e.g., Sacramento Deep Water Ship Channel, SDWSC), and understanding of the system and the effects of possible actions.

The SFHA Plan for each year will need to adhere to the regulatory requirements. As understanding increases (we gain new knowledge), there may be reason to adjust management (i.e., adaptive management approach). Some adjustments may require permit amendments.

Linked decisions:

- The DCG will use this framework to explore SFHA options beyond what is currently included, as well as to target learning.
- The studies that DCG recommends as part of its annual planning will influence what options are available for inclusion in future years.
- Although amendment requests may be filed at any time, the 4 and 8 year independent reviews (2024 and 2028) provide scheduled opportunities for higher-level re-evaluation.

Participants

DCG Steering Committee

DCG Working Groups

Jennie Hoffman, facilitator

Sally Rudd, facilitation support

TWG Status	Organization	Representative	Alternate
DCG Members	Reclamation	Kristi Arend	Brian Mahardja
	FWS	Matt Nobriga	Jana Affonso
	DFW	Brooke Jacobs	Kristal Davis
	Federal Water Contractors	Scott Petersen	Deanna Sereno
	State Water Contractors	Darcy Austin	Chandra Chilmakuri
	DWR	Brittany Davis	Rosemary Hartman
	NMFS	Garwin Yip	Barbara Byrne
DCG Technical Support	Reclamation	Kristi Arend	Brian Mahardja
	Science and Monitoring WG	Rosemary Hartman, DWR chair	—
	Hydrology and Operations WG	Ian Uecker, DWR chair	—
	DFW	Mike Eakin	—
	CCWD supporting Federal Contractors	Deanna Sereno	Ching-Fu Chang (SMWG) Yuan Liu (HOWG)
	Metropolitan Water supporting SWC	Shawn Acuña	—
Facilitation Team	Lead SDM Facilitator, Contractor	Jennie Hoffman	—
	SDM Facilitation Support, Compass Resource Management	Sally Rudd	—

Responsibilities and Decision Authorities

Figure 1 presents a schematic of the relationship between the DCG, its working groups, and agency directors.

The agency directors/designees make decisions as needed based on regulatory responsibilities.

The DWR and USBR implement actions, prepare official hydrologic forecasts, and lead preparation of reports.

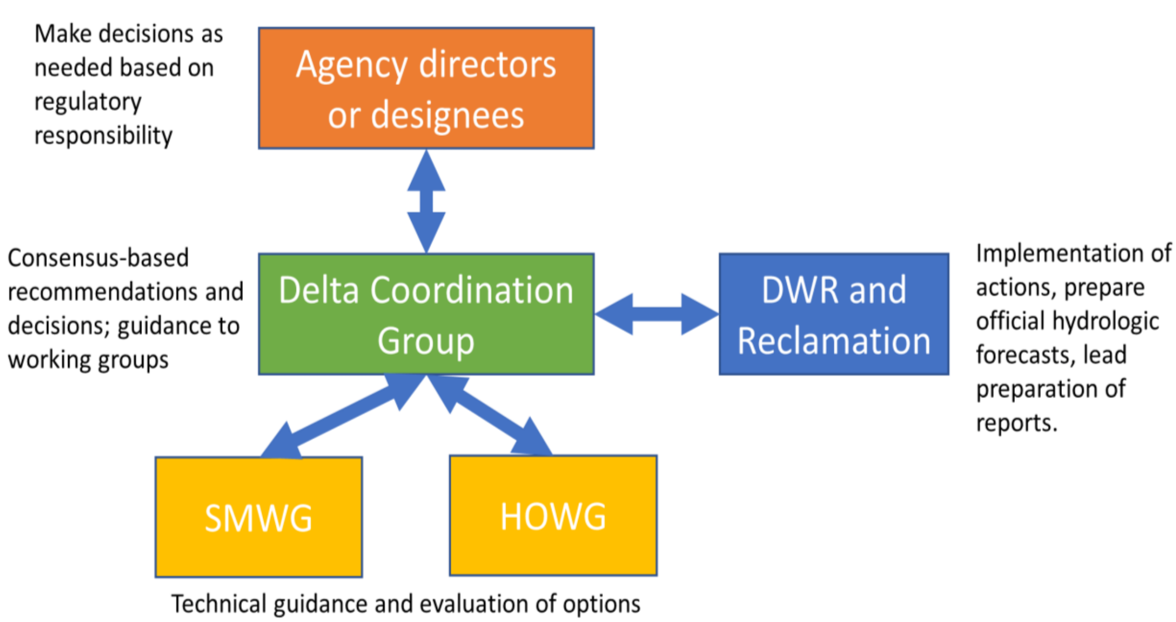
The DCG makes consensus-based decisions relative to the SDM process and provides guidance to the two working groups, the Science and Monitoring Working Group (SMWG) and Hydrology and Operations Working Group (HOWG). The DCG advises on what SFHA to carry out but may not have final say over what agencies do.

The two working groups provide technical guidance and evaluation of options.

DCG members are responsible for attending meetings, reviewing information, providing input, and actively participating in deliberation.

DCG Working Groups provide technical input as appropriate.

Figure 1 DCG governance structure.



Representation is important. The SDM Facilitator for the DCG will schedule all meetings for times when at least one Steering Committee representative or alternate from each agency indicates that they are available. If a member can't make a meeting, it is expected that they will designate an alternate and ensure the alternate is up to date on the process and issues under discussion.

Other than alternates, observers will only be allowed with prior agreement by the group.

SDM Facilitation

The SDM Facilitator is responsible for implementing a process that is responsive to input from DCG members while respecting overall process schedules and budgets and remaining focused on the agreed scope of the decision process. For the SDM process, the Facilitator will:

- Design the overall process
- Provide impartial facilitation of all meetings, workshops, and teleconferences
- Elicit and structure decision objectives, performance measures, and alternatives
- Utilize trade-off analysis tools to clarify key trade-offs and help the DCG in seeking consensus on preferred alternatives
- Produce a concise record of the process and outcomes.

Process Principles

The principles below are intended to guide how group members interact during this SDM process. The goal is to have ground rules that will set this SDM process up for success.

The DCG reviewed these principles during the August 11, 2021 DCG meeting and agreed with no changes. These principles may be revisited by the group as needed.

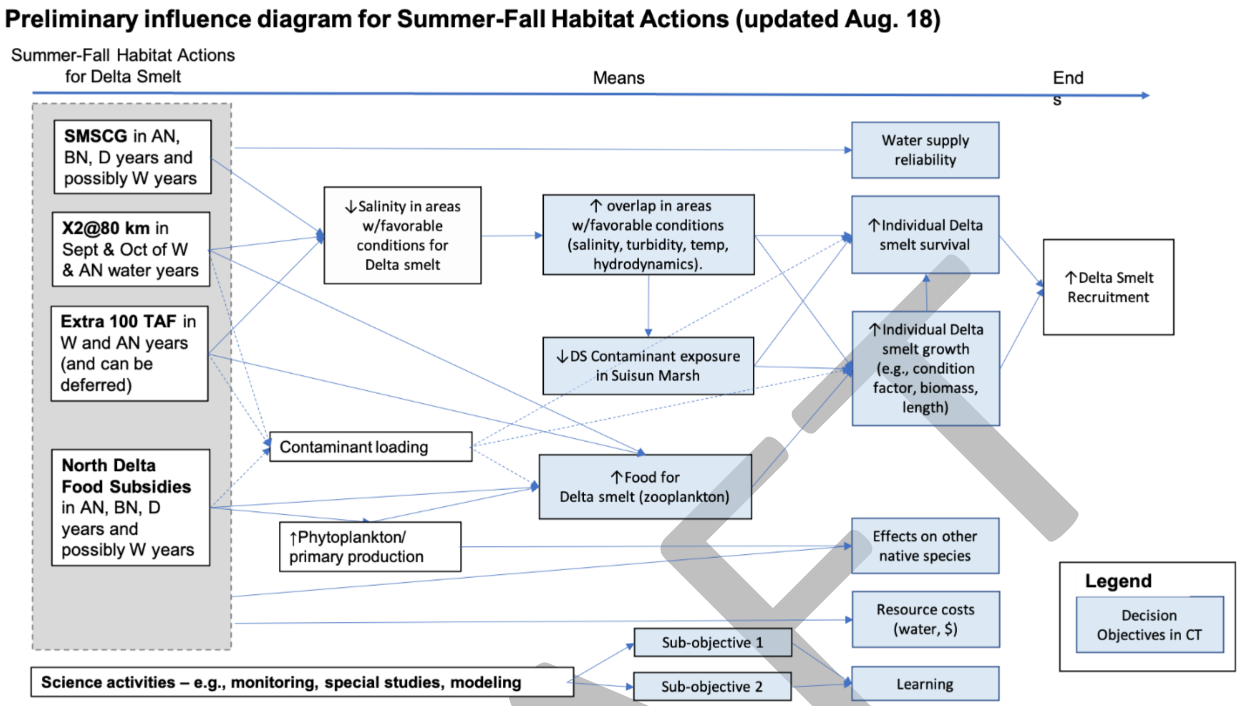
1. Strive for consensus
2. Strive to be inclusive
3. Stay present
4. Share relevant information
5. Explain reasoning and intent
6. State views and ask questions
7. Recognize that the BiOp and the ITP are different, and different DCG members are differentially bound by each.
8. This process doesn't alter existing legal rights and responsibilities of member agencies.
9. The facilitator is responsible for producing SDM process documents, although she will get input from the group. Documents will be finalized by consensus.
10. Acknowledge past SDM work, but focus on building a shared framing and prototype in a collaborative way

Decision Objectives

For the purposes of this decision process and this Decision Process Document in particular, the term "decision objectives" describes the factors important enough to the DCG to warrant consideration when choosing strategies for SFHA. A core feature of SDM processes is a focus on values – rather than on pre-established targets or agency mandates – to guide the development of these objectives. In SDM processes, decision objectives serve several important functions; they communicate what is important to consider when making decisions for a specific decision context, they help to guide the development of alternatives, and they provide the foundation for the analysis of consequences and trade-offs.

A means-ends diagram, shown in Figure 2, can be useful for understanding the relationships between objectives and management actions under consideration.

Figure 2 Influence diagram used for 2022 SDM.



At the right-hand side of the diagram are fundamental objectives – the outcomes that DCG members care about and can be affected by the SFHA decision. At the left-hand side are the means or management levers available to influence the fundamental objectives. In between are the factors that describe the important connections between actions the DCG can recommend and the outcomes the DCG values. From a practical perspective, it is important to think about the means-ends continuum and use the diagram to determine which decision objectives will be most useful for discriminating among alternatives.

The grey box on the left-hand side of the diagram contains the main categories of management actions the DCG may include in the water year 2022 SDM process. The white box at the far right of the diagram (increased DS recruitment) is recognized as the broader objective supported by increased DS growth and survival. Because there are many efforts beyond those covered by the SFHA geared towards increasing DS recruitment, and the broader system is complex and poorly understood, DS recruitment is unlikely to be useful as a decision objective for this decision. Note that there is some duplication or overlap within the DS decision objectives (e.g., food is a means to increasing growth), and as the process proceeds, it may make sense to refine or combine some of these. It is an SDM best practice to be as concise as possible with decision objectives and avoid duplication.

During DCG SDM meetings in January and February 2022, the DCG reviewed and revised decision objectives and subobjectives from the 2021 SDM prototype. The new objectives and subobjectives are summarized in Table 1. DCG members acknowledged that there are other potential decision objectives (e.g., recreation) but do not feel they will be significantly affected by this decision. As with all aspects of this decision prototype, this decision may be revisited.

Notable changes between the 2021 and the 2022 objectives include:

1. Water supply reliability was omitted from the 2022 objectives. The DCG felt that the water supply cost objective adequately captures concerns about water supply reliability in the context of this decision.
2. Rather than breaking the "effects on other native species " objective into geographic sub-objectives (upstream, South of Delta, and estuarine), the DCG decided to focus instead on taxonomic sub-objectives. This decision was driven in part by what we have the ability to analyze and in part by specific concerns, e.g. the ITP calls out concerns about stranding risk for spring-run juveniles. The DCG felt that effects on Longfin Smelt and Green Sturgeon were unlikely to be relevant to this decision given the focus on BN and dry water year types so omitted them as objectives. The DCG may revisit this question for water year types that include the option of deploying an additional 100 TAF of Delta outflow.
3. Although the DCG considers learning an important objective, it was not formally included in this year's analysis because of time considerations. There are two main types of learning that are of interest and may be included in subsequent rounds of SDM: (1) learning related to new potential management actions that could be implemented in the future (e.g., food production in Roaring River and SDWSC), and (2) understanding the magnitude of effects of actions that are currently being implemented (e.g., NDFA, SMSCG). In particular, learning may help to identify opportunities to increase efficiency, i.e., to lower resource costs for the same magnitude of benefit.

Table 1 Summary of objectives, subobjectives, and why they matter

Objective	Subobjectives	Description, importance
DS Growth and Survival	Individual growth Individual survival	The primary goal and driver of the decision process is to improve individual Delta smelt growth and survival in the summer-fall period, which will contribute to overall DS recruitment and persistence. Increasing delta smelt survival is the ultimate aim of the SFHAs. Growth and survival are correlated at times, but growth is more readily estimable at present and was the sub-objective used in the 2022 SDM process.
DS Food and Habitat	Food Habitat	The fundamental scientific hypothesis that underlies the SFHA is that targeted actions to increase feeding success of Delta smelt in key locations can replace more water-costly actions such as Delta outflow requirements. This is the rationale for separating “food” from “habitat” because habitat is shorthand here for physical habitat attributes like salinity, temperature, and turbidity, among others.
DS Contaminant effects		Some SFH actions have the potential to increase or decrease Delta Smelt exposure to contaminants, either through changing contaminant concentrations in areas where Delta smelt are expected to be and/or by affecting the overlap of suitable habitat for Delta smelt and areas of lower contaminant concentrations (e.g., Suisun Marsh and Suisun Bay have generally lower contaminant concentrations compared to other areas used by Delta smelt). Contaminant exposure could affect individual growth and survival as well as have potential multi-generational sublethal effects.

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

Objective	Subobjectives	Description, importance
	Steelhead	Some alternatives may decrease New Melones storage and associated cold water pool availability which may result in warmer water temperatures (most likely during the summer) and, consequently, less suitable rearing conditions for steelhead in the Stanislaus River. Some of these detrimental effects may occur in the water year of the SFHA action; others in the subsequent year depending on whether New Melones Reservoirs is refilled.
	Fall-run salmon	Adult fall-run salmon migrating into the Delta cue on their natal rivers by smelling the source water. Re-routing Sacramento River water into the Yolo Bypass per some NDFS alternatives may increase straying of salmon into the bypass where they cannot spawn and may not find a path back into the river.

Performance Measures

Table 2 summarizes candidate performance measures for each decision objective, which are the metrics that will be used to characterize the DCG's predictions of how an alternative performs relative to a decision objective. The DCG considered multiple options for predicting consequences (see Model Fact Sheets) For further information on PMs, how they were calculated, assumptions, uncertainties, and other information relevant to interpreting results, see the PM Infosheets for Growth, Habitat, Food, and Resource costs objectives, and the elicitation instructions for Effects on other species and Contaminants.

Table 2 Summary of Decision Objectives and Performance Measures as clarified at February 10 and 15, 2022 DCG meetings

Decision Objective	Sub-Objective	Candidate Performance Measures	Scorers	Units	PM brief Description, information source
DS Growth and survival	Individual growth	Delta Smelt growth rate potential	Lead: Will Smith	mm/summer	The PM was a metric to evaluate whether simulated actions increased the bioenergetics-based suitability of a region. The performance measure was the difference in potential growth predicted by the bioenergetics model between conditions representing no action and conditions representing the effects of a management action. Results were for the period June – October, with means calculated for four regions: Yolo, Lower Sacramento, Confluence, and Suisun Marsh.
	Individual survival	survival	Lead: Will Smith	0 - 1	Calculated from mean daily GRP values for 1000 simulated fish. Modeled for the period June – October with means calculated from regional, monthly means using the IBMR model and IBMR regions. **The DCG did not end up evaluating survival for the 2022 SDM process**

Decision Objective	Sub-Objective	Candidate Performance Measures	Scorers	Units	PM brief Description, information source
DS Food and habitat	Zooplankton	Weighted food availability score	Lead: Rosie Hartman	Difference from no action alternative, ug/L	The PM for zooplankton is the change in a weighed food availability score between an action scenario and a no action scenario. This score is calculated by taking the average zooplankton biomass in each region/month for each scenario and multiplying that by the habitat suitability index (which includes water velocity, temperature, turbidity, and salinity)
	Overlap of suitable salinity, turbidity, food, temp, hydrodynamics	Habitat Suitability Index (HSI) w/temp	Lead: Brian Mahardja	Value between 0 and 1	The habitat suitability index (HSI) is based on four abiotic variables: salinity, temperature, turbidity, and current speed and was calculated using a methodology derived from Bever et al. (2016) and RMA (2021). The index represents spatially- and temporally-averaged suitability of habitats within the 12 delineated subregions in the Bay-Delta shown in the PM infosheet.

Decision Objective	Sub-Objective	Candidate Performance Measures	Scorers	Units	PM brief Description, information source
Contaminant Effects	Contaminant concentration in areas of good habitat	Contaminant risk	Lead: Shawn Acuña	Constructed scale, -1 to 1.	Experts were asked to score alternatives relative to No Action Alternative for 5 PMs: DS survival, growth, and recruitment, and zooplankton abundance and quality. Experts were asked to focus only on direct effects of contaminants, and to use the following scale -1 = significant reduction in PM relative to the No Action Alternative 0 = insignificant effect on PM relative to the No Action Alternative 1 = significant increase in PM relative to the No Action Alternative
Water supply cost		Additional outflow needed to offset action	Lead: Ian Uecker	TAF /yr	DSM2 was used to assess a case where no action is present and compared to a case where the SMSCG is operated; the PM is the additional outflow added to offset degradation from operating the gates to the control location.
Resource costs	Direct management costs (money for staff, operating gates, etc.)	$/yr	Lead: Brittany Davis	$/yr	Costs include direct management costs for staff, operations used to implement actions, and science and monitor including field and lab work, contracting costs, analysis and reporting.

Decision Objective	Sub-Objective	Candidate Performance Measures	Scorers	Units	PM brief Description, information source
Effects on other native species	Winter run	Effects on species	Mike Eakin	Constructed scale, -3 to 1	Experts were asked to provide judgements about effects at the individual and population level using the scale provided in the elicitation instructions.
	Spring run	Effects on species	Mike Eakin	Constructed scale, -3 to 1	Experts were asked to provide judgements about effects at the individual and population level using the scale provided in the elicitation instructions.
	Fall run	Effects on species	Mike Eakin	Constructed scale, -3 to 1	Experts were asked to provide judgements about effects at the individual and population level using the scale provided in the elicitation instructions.
	Steelhead	Effects on species	Mike Eakin	Constructed scale, -3 to 1	Experts were asked to provide judgements about effects at the individual and population level using the scale provided in the elicitation instructions.

Alternatives

For WY 2022 the alternatives will focus on management actions (those intended primarily to get a positive response for Delta Smelt); science and monitoring recommendations were addressed separately by the Science and Monitoring Working Group. Some actions are required by the ITP or BiOp, while others are not. Based on available projections and information about the likelihood of various water year types, the DCG decided on February 10, 2022, to develop and evaluate alternatives for dry and below normal water year types.

Table 9a from the ITP (Table 3 in this document) outlines which actions are required for which water year types. Because WY 2021 was critically dry, for WY 2022 no action would be required in a dry year; in a below normal year, the SMSCG would need to be operated for 60 days between June 1 and October 31. Operating the SMSCGs allows fresh water from the Sacramento River to enter the Marsh on the ebb tide while preventing brackish water from Grizzly Bay from entering on the flood tide. This increases low salinity habitat in the Marsh for Delta smelt. which is hypothesized to provide better habitat than the Sacramento River due to increased hydrodynamic complexity and higher turbidity. For WY 2022 the DCG decided against including any alternatives involving 60 days of consecutive gate operations, instead focusing on non-consecutive operation triggered to start when salinity at Beldin's Landing reaches either 4 ppt or 6 ppt. These alternatives were seen as exploring the relative benefits of maintaining salinity below 4ppt for as long as possible (4 ppt trigger) vs potentially extending the low-salinity period for a longer time (6 ppt trigger). The DCG left it up to DWR to determine the spacing of operations; DWR specified that the 4 ppt alternative would involve operating the gates for 15 days on, followed by 10 days off, while the 6 ppt alternative would involve operating the gates for 15 days on, followed by 15 days off.

In addition, the DCG included a set of alternatives related to the North Delta Food Action. The NDFA uses existing infrastructure to redirect water (~20-30 TAF) down the Yolo Bypass in effort to restore net positive flow and improve plankton in downstream Delta Smelt habitat. The NDFA action relies on the coordination of water operations upstream of the Delta either to implement a

Sacramento River action, an Agricultural drainage action, or a combined action.

- The Sacramento Action redirects Sacramento River water during summer through Glenn-Colusa Irrigation District and the Reclamation District 108 to pass the water into the Yolo Bypass and downstream to Cache Slough Complex
- The Agricultural drainage action redirects agricultural return water mostly from rice fields in the Colusa Basin Drain through the Ridge Cut Slough and down the Yolo Bypass that would otherwise be drained into the mainstem Sacramento River. The DCG did not specify the timing of an Agricultural drainage action, although the elicitation materials for the Effects on other species objective stated that an Agricultural drainage action would occur in the fall.
- A third type of action that has never been carried out is a summer Sacramento River action followed by a fall Agriculture action to generate a longer duration pulse (60 days) and time period with net positive flow.

In addition to differences in water source, NDFA actions can also be carried out to create a longer flow pulse with a lower magnitude, or a shorter pulse with a higher magnitude.

Table 3 Table 9a from the ITP

<table>
<tr><th rowspan="2">Month</th><th colspan="5">Water Year Type (SVI)</th></tr>
<tr><th>Wet</th><th>Above-normal</th><th>Below-normal</th><th>Dry</th><th>Critical</th></tr>
<tr><td>June</td><td rowspan="3">Additional 100 TAF Delta outflow, June through October**</td><td rowspan="3">Criteria: Operate SMSCG for 60 days*

Additional 100 TAF Delta outflow, June through October**</td><td rowspan="5">Criteria: Operate SMSCG for 60 days*</td><td rowspan="5">Criteria: In dry years following below-normal years operate SMSCG for 30 days*

Criteria: In dry years following wet or above-normal water years operate SMSCG for 60 days* ***</td><td rowspan="5">No action</td></tr>
<tr><td>July</td></tr>
<tr><td>August</td></tr>
<tr><td>September</td><td rowspan="2">Criteria: 30-day average X2 ≤ 80km</td><td rowspan="2">Criteria: 30-day average X2 ≤ 80km</td></tr>
<tr><td>October</td></tr>
</table>

* Water necessary to implement SMSCG operations may be provided through export curtailments supported by the SWP Contractors through a commitment pursuant to Voluntary Agreements or as early implementation of such agreements.

** If approved by CDFW the Additional 100 TAF may be deferred and redeployed to supplement Delta outflow the following water year during the March – October timeframe, unless the following water year is critical (see Condition of Approval 8.19). This use of the redeployed water is not intended to serve as a criteria.

*** CDFW anticipates deferring a portion of the 100 TAF received from an above normal or wet year when the following year is dry to facilitate SMSCG operation for 60 days in the absence of other available water.

The full suite of alternatives under consideration in the 2022 SDM process are outlined in Table 4. Note that consequences for SMSCG and NDFA actions were evaluated separately rather than in combination. This assumes no significant interactive effects of these action types.

Table 4 Summary of Management Actions Under Consideration for the WY 2022 SDM Process

Type of action	Alternative name	Alternative description
Suisun Marsh Salinity Control Gates	SMSCG 4 ppt	Intermittent SMSCG operation of 60 days triggered to begin when salinity at Belden's landing is >4 ppt. The strategy was to operate the gates for 15 days on, followed by 10 days off. For all consequence analyses other that Effects on other species, additional outflow for this alternative is assumed to come from export reductions. The elicitation for "Effects on other species" evaluated consequences for 4 possible sources of additional outflow: Shasta, Oroville, Folsom, and export reductions.
	SMSCG 6 ppt	Intermittent SMSCG operation of 60 days triggered to begin when salinity at Belden's landing is >6 ppt. The strategy was to operate the gates for 15 days on, followed by 15 days off. Additional outflow for this alternative is assumed to come from export cuts.
North Delta Food Action	Sac long-low	Sacramento River water would be directed through Yolo Bypass for a longer duration (4 weeks) at a lower intensity (400 cfs)
	Sac short-high	Sacramento River water would be directed through Yolo Bypass for a shorter duration (2 weeks) at a higher intensity (800cfs)
	Ag long-low	Agricultural return water would be directed through Yolo Bypass for a longer duration (4 weeks) at a lower intensity (400 cfs)

Type of action	Alternative name	Alternative description
	Ag short-high	Agricultural return water would be directed through Yolo Bypass for a shorter duration (2 weeks) at a higher intensity (800cfs)
	Sac-Ag	This alternative involves a Sac long-low summer action followed by an Ag long-low fall action to generate a longer duration pulse (60 rather than 30 days) and time period with net positive flow. While assumed to be operationally feasible, this approach has never been implemented.

Possible future management actions that the DCG decided to take off the table for this round of SDM:

- Roaring River Distribution System Food Production. There is not enough information to evaluate the proposed Roaring River action at this point or to consider its implementation in the next year. More studies would be beneficial to advancing this action to an implementation stage.
- SDWSC Food Transport and Production: We won't be able to do the full fertilization and export action until infrastructure is in place (which isn't expected before 2025). We could just do fertilization of the existing channel at this point but don't anticipate doing so (as the results from the previous fertilization experiment are still being synthesized).

Science actions

Science actions (those focused primarily on reducing uncertainty to improve future management decisions) may include modeling, monitoring, and experimental studies.

There are monitoring and science programs in place for the NDFS and SMSCG actions (see the 2021 NDFA operations plan and SMSCG monitoring plan as well as the 2020 SFHA Monitoring and Science Plan). In subsequent rounds of SDM the DCG may consider modifying monitoring programs to better inform tradeoffs, uncertainties, or other factors identified by the DCG as part of this SDM process.

The DCG may also suggest specific modeling or other special studies. Existing recommendations may be found in the 2022 SFHA Monitoring and Science Plan.

Consequences

This section presents the consequences of each alternative for each decision objective by predicting performance using methods agreed on by the DCG. For more detailed information on performance metrics, how they were calculated, assumptions, uncertainties, and other information relevant to interpreting results, see the PM Infosheets for Growth, Habitat, Food, and Resource costs objectives, and the elicitation instructions for Effects on other species and Contaminants. Consequences and tradeoffs were explored using Compass Resource Management's online Altaviz tool. For each water year type, consequence tables were simplified as much as possible by removing uninformative objectives (those whose values did not differ significantly across objectives) and dominated alternatives.

The DCG members leading the expert elicitation processes to assess consequences for the "contaminants" and "effects on other species" objectives emphasized that results should be viewed as preliminary since experts did not have an opportunity to review, discuss, or revise scores. For at least some scores by some experts it was clear from the reasoning provided that the expert had misinterpreted what was being asked of them.

Because the elicitation for Effects on other species addressed a distinct set of alternatives, results for these PMs are presented separately from the others.

Table 5 Complete Consequences Table for the WY 2022 SDM Process

Objective	Sub-objective	Performance Measure	Unit	Preferred Direction	Dry No Action	Dry NDFA Ag Short-High	Dry NDFA Ag Long-Low	BN No Action	BN SMSCG 4ppt	BN SMSCG 6ppt	BN NDFA Sac Short-High	BN NDFA Sac Long-Low	BN NDFA Ag Short High	BN NDFA Ag Long-Low	BN NDFA Sac-Ag
Delta Smelt Growth and Survival	Yolo	Growth increment	mm	Higher	0	0.34	0.42	0	0	0	.21	0.33	0.22	0.30	0.63
	Lower Sac	Growth increment	mm	Higher	0	0.07	0.07	0	0	0	0.05	0.05	0.05	0.05	0.07
	Confluence	Growth increment	mm	Higher	0	0	0	0	0	0	0	0	0	0	0
	Marsh	Growth increment	mm	Higher	0	0	0	0	0.43	0.34	0	0	0	0	0
Habitat Suitability Index (HSI)	Yolo HSI	HSI + temp		Higher	0.38	0.38	0.38	0.40	0.38	0.38	0.40	0.40	0.40	0.40	0.40
	Sac HSI	HSI + temp		Higher	0.41	0.41	0.41	0.43	0.42	0.41	0.43	0.43	0.43	0.43	0.43
	E Delta HSI	HSI + temp		Higher	0.33	0.33	0.33	0.32	0.32	0.33	0.32	0.32	0.32	0.32	0.32
	Low Sac HSI	HSI + temp		Higher	0.53	0.53	0.53	0.54	0.54	0.53	0.54	0.54	0.54	0.54	0.54
	South HSI	HSI + temp		Higher	0.28	0.28	0.28	0.26	0.25	0.28	0.26	0.26	0.26	0.26	0.26
	Marsh HSI	HSI + temp		Higher	0.16	0.16	0.16	0.36	0.51	0.42	0.36	0.50	0.36	0.36	0.36
	Confluence HSI	HSI + temp		Higher	0.50	0.50	0.50	0.59	0.59	0.55	0.59	0.59	0.59	0.59	0.59
	Low SJ HSI	HSI + temp		Higher	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36
	SW Suisun HSI	HSI + temp		Higher	0.23	0.23	0.23	0.24	0.24	0.23	0.24	0.24	0.24	0.24	0.24
	SE Suisun HSI	HSI + temp		Higher	0.25	0.25	0.25	0.41	0.42	0.36	0.41	0.42	0.41	0.41	0.41
	NE Suisun HSI	HSI + temp		Higher	0.15	0.15	0.15	0.34	0.35	0.29	0.34	0.35	0.34	0.34	0.34
	NW Suisun HSI	HSI + temp		Higher	0.12	0.12	0.12	0.18	0.18	0.16	0.18	0.18	0.18	0.18	0.18
Zooplankton	Delta-wide	Change in weighted food availability score	(ug/L)*HSI	Higher	0	3	6	0	66	33	7	13	6	3	22
Contaminant Effects	Zoop quality effects	constructed scale	-1 to 1	Higher	0	-0.75	-0.25	0	0	0.25	-0.75	0.25	-0.75	-0.25	-0.5
	Zoop abundance (survival) effects	constructed scale	-1 to 1	Higher	0	-0.75	-0.25	0	0	0.25	-0.5	0.5	-1	-0.33	0
	DS growth effects	constructed scale	-1 to 1	Higher	0	-1	-0.25	0	0	0.25	-0.5	0.5	-1	-0.25	0
	DS survival effects	constructed scale	-1 to 1	Higher	0	-0.67	0	0	0.25	0.5	0.33	0.67	-0.67	0	0

Objective	Sub-objective	Performance Measure	Unit	Preferred Direction	Dry No Action	Dry NDFA Ag Short-High	Dry NDFA Ag Long-Low	BN No Action	BN SMSCG 4ppt	BN SMSCG 6ppt	BN NDFA Sac Short-High	BN NDFA Sac Long-Low	BN NDFA Ag Short High	BN NDFA Ag Long-Low	BN NDFA Sac-Ag
	DS recruitment effects	constructed scale	-1 to 1	Higher	0	-0.75	-0.25	0	0.25	0.5	-0.25	0.5	-0.75	-0.25	0
Resource Costs	Water Cost	Change in outflow	TAF	Lower		0	0	0	69	63	0	0	0	0	0
	Operating Cost	Difference from no-action	$1000/year	Lower	0	100	100	0	250	250	250	250	100	100	500

Dry Water Year Results

For Dry WYT, habitat and water costs consequences did not vary among alternatives, nor did growth for the Confluence and Marsh regions. The Ag short-high alternative was dominated by the Ag long-low action (Figure 3), and the Ag long-low action performed better than or equal to the no action alternative on all objectives other than operating costs. Effects on other species were only evaluated for an Ag long-low fall action; experts did not expect this action to have a significant effect on most species. Overall, the DCG had a sense of ambivalence when it comes to Ag Long-low vs. No Action because while the long-low alternative provides growth benefits they are quite small and come with increased contaminant risk. That said, the DCG recognized that there are learning benefits to any NDFA action that were not formally captured in this year's SDM process. Also, the growth prediction was an "expected" value; there was no information on what the best-case growth results might be. The DCG reached consensus on recommending the Ag long-Low action in a dry year, conditioned on water quality in Ridge Cut (dissolved oxygen >6mg/L).

Figure 3 Screenshots of Simplified Consequence Table for Dry Water Year Type Smelt, Contaminant, and Cost objectives (left) and Effects on other species (right) from AltaViz program.

Legend: Selected, Better, Worse, Same

Objective	Dry No Action	Dry NDFA Ag Short-High	Dry NDFA Ag Long-Low
Delta Smelt			
Delta Smelt Growth and Survival			
Yolo	0	0.34	0.42
Lower Sac	0	0.07	0.07
Confluence	0	0	0
Marsh	0	0	0
Suitable Habitat			
Zooplankton			
Delta-wide	0	7.2	11
Contaminant Effects			
Zoop quality effects	0	-.75	-.25
Zoop abundance (survival) effects	0	-.75	-.25
DS growth effects	0	-1	-.25
DS survival effects	0	-0.67	0
DS recruitment effects	0	-.75	-.25
Resource Costs			
Water Cost	0	0	0
Operating Cost	0	100	100
Effects on other native species			

Objective	Dry NDFA Ag fall
Effects on other native species	
Spring Run	
SR Individual	0
SR population	0
Fall Run	
FR Individual	-0.5
FR population	0
Steelhead	
Steelhead individual	0
Steelhead population	0
Winter Run	
WR individual	0
WR population	0
Green Sturgeon	
Sturgeon individual	0
Sturgeon population	0

Below Normal Water Year Results

For Below Normal (BN) WYT SMSCG actions, there were no significant differences among alternatives on growth or habitat in any region other than the Marsh (Figure 4). Differences in HSI between 4 ppt and 6 ppt seemed small to the DCG, perhaps due to rounding or perhaps due to interactive effects with water temperature.

There was a tradeoff between contaminant effects and increases in zooplankton, although the DCG felt that contaminant results should not be given much weight due to uncertainty in the expert elicitation responses.

For effects on other species, there were differences between alternatives only for Spring Run and Winter Run Chinook at the individual and for Fall Run Chinook at the population level. In all cases, export reductions produced better consequences than other water sources.

The DCG reached consensus on recommending intermittent operation of SMSCG starting at 4 ppt had it been a BN year.

Figure 4a Screenshots of Unsimplified (left) and Simplified Consequence Table (right) for BN WYT SMSCG actions from AltaViz program actions.

Objective (Less Preferred – More Preferred)	BN No Action	BN SMSCG 4ppt	BN SMSCG 6ppt
Delta Smelt			
Delta Smelt Growth and Survival			
Yolo	0	0	0
Lower Sac	0	0	0
Confluence	0	0	0
Marsh	0	0.43	0.34
Suitable Habitat			
Yolo HSI	0.40	.38	.38
Sac HSI	0.43	.42	.42
E Delta HSI	0.32	.32	.32
Low Sac HSI	0.54	.54	.54
South HSI	0.25	.25	.25
Marsh HSI	0.36	.5	.41
Confluence HSI	0.59	.59	.59
Low SJ HSI	0.36	.36	.36
SW Suisun HSI	0.24	.24	.24
SE Suisun HSI	0.41	.42	.42
NE Suisun HSI	0.34	.35	.35
NW Suisun HSI	0.18	.18	.18
Zooplankton			
Delta-wide	0	66	33
Contaminant Effects			
Zoop quality effects	0	0	0.25
Zoop abundance (survival) effects	0	0	0.25
DS growth effects	0	0	0.25
DS survival effects	0	0.25	0.5
DS recruitment effects	0	0.25	0.5
Resource Costs			
Water Cost	0	69	63
Operating Cost	0	250	250
Effects on other native species			

Legend

- Selected
- Better
- Worse
- Same

Objective	BN No Action	BN SMSCG 4ppt	BN SMSCG 6ppt
Delta Smelt			
Delta Smelt Growth and Survival			
Yolo	0	0	0
Lower Sac	0	0	0
Confluence	0	0	0
Marsh	0	0.43	0.34
Suitable Habitat			
Marsh HSI	0.36	.5	.41
Zooplankton			
Delta-wide	0	66	33
Contaminant Effects			
Zoop quality effects	0	0	0.25
Zoop abundance (survival) effects	0	0	0.25
DS growth effects	0	0	0.25
DS survival effects	0	0.25	0.5
DS recruitment effects	0	0.25	0.5
Resource Costs			
Water Cost	0	69	63
Operating Cost	0	250	250
Effects on other native species			

Figure 4b Screenshots of Consequence Table for BN WYT SMSCG actions, Effects on other species from AltaViz program species.

Objective (Less Preferred – More Preferred)	BN SMSCG 4ppt Shasta	BN SMSCG 4ppt Oroville	BN SMSCG 4ppt Folsom	BN SMSCG 4ppt Export redux
Effects on other native species				
Spring Run				
SR Individual	-0.5	-0.5	0	0.5
SR population	0	0	0	0
Fall Run				
FR Individual	1	1	1	1
FR population	0	0	0	0.5
Steelhead				
Steelhead individual	0	0	0	0
Steelhead population	0	0	0	0
Winter Run				
WR individual	-1	0	0	0.5
WR population	0	0	0	0
Green Sturgeon				
Sturgeon individual	0	0	0	0
Sturgeon population	0	0	0	0

For BN WYT NDFA, there were no significant differences among alternatives on growth other than in the Yolo area, and no significant differences in Habitat in any region (Figure 5a). There were also no differences in water costs. The Ag and Sac short-high actions were dominated by the Ag and Sac long-low actions, respectively. There appeared to be direct tradeoffs between growth and food on the one hand and operating cost on the other. The ranking of alternatives based on operating cost was the reverse of their ranking based on survival or food. Contaminant results did not follow this pattern: Sac Long-Low was best while Ag Long-Low was worst. The DCG reached consensus on recommending the Sac Long-Low action had it been a BN year. The Sac-Ag action was disfavored not just because of its high cost, but also because of uncertainty around whether it is actually feasible.

Figure 5a Screenshots of Unsimplified (left) and Simplified Consequence Table for BN WYT NDFA actions from AltaViz program.

Objective (Less Preferred – More Preferred)	BN No Action	BN NDFA Sac Short High	BN NDFA Sac Long-Low	BN NDFA Ag Short High	BN NDFA Ag Long-Low	BN NDFA Sac-Ag
Delta Smelt						
Delta Smelt Growth and Survival						
Yolo	0	0.21	0.33	0.22	0.3	0.63
Lower Sac	0	0.05	0.05	0.05	0.05	0.07
Confluence	0	0	0	0	0	0
Marsh	0	0	0	0	0	0
Suitable Habitat						
Yolo HSI	0.40	0.40	0.38	0.40	0.40	0.40
Sac HSI	0.43	0.43	0.42	0.43	0.43	0.43
E Delta HSI	0.32	0.32	0.32	0.32	0.32	0.32
Low Sac HSI	0.54	0.54	0.54	0.54	0.54	0.54
South HSI	0.25	0.25	0.25	.25	.25	0.25
Marsh HSI	0.36	0.36	0.36	.36	.36	0.36
Confluence HSI	0.59	0.59	0.59	.59	.59	0.59
Low SJ HSI	0.36	0.36	0.36	.36	.36	0.36
SW Suisun HSI	0.24	0.24	0.24	.24	.24	0.24
SE Suisun HSI	0.41	0.41	0.42	.41	.41	0.41
NE Suisun HSI	0.34	0.34	0.35	.34	.34	0.34
NW Suisun HSI	0.18	0.18	0.18	.18	.18	0.18
Zooplankton						
Delta-wide	0	6.5	13	3.4	6	21.5
Contaminant Effects						
Zoop quality effects	0	-.75	.25	-.75	-.25	-.5
Zoop abundance (survival) effects	0	-.5	.5	-1	-.33	0
DS growth effects	0	-.5	.5	-1	-.25	0
DS survival effects	0	0.33	0.67	-0.67	0	0
DS recruitment effects	0	-.25	.5	-0.75	-.25	0
Resource Costs						
Water Cost	0	0	0	0	0	0
Operating Cost	0	250	250	100	100	500
Effects on other native species						

Legend
- Selected
- Better
- Worse
- Same

Objective	BN No Action	BN NDFA Sac Short High	BN NDFA Sac Long-Low	BN NDFA Ag Short High	BN NDFA Ag Long-Low	BN NDFA Sac-Ag
Delta Smelt						
Delta Smelt Growth and Survival						
Yolo	0	0.21	0.33	0.22	0.3	0.63
Lower Sac	0	0.05	0.05	0.05	0.05	0.07
Confluence	0	0	0	0	0	0
Marsh	0	0	0	0	0	0
Suitable Habitat						
Zooplankton						
Delta-wide	0	6.5	13	3.4	6	21.5
Contaminant Effects						
Zoop quality effects	0	-.75	.25	-.75	-.25	-.5
Zoop abundance (survival) effects	0	-.5	.5	-1	-.33	0
DS growth effects	0	-.5	.5	-1	-.25	0
DS survival effects	0	0.33	0.67	-0.67	0	0
DS recruitment effects	0	-.25	.5	-0.75	-.25	0
Resource Costs						
Water Cost	0	0	0	0	0	0
Operating Cost	0	250	250	100	100	500
Effects on other native species						

Figure 5b Screenshots of Consequence Table for BN WYT NDFA actions, effects on other species from AltaViz program.

Legend

Selected

Better

Worse

Same

Objective	BN NDFA Sac Long-Low	BN NDFA Ag fall
Effects on other native species		
Spring Run		
SR Individual	0	-0.3
SR population	0	0
Fall Run		
FR Individual	0	-2
FR population	-0.50	-1
Steelhead		
Steelhead individual	0	-1.7
Steelhead population	0	-1
Winter Run		
WR individual	0	0
WR population	0	0
Green Sturgeon		
Sturgeon individual	0	-1
Sturgeon population	0	0

Key take-aways for the next round of SDM

On April 28, 2022 the DCG debriefed the water year 2022 SDM process. Breakout groups captured their thoughts on a Miro board. The complete notes are available as an appendix; key take-aways are captured below.

- Overall, the DCG worked well as a group. The right people were in the room, DCG members felt empowered to speak for their agency, and people were engaged and willing to explore.
- There is a strong interest in exploring all water year types, and in figuring out how to do some level of advance analysis to limit the mad scramble at the end. In particular, developing and evaluating alternatives related to the 100 TAF would be quite challenging without more lead time than the DCG had this year.

- Many DCG members wanted more time and opportunities for reviewing, understanding, and providing input on the technical analysis of consequences. This includes contextualizing changes to better understand what the numbers mean, better understanding how scenarios will get set up for experts, more education on the biology, and providing more input to the technical teams.
- The expert elicitation processes need more time to produce usable results. This includes more time to develop the response metrics, to recruit experts and explain the context and process to them, for experts to review results from the first round of elicitation and to revise their responses in a second round of elicitation, and for DCG members to explore and understand responses and make informed decisions.
- DCG members want to incorporate learning as a fundamental objective, and capture risks associated with learning or other actions.
- There needs to be more QA/QC of modeling steps, and better modeling coordination that doesn't depend on an already over-stretched DCG member!
- Although documentation was better this year than last, there was some disagreement on the specifics of scenarios during the discussion of consequences so clearly there's still room for improvement.
- There were mixed responses about the level of efficiency and need for further streamlining.
- Some DCG members suggested creating a to-do list over the next few months.

APPENDICES

A. SFHA Model Fact Sheets

B. Performance Metric Infosheets

C. Expert Elicitation Materials

Appendix A

Summer Fall Habitat Action (SFHA) Model Fact Sheets

Compiled for SFHA Structured Decision Making 2022

Delta Coordination Group

SFHA Model Fact Sheet – DSM2

Date: 1/28/22

Point of contact: Ian Uecker

Model: DSM2

Objective: Salinity, water cost

Performance Measure: water cost

Assumptions: Will need hydrology forecasts from DWR allocation studies to form boundary conditions

Constraints: The biggest limitation is the uncertainty associated with the hydrology forecasts

Strengths: Ample expertise, has been used for this application in years past, established methods

Weaknesses: the biggest limitation is the certainty of the forecast fed to the model, not the accuracy of the model itself, but the accuracy of the inputs

Data input requirements and computation time: will need hydrology forecasts from DWR allocation studies to form boundary conditions. Short Run-time

Confidence and/or predictive accuracy: The biggest limitation is the uncertainty associated with the hydrology forecasts

Links to documentation or papers written about the model:

Methodology for Flow and Salinity Estimates in the Sacramento-San Joaquin Delta and Suisun Marsh - Datasets - California Natural Resources Agency Open Data

Delta Coordination Group

SFHA Model Fact Sheet – Bay-Delta SCHISM

Date: 2/9/2022

Point of contact: Eli Ateljevich, Eli.Ateljevich@water.ca.gov

Model: Bay-Delta SCHISM

Objective: Delta Smelt Habitat

Performance Measure: Low salinity zone and Suitable Habitat Metrics, including acreage and frequency.

Assumptions: Flows are assumed to have been produced by water cost and operational models, although they can be adjusted if the study warrants it. Atmospheric inputs will have to be assumed based on whether it is a warm or cool year. We can attempt a statistical treatment, but it is unclear if the sample size will be adequate to do something more informative than bookends.

Constraints: The model does not predict turbidity well enough at the present time for use as deterministic model output to answer the high precision questions that are being asked. We have methods of screening for turbidity for hindcasts based on interpolations of continuous stations; these are probably more accurate than model turbidity and agree well with remote sensing.

The question of prediction is one that has caused confusion, is the potential to predict temperature and turbidity months in advance. These variables are predominantly dependent on atmospheric inputs – wind in the case of turbidity and air temperature (and to a lesser extent solar radiation anomaly) for water temperature. These are inputs that are readily available in hindcasts but not in forecasts. For this reason, we will use representative year or statistical methods to bookend the effects of a warm/cold year.

Strengths: Given adequate boundary conditions, Bay-Delta SCHISM produces forecasts of good fidelity for salinity and temperature throughout the Delta, including the Suisun Marsh. The model has been used for several years to produce habitat metrics in hindcast. The model reacts correctly to Suisun Marsh gate operations and apportions transport well between subtidal (net) transport and tidal fluctuation/dispersion.

Weaknesses: The model occasionally underestimates salinity or overestimates temperature in the marsh, but this is infrequent.

Data input requirements and computation time: SCHISM is typically run after forecasts and water cost analyses have been prepared, so here will not double count that process. Those are the models that develop flow boundary conditions. After those are in hand, preparation of operational forecasts for a single scenario typically takes 6-8 days. Additional scenarios 1 -3 additional days to prepare, and there are returns to scale on scenarios. Each scenario takes 1-1.5 days to simulate the May-December period, but scenarios can be done in parallel. Simulation time is rarely a significant portion of the workflow, but the model is nowhere near fast enough to be used in a "gaming" style on demand at meetings.

Confidence and/or predictive accuracy: On a qualitative level, how accurate are the predictions? Predictive skill is generally very good, and the differential accuracy between scenarios will be better. Conditional on what we assume for wind and air temperature, salinity and water temperature results are likely to be very good and we can make good statements about the influence of turbidity.

Links to documentation or papers written about the model:

Ateljevich E, Nam K, Zhang Y, Wang R, Shu Q. 2014. "Bay-Delta SELFE calibration overview." In: Methodology for Flow and Salinity Estimates in the Sacramento-San Joaquin Delta and Suisun Marsh. 35th Annual Progress Report to the State Water Resources Control Board. Chapter 7. Sacramento (CA): Bay-Delta Office. Delta Modeling Section. California Department of Water Resources. [link]

Chao, Y., Farrara, J.D., Zhang, H., Zhang, Y., Ateljevich, E., Chai, F., Davis, C.O., Dugdale, R., Wilkerson, F. (2017) Development, implementation, and validation of a modeling system for the San Francisco Bay and Estuary, Estuarine, Coastal and Shelf Science, 194, 40-56. https://doi.org/10.1016/j.ecss.2017.06.005.

Chao, Y., Farrara, J.D., Bjorkstedt, E., Chai, F., Chavez, F., Rudnick, D., Enright, W., Fisher, J.L., Peterson, W.T., Welch, G.F., Davis, C.O., Dugdale, R.C., Wilkerson, F.P., Zhang, H., Zhang, Y., Ateljevich, E. (2017) The origins of the anomalous warming in the California coastal ocean and San Francisco Bay during 2014-2016 , J. Geophysical Research-Oceans. DOI: 10.1002/2017JC013120

Zhang, Y. and Baptista, A.M. (2008) SELFE: A semi-implicit Eulerian-Lagrangian finite-element model for cross-scale ocean circulation", Ocean Modelling, 21(3-4), 71-96.

Zhang, Y., Ye, F., Stanev, E.V., Grashorn, S. (2016) Seamless cross-scale modeling with SCHISM, Ocean Modelling, 102, 64-81.

Zhang, Y., Gerdts, N., Ateljevich, E., and Nam, K. (2019) Simulating vegetation effects on flows in 3D using an unstructured grid model: model development and validation, Ocean Dynamics, https://doi.org/10.1007/s10236-019-01333-8. link. pdf.

Delta Coordination Group

SFHA Model Fact Sheet – Individual-Based Model in R

Date: February 7, 2022

Point of contact: William Smith (FWS)

Model: Individual-Based Model in R (IBMR)

Objective: Growth and survival

Performance Measure: Simulated population growth rate

Assumptions: The IBMR simulation is driven by five physical and biological variables, prey density, Secchi depth, temperature, OMR, and smelt distribution. To explore the effects of management actions, one must make assumptions about the spatiotemporal effects of an action of each of the five variables. There are also several assumptions about the effects of physical conditions on delta smelt bioenergetics, behavior, and survival, that are supported by information from controlled experiments.

Constraints: Given that IBMR is only loosely based on experimental studies and cannot be validated with observations from the field, because delta smelt are at such low densities, a coarse application of the model is recommended. The metric of mean population growth rate over a subset of representative years was the recommendation from the original author of the delta smelt bioenergetics model, Kenny Rose.

Strengths: IBMR provides a way to integrate hypothesized effects of management actions on multiple ecosystem conditions in the Delta, into a single metric, representing the long-term benefit to delta smelt.

Weaknesses: As the recommended summary metric for IBMR is mean population growth rate, over a number of years, it is best applied to explore the long-term consequences of broad categories of management action. If short-term effects are of interest, or effects on at a finer spatial scale (e.g. the DWSC), a special case of IBMR focusing on habitat suitability and growth potential is more suitable.

Data input requirements and computation time: The five physical and biological variables driving IBMR are temperature, Secchi depth, delta smelt distribution, OMR, and prey density. All variables have dimensions of year x month x spatial strata, except OMR. Prey densities have additional dimension of prey type, but modeling effects at the level of prey type is not recommended.

Assuming that all input data have been appropriately summarized to articulate with the IBMR code, each run of the simulation, representing a particular action, requires approximately four hours.

Confidence and/or predictive accuracy: IBMR was tuned to delta smelt abundance indices, so that it approximated the long-term abundance patterns observed in 1995-2014. It was further tuned to approximate the average size of female delta smelt observed in February.

IBMR cannot, however, be validated by making model predictions then observing the accuracy of those predictions in the field. Delta smelt catches are currently insufficient for this.

Links to documentation or papers written about the model:

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

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

Smith, W. E. 2021. A delta smelt individual-based model in R statistical environment. US Fish and Wildlife Service, Bay-Delta Office, Sacramento, CA.

SFHA Model Fact Sheet – Bioenergetics-based habitat suitability

Date: February 7, 2022

Point of contact: William Smith (FWS)

Model: Bioenergetics-based habitat suitability, from the Individual-Based Model in R (IBMR)

Objective: Growth

Performance Measure: Simulated individual growth rates, or growth potential.

Assumptions: There are several assumptions about the effects of physical conditions on delta smelt bioenergetics and behavior, that are supported by information from controlled experiments.

Constraints: The habitat suitability model is not suited to explore long-term consequences of management actions because it does not integrate over time or space.

Strengths: The habitat suitability model is suited to explore short-term consequences of management actions. It starts with the assumption that delta smelt are present, then estimates the growth potential given temperature (C), turbidity (NTU), and prey availability.

Weaknesses: T there is only the most remote chance in the nether world that we would get permissions to report in any other format

Data input requirements and computation time: The three physical and biological variables driving the simulation are temperature, turbidity, and prey density. Assuming that all input data have been appropriately summarized to articulate with the code, each run of the simulation, representing a particular action, requires less than one minute.

Confidence and/or predictive accuracy: The parameters of the bioenergetics model cannot be validated by making model predictions then observing the accuracy of those predictions in the field. Delta smelt catches are currently insufficient for this.

Links to documentation or papers written about the model:

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

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

Smith, W. E. 2021. A delta smelt individual-based model in R statistical environment. US Fish and Wildlife Service, Bay-Delta Office, Sacramento, CA.

Delta Coordination Group

SFHA Model Fact Sheet – Bever et al. 2016 + Temperature: Habitat Suitability Model

Date: 2/1/2022

Point of contact: Rosie Hartman

Model: Bever et al. 2016 + Temperature: Habitat Suitability Model

Objective: Delta Smelt Habitat

Performance Measure: Habitat Suitability Index

Assumptions: Assumes temperatures and turbidities will be similar to prior years.

Constraints: Does not include food metrics.

Strengths: Sophisticated integration of catch data with 3D hydrodynamics modeling. Better fit to FMWT data improved mapping of results relative to Feyrer et al. 2011. We can predict the hydrodynamic effects of the actions pretty easily. It was used to evaluate the 2018 SMSCG action and it's what the DCG has been working with so far.

Weaknesses: No prey density. Had a bit of a 'hunt and peck' aspect to finding variables of interest (see Table 2)

Data input requirements and computation time: Needs a hydrodynamic model (we have used UNTRIM or SCHISM in the past), and data on temperature and turbidity for a similar water year type.

Confidence and/or predictive accuracy: Salinity is easy to model.

Links to documentation or papers written about the model:

Sommer T, Hartman R, Koller M, Koohafkan M, Conrad JL, MacWilliams M, et al. (2020) Evaluation of a large-scale flow manipulation to the upper San Francisco Estuary: Response of habitat conditions for an endangered native fish. PLoS ONE 15(10): e0234673. https://doi.org/10.1371/journal.pone.0234673

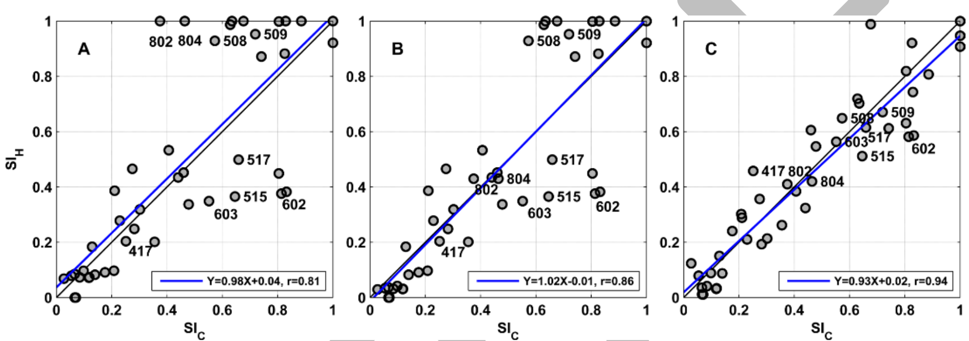
Bever, A. J., M. L. MacWilliams, B. Herbold, L. R. Brown, and F. V. Feyrer. 2016. Linking hydrodynamic complexity to Delta Smelt (Hypomesus transpacificus) distribution in the San Francisco Estuary, USA. San Francisco Estuary and Watershed Science 14(1). doi:10.15447/sfews.2016v14iss1art3

https://doi.org/10.15447/sfews.2016v14iss1art3

Long-term fish sampling data from the San Francisco Estuary were combined with detailed three-dimensional hydrodynamic modeling to investigate the relationship between historical fish catch and hydrodynamic complexity. Delta Smelt catch data at 45 stations from the Fall Midwater Trawl (FMWT) survey in the vicinity of Suisun Bay were used to develop a quantitative catch-based station index. This index was used to rank stations based on historical Delta Smelt catch. The correlations between historical Delta Smelt catch and 35 quantitative metrics of environmental complexity were evaluated at each station. Eight metrics of environmental conditions were derived from FMWT data and 27 metrics were derived from model predictions at each FMWT station. To relate the station index to conceptual models of Delta Smelt habitat, the metrics were used to predict the station ranking based on the quantified environmental conditions. Salinity, current speed, and turbidity metrics were used to predict the relative ranking of each station for Delta Smelt catch. Including a measure of the current speed at each station improved predictions of the historical ranking for Delta Smelt catch relative to similar predictions made using only salinity and turbidity. Current speed was also found to be a better predictor of historical Delta Smelt catch than water depth. The quantitative approach developed using the FMWT data was validated using the Delta Smelt catch data from the San Francisco Bay Study. Complexity metrics in Suisun Bay were evaluated during 2010 and 2011. This analysis indicated that a key to historical Delta Smelt catch is the overlap of low salinity, low maximum velocity, and low

Secchi depth regions. This overlap occurred in Suisun Bay during 2011, and may have contributed to higher Delta Smelt abundance in 2011 than in 2010 when the favorable ranges of the metrics did not overlap in Suisun Bay.

Figure A-1 The catch-based station index from the FMWT Delta Smelt catch data, SI_C, and predicted using Equation 2 (SI_H) for each station in the vicinity of Suisun Bay: (A) is SI_H based solely on the percent of time the depth-averaged salinity was less than 6 psu; (B) also includes the Secchi depth threshold at each station; and (C) is SI_H based on the percent of time the depth-averaged salinity was less than 6 psu, the maximum depth-averaged current speed, and the Secchi depth threshold at each station. The black lines show a one-to-one line and the blue lines are the least-squares best-fit lines. Stations identified in the text are labeled.



Delta Coordination Group

SFHA Model Fact Sheet – Feyrer 2011/2016 and Manly 2015

Date: 2/1/2022

Point of contact: Rosie/Matt

Model: Feyrer 2011/2016 and Manly 2015. These three models are very similar, just differences in spatial stuff.

Objective: Delta Smelt Habitat

Performance Measure: Habitat Suitability Index (we would need to adjust our index though)

Assumptions: Surface area associated with stations**.**

Constraints: Will this use data from Feyrer et al. 2011 to reconstruct the exact same GAM? Or use newer data?

Strengths: Enabled explicit mapping of habitat suitability; reaffirmed trend of declining fall habitat suitability originally indicated by Feyrer et al. (2007). Documented a nonlinear relationship between X2 and habitat suitability.

Weaknesses: No prey density. Some minor spatial bias in Feyrer 2011, further discussed Manly 2015 and Feyrer 2016. Used only data from the fall (FMWT) and deal with just two parameters: salinity and turbidity.

Data input requirements and computation time: Salinity, and turbidity.

Confidence and/or predictive accuracy: Deviance reduction of 26%. Low predictive accuracy for presence of Delta Smelt.

Links to documentation or papers written about the model:

Feyrer, F., Newman, K., Nobriga, M. *et al.* Modeling the Effects of Future Outflow on the Abiotic Habitat of an Imperiled Estuarine Fish. *Estuaries and Coasts* **34,** 120–128 (2011). https://doi.org/10.1007/s12237-010-9343-9

Future development and climate change pose potentially serious threats to estuarine fish populations around the world. We examined how habitat suitability for delta smelt (*Hypomesus transpacificus*), a state and federally protected species, might be affected by changes in outflow in the San Francisco Estuary due to future development and climate change. Forty years of sampling data collected during fall from 1967 to 2008 were examined to define abiotic habitat suitability for delta smelt as a function of salinity and water transparency, and to describe long-term trends in habitat conditions. The annual habitat index we developed, which incorporated both quantity and quality of habitat, decreased by 78% over the study period. Future habitat index values under seven different development and climate change scenarios, representing a range of drier and wetter possibilities, were predicted using a model which related estuarine outflow to the habitat index. The results suggested that each of the scenarios would generally lead to further declines in delta smelt habitat across all water year types. Recovery targets for delta smelt will be difficult to attain if the modeled habitat conditions are realized.

Manly, B.F.J., Fullerton, D., Hendrix, A.N. *et al.* Comments on Feyrer et al. “Modeling the Effects of Future Outflow on the Abiotic Habitat of an Imperiled Estuarine Fish”. *Estuaries and Coasts* **38,** 1815–1820 (2015). https://doi.org/10.1007/s12237-014-9905-3

Feyrer et al. (*Estuaries and Coasts* 34:120–128, 2011) constructed a habitat index for delta smelt (*Hypomesus transpacificus*) as a function of abiotic covariates (specific conductance, Secchi depth, and temperature) to evaluate how future hydrologic conditions in the San Francisco Estuary might affect the habitat of delta smelt. In this article, we identify three methodological issues that pertain to the results of Feyrer et al.: (1) the use of an independent abundance estimate, (2) the detection of spatial bias in the Feyrer et al. habitat index, and (3) the procedure used to link the habitat index to estuarine outflow. Like Feyrer et al. (*Estuaries and Coasts* 34:120–128, 2011), we fit general additive models (GAM) to presence of delta smelt data; however, our models included a region factor. We found that the amount of variability in the presence of delta smelt explained by the conductivity and Secchi terms was reduced relative to Feyrer et al.; conductance dropped from 12.2 to 2.5 % and Secchi dropped from 8.2 to 2.1 %. Furthermore, we found that an annual habitat index based solely on estuarine flow had low predictive ability, but the two-stage process of GAM analysis and subsequent regression modeling on GAM analysis output may mask the detection of low predictive performance. We agree with Feyrer et al. that defining a habitat index for delta smelt is an important contribution to understanding the ecology of the species and to facilitating its recovery. Given our results, the delta smelt habitat index could be improved by including static regional effects, dynamic salinity and turbidity effects, and an independent abundance index.

Feyrer, F., Newman, K., Nobriga, M. *et al.* Delta Smelt Habitat in the San Francisco Estuary: A Reply to Manly, Fullerton, Hendrix, and Burnham's "Comments on Feyrer et al. Modeling the Effects of Future Outflow on the Abiotic Habitat of an Imperiled Estuarine Fish". *Estuaries and Coasts* **39,** 287–289 (2016). https://doi.org/10.1007/s12237-015-9987-6

Delta Coordination Group

SFHA Model Fact Sheet – Hamilton and Murphy

Date: 2/1/2022

Point of contact: Rosie

Model: Hamilton and Murphy -2020 Smelt Habitat

Objective: Delta Smelt Habitat

Performance Measure: Habitat Suitability Index (we would need to adjust our index though)

Assumptions: Assumes that all habitat is equally available to Delta Smelt.

Constraints: Copepod biomass is only food source

Strengths: Used all four primary surveys. Easy to understand method (based on ratios of use:samples). Affinity curves for abiotic variables generally resemble those derived by others using GAM-based approaches (see Figs 2-3 in Hamilton and Murphy 2020); peak use of fresh to LSZ, association with turbidity, tend toward cooler water May-Sept. Included prey density metric, found generally positive relationships; see Figs 2-3). I don't have the SI but I think the metric was calanoid copepod BPUE.

Weaknesses: The ratio approach is very empirical and comes with an extra analytical reliance (compared to statistical methods) on the implicit assumption that source data are precisely correct; see Table 6 and Figs 2-3. Subjective categorization of explanatory variables; see pg 107. Categorical affinities fit with Excel functions and data were removed if they caused those functions to have more than one peak or valley; see pg 108 in Hamilton and Murphy 2020. No analytical integration of water quality habitat parameters and the 10 regions; see Table 5 vs Fig 2.

Data input requirements and computation time: Need copepod biomass, temperature, turbidity, and prey. Also depth in different regions.

Confidence and/or predictive accuracy: ?

Links to documentation or papers written about the model:

Hamilton, S. A., and D. D. Murphy. 2020. Use of affinity analysis to guide habitat restoration and enhancement for the imperiled delta smelt. Endangered Species Research 43:103-120. https://www.int-res.com/abstracts/esr/v43/p103-120/

Habitat restoration efforts in the upper San Francisco Estuary, including the Sacramento-San Joaquin Delta, California, move forward, despite a paucity of information on the environmental requirements of many targeted species. The endemic delta smelt *Hypomesus transpacificus*, protected under the federal Endangered Species Act, is a primary focus of those efforts despite uncertainties regarding many aspects of its relationship with the estuary's physical and biotic resources. Here we use time-series data from 4 trawl surveys and data on environmental attributes collected from throughout the delta smelt's distribution to identify ranges of conditions acceptable to delta smelt for each of 5 environmental attributes: water-body type, temperature, turbidity, salinity, and prey availability. Low turbidity and elevated water temperatures render a large portion of the estuary seasonally unsuitable for delta smelt. Within areas in which water quality is suitable, patterns of delta smelt occurrences indicate that habitat is found in subregions where channels of intermediate depth adjoin shallow water. In certain subregions, conditions are inadequate for at least one of the environmental attributes for periods up to several months. We suggest a habitat-restoration strategy that can achieve adequate habitat conditions for delta smelt regardless of through-Delta flow levels, and which can be carried out at a number of locations, but not necessarily the same locations, during each life stage.

Hamilton, S. A., & Murphy, D. D. (2018). Analysis of limiting factors across the life cycle of delta smelt (*Hypomesus transpacificus*). *Environmental management*, *62*(2), 365-382.

Delta Coordination Group

SFHA Model Fact Sheet – Nobriga et al. 2008

Date: 2/1/2022

Point of contact: Rosie Hartman/Matt Nobriga

Model: Nobriga 2008

Objective: Delta Smelt Habitat

Performance Measure: Habitat Suitability Index (we would need to adjust our index though)

Assumptions: Assumed that error in the association between delta smelt occurrence and water quality attributable to tidal time-scale variation from taking point measurements of water quality was insignificant.

Constraints: Only used STN data, not FMWT, so may not be relevant for later actions.

Strengths: Used a data driven regionalization scheme in which spatial strata were defined by similarity of long-term trend in predicted catches, which suggested only 3 regions were needed (Fig 5 in Nobriga et al 2008). This integrated water quality with space in a way that was specific to what was supported by delta smelt catch dat. Authors showed variability in predictions of each habitat variable caused by the others (Fig 4). Results in Fig 4 qualitatively match H&M Fig 2

Weaknesses: No prey density. Binomial response models overestimate importance of data at the tails of the distributions. More advanced models have come along since this one.

Data input requirements and computation time: Temperature, secchi, and salinity.

Confidence and/or predictive accuracy: Null deviance reduced 39%.

Links to documentation or papers written about the model:

Nobriga, M. L., T. R. Sommer, F. Feyrer, and K. Fleming. 2008. Long-term trends in summertime habitat suitability for delta smelt (*Hypomesus transpacificus*). San Francisco Estuary and Watershed Science 6(1).

The biological productivity of river-dominated estuaries is affected strongly by variation in freshwater inflow, which affects nursery habitat quality. Previous research has shown this is generally true in the upper San Francisco Estuary, California, USA; however, one endemic species of high management importance, delta smelt (*Hypomesus transpacificus*), has shown ambiguous population responses to river inflow variation. We hypothesized that population-level associations with abiotic habitat metrics have not been apparent because the effects occur seasonally, and at spatial scales smaller than the entire upper San Francisco Estuary. We tested this hypothesis by applying regression techniques and principal components analysis (PCA) to a long-term data-set (1970–2004) of summertime fish catch, and concurrently measured water quality (specific conductance, Secchi disk depth, and water temperature). We found that all three water quality variables predicted delta smelt occurrence, and we identified three distinct geographic regions that had similar long-term trends in delta smelt capture probabilities. The primary habitat region was centered on the confluence of the Sacramento and San Joaquin rivers; delta smelt relative abundance was typically highest in the Confluence region throughout the study period. There were two marginal habitat regions—including one centered on Suisun Bay—where specific conductance was highest and delta smelt relative abundance varied with specific conductance. The second marginal habitat region was centered on the San Joaquin River and southern Sacramento-San Joaquin Delta. The San Joaquin region had the warmest water temperatures and the highest water clarity, which increased strongly in this region during 1970–2004. In the San Joaquin region, where delta smelt relative abundance was correlated with water clarity, catches declined rapidly to zero from 1970–1978 and remained consistently near zero thereafter. However, when we combined these regional results into estuary-wide means, there were no significant relationships between any of the water quality variables and delta smelt relative abundance. Our findings support the hypothesis that basic water quality parameters are predictors of delta smelt relative abundance, but only at regional spatial scales.

Delta Coordination Group

SFHA Model Fact Sheet - RMA Hydrodynamics and Abiotic Habitat Conditions

Date: 02/02/2022

Point of contact: Kristi Arend (karend@usbr.gov); Brian Mahardja (bmahardja@usbr.gov)

Model: RMA Bay-Delta model, RMA San Francisco Estuary UnTRIM Model

Objective: Delta Smelt Food and Habitat (overlap of suitable habitat subobjective)

Performance Measure: produces output that can be used as input for a habitat suitability index (salinity, temperature, turbidity, water velocity/current speed)

Assumptions: What assumptions of the model will impact its utility for the DCG?

General

- The wind velocity, air temperature, solar radiation and cloudiness from historic conditions were used in the scenario simulations for the equivalent water year type (WYT). Salinity and water temperature boundary conditions were also taken from historical data except for Vernalis salinity, which was specified using DSM2 inputs. These results were then analyzed to calculate monthly metrics of current speed, salinity and temperature conditions. Historical observations from the same WYT were used to define Secchi depth.

- The following management action alternatives were simulated; a fall X2 action was included for all alternatives for Above Normal and Wet WYTs:
  - No Action alternative
  - North Delta Food Subsidies action (NDFS)
  - Suisun Marsh Salinity Control Gates action (SMSCG)
  - NDFS+SMSCG
  - Note: RMA also modeled the Sacramento Deep Water Ship Channel action and combinations of it with the other actions; however, this action is not being considered for the 2022 SDM.

Table A-1 Summary of each action option. *Additional volume through Montezuma Slough during SMSCG management action period

Action	Start Date	End Date	Average Flow (cfs)	Water Year Types	Volume (ac-ft)
X2 at 80	Sep 1	Oct 31	--	Above Normal, Wet	--
NDFA	Aug 28	Sep 23	500 cfs	All	28,000
SMSCG	Jul 1	Aug 31		Above Normal, Wet	~255,000*
SMSCG	Aug 1	Sep 30		Below Normal	~255,000*
WSC	Jul 1	Jul 28	700 cfs	All	39,000

Hydrodynamics

- Historical periods were simulated to quantify the historical conditions associated with Dry, Below Normal, Above Normal, and Wet WYTs and to validate the ability of the selected models to represent effects associated with proposed management actions.
- Scenarios of proposed management actions were simulated using flow inputs generated by CalSim II.
- Historical and CAlSim II years selected for each WYT.

Table A-2 Historical periods used for each water year type.

Water Year Type	Historical Year	CalSim II (CS) Year	Turbidity Year	X2 at 80km
Dry	2009	1930	2018	No
Below Normal	2018	1979	2018	No
Above Normal	2005	1940	2019	Yes
Wet	2019	1986	2019	Yes

- CalSim II results correspond to a contemporary regulatory environment (as of December 27, 2017) and a project year 2030 level of development (LTO EIS).
- The simulations are performed using precipitation from water year 1922 through 2003.
- For the scenario simulations, Yolo Bypass Toe Drain flows from the similar historical year were applied, as they were not available from CalSim II.
- For the Below Normal (1979 CS) No Action simulation, the historical NDFS flows were removed from the 2018 (Below Normal) Toe Drain flows. For the NDFS simulation a synthetic NDFS constant 500 cfs flow was added to the No Action Toe Drain flows from August 28 through September 23. For all other scenario years, the 500 cfs NDFA flow was applied directly to the historical Toe Drain flows with no other modifications needed.
- With the CalSim II results as inputs, DSM2 was run to generate some Delta boundary conditions that are not available from CalSim II. Specifically, these include 15-minute Clifton Court flows and south Delta barrier operations. The daily smoothed inflows for the Sacramento and San Joaquin rivers that are used in DSM2 were also utilized in lieu of the original monthly flows from CalSim II.
- **Constraints:** What are the limitations on what it can predict?
- Did not include different implementation scenarios for the Suisun Marsh Salinity Control Gate action (e.g., continuous versus non-continuous operation)

- Did not include different implementation scenarios for the North Delta Food Subsidies action (e.g., different timing and managed versus unmanaged pulse water sources)
- For 2022 SDM, can only use the output generated from RMA's initial model runs; can explore the possibility of including different implementation scenarios and addressing other weakness/assumptions for future SDM.

Strengths: Why should the DCG use it?

- Uses well-established models and related tools for the Delta.
- Models underwent calibration and validation.
- Model approach/methods and data sources are well-documented (see documentation section below).

Weaknesses: Why shouldn't the DCG use it? Or what areas is it particularly poor at predicting?

- Relies on historical conditions; however, has the potential to be run as forecasts.
- Turbidity was an interpolation from just two years based on the previous effort (2018 applied to dry and below normal years, while 2019 was applied to above normal and wet years).
- Currently, only RMA has the ability to run the model; however, given more time modeling outside of RMA could be done.

Data input requirements and computation time:

- As indicated above, the model cannot be re-run for 2022 SDM; if this model is considered for future SDM, information about requirements, computation time, staff availability, and cost can be requested from RMA.

Confidence and/or predictive accuracy: On a qualitative level, how accurate are the predictions?

- Fairly high confidence for some variables (salinity); lower confidence for others, particularly turbidity

Links to documentation or papers written about the model:

https://dshm.rmanet.app/overview/

https://dshm.rmanet.app/overview/rma_calibration_reports/USBR_LTO_Summer_Fall_Delta_Smelt_Habitat.pdf

Delta Coordination Group

SFHA Model Fact Sheet – Kimmerer Copepod Box Model

Date: 1/28/2021

Point of contact: Rosemary Hartman

Model: Kimmerer copepod box model

Objective: Increase Delta Smelt food supply

Performance Measure: Zooplankton biomass in areas with appropriate salinity/temperature/turbidity for Delta Smelt Habitat

Assumptions: Copepod densities and reproductive rates are similar to historic levels

Constraints: Only models *Pseudodiaptomus forbesi*. Does not include data/model from Cache Slough or Suisun Marsh

Strengths: It's a mechanistic model that includes transport, growth, and mortality, so can be used in a predictive way. We could use our hydrodynamic model as inputs to see how it changes the outputs.

Weaknesses: Without including Suisun Marsh or Cache Slough as separate parts of the model, it will not be very useful for SMSCG or NDFA actions. It was parameterized with copepod data from 1992-2012, may not still be accurate.

Data input requirements and computation time:

- Original model used UnTRIM 3d and FISH-PTM to calculate velocity, salinity, volume, and particles moving per day. We could probably use another hydrodynamic model to get these inputs.

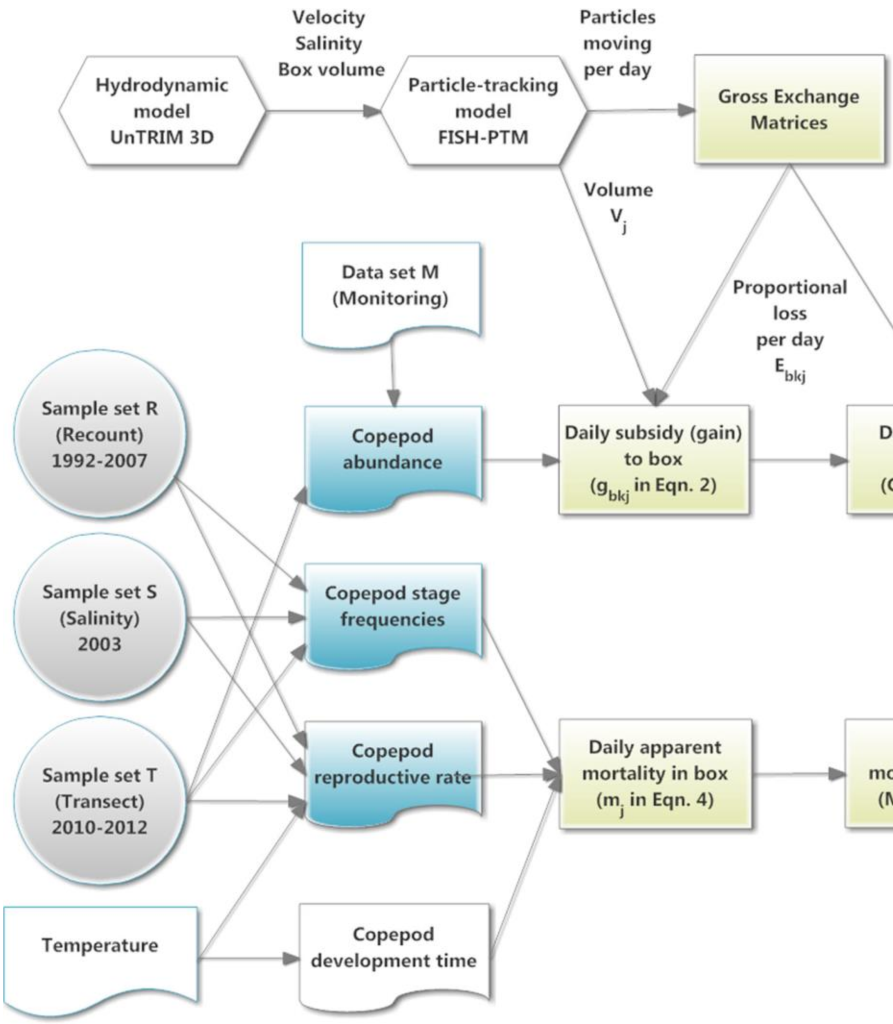
- EMP data for copepod abundance
- Temperature
- Probably a few weeks to recalibrate things with new inputs, if we can get the original code.
- **Confidence and/or predictive accuracy:** Pretty wide error bars on all the results. Zooplankton data is just plain messy.

Links to documentation or papers written about the model:

Kimmerer, W. J., E. S. Gross, A. M. Slaughter, and J. R. Durand. 2018. Spatial Subsidies and Mortality of an Estuarine Copepod Revealed Using a Box Model. Estuaries and Coasts. doi:10.1007/s12237-018-0436-1

Mortality of planktonic populations is difficult to determine because assumptions of the methods are rarely met, more so in estuaries where tidal exchange ensures violation of the assumption of a closed or spatially uniform population. Estuarine plankton populations undergo losses through movement from productive regions, creating a corresponding subsidy to regions that are less productive. We estimated mortality rates of the copepod *Pseudodiaptomus forbesi* in the San Francisco Estuary using a vertical life-table approach with a Bayesian estimation method, combined with estimates of spatial subsidies and losses using a spatial box model with salinity-based boundaries. Data came from a long-term monitoring program and from three sample sets for 1991– 2007 and 2010–2012. A hydrodynamic model coupled with a particle-tracking model supplied exchange rates between boxes and from each box to several sinks. In situ mortality, i.e., mortality corrected for movement, was highly variable. In situ mortality of adults was high (means by box and sampling program 0.1–0.9 day−1) and appeared invariant with salinity or year. In situ mortality of nauplii and copepodites increased from fresh (~ 0) to brackish water (means 0.4–0.8 day−1), probably because of consumption by clams and predatory copepods in brackish water. High mortality in the low-salinity box was offset by a subsidy which increased after 1993, indicating an increase in mortality. Our results emphasize the importance of mortality and spatial subsidies in structuring populations. Mortality estimates of estuarine plankton are feasible with sufficient sampling to overcome high variability, provided adjustments are made to account for movement.

Figure A-2 Flow diagram of calculations; shaded shapes represent calculations made for this paper, while other calculations are by reference. Hexagons are three-dimensional simulation models; circles are sample sets; document shapes are data sets, either external or derived from sample sets; rectangles are results of calculations based on data and 3-D model output. Temperature was from field samples. The table in the upper right is one example of a Gross Exchange Matrix (from Kimmerer et al. 2018)



	HS	LS	VL	SA	SJ	SINK
HS	0	7	0	0	0	0
LS	14	0	3	0	0	0
VL	0	34	0	1	5	1
SA	0	1	3	0	6	0
SJ	0	0	2	1	0	5

Delta Coordination Group

SFHA Model Fact Sheet – RMA Copepod BPUE

Date: 02/02/2022

Point of contact: Kristi Arend (karend@usbr.gov)

Model: Numerical modeling in support of Reclamation Delta Smelt summer/fall habitat analysis: Calanoid copepod analysis addendum

Objective: Delta Smelt food and habitat

Performance Measure: Zooplankton BPUE (regional)

Assumptions:

- Model was designed to provide an upper estimate for food subsidization as a result of the North Delta Food Subsidies actions (and, separately, for the Sacramento Deep Water Ship Channel action, which is not being considered as part of the 2022 SDM).
- A single carbon weight was used for all juveniles for each taxon, although actual carbon weight can vary greatly among different stages of juvenile copepods (Kimmerer et al. 2018).
- Ambient copepod BPUE was calculated using the Zooplankton Data Synthesizer for 2018 (a Below Normal year) and 2019 (an Above Normal year); ambient copepod BPUE may have been influenced by NDFS actions that occurred during September of 2018 and 2019; however, elevated calanoid BPUE was not evident (RMA 2021).
- NDFS source water continued to enter the model domain throughout the time period modeled as long as flow in the Toe Drain was directed seaward (i.e., positive). In contrast, DWSC source water was introduced at the beginning only, reflecting the movement of biomass in the upper DWSC in response to the introduced flow.

- Copepods are transported passively.
- Conversion of chlorophyll a to copepod BPUE included the following approximations:
  - The proportion of chlorophyll a (i.e., phytoplankton biomass) that becomes copepod biomass was 0.35, similar to Cloern (2007); and
  - Competition for phytoplankton was set at a possible upper bound 0.5, to account for grazing by clams and other zooplankton species; this value is highly uncertain.
- Growth and loss processes for copepods were in balance after source water chlorophyll a was taken up.

Constraints:

- Model was developed to explore effects of the North Delta Food Subsidies action under hydrologic conditions for Dry, Below Normal, Above Normal, and Wet water year types (WYTs); 2018 copepod BPUE was applied to both Dry and Below Normal WYT simulations and 2019 copepod BPUE was applied to both Above Normal and Wet WYT simulations.

Table A-3 Periods associated with calanoid copepod analysis inputs. Calanoid copepod BPUE was estimated both for the DWS action and the NDFA action for each of the listed water year types. Model inputs for atmospheric forcing and other hydrodynamic model boundary conditions were applied from the Historical Year, boundary inflows were provided from CalSim II for the CalSim Year and copepod data was applied for the Copepod Data Year

Water Year Type	Historical Year	CalSim Year	Copepod Data Year
Dry	2009	1930	2018
Above Normal	2005	1940	2019
Below Normal	2018	1979	2018
Wet	2019	1986	2019

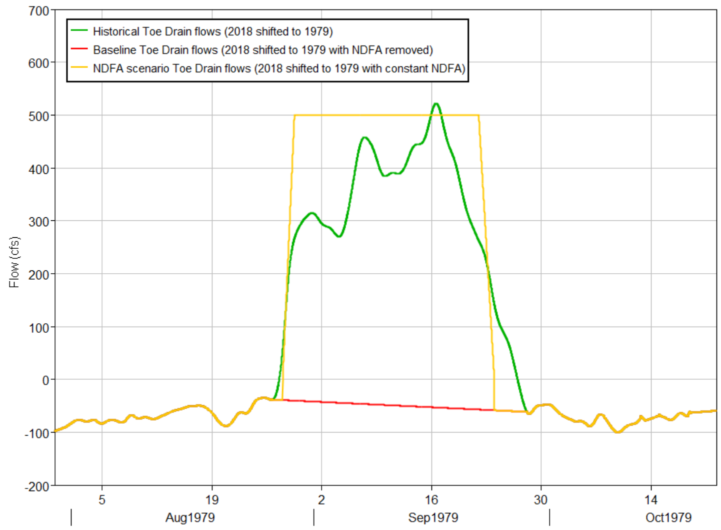
- Model only includes calanoid copepod species.

Table A-4 Carbon weight for relevant taxa and life stages

Taxon	Life Stage	Carbon Weight (ug)
Acartiella sinensis	Adult	2.81
Acartia spp.	Adult	3.14
Diaptomidae	Adult	3.36
Eurytemora affinis	Adult	3.48
Other Calanoid adults	Adult	3
Pseudodiaptomus forbesis	Adult	3.265
Pseudodiaptomus marinus	Adult	4.9
Sinocalanus doerrii	Adult	3.413
Tortanus spp.	Adult	15.895
Acartia spp.	Juvenile	1.162
Diaptomidae	Juvenile	1.301
Eurytemora affinis	Juvenile	2
Other Calanoid juvenile	Juvenile	1.443
Pseudodiaptomus forbesis	Juvenile	1.5
Pseudodiaptomus marinus	Juvenile	1.246
Sinocalanus doerrii juvenile	Juvenile	1.811
Tortanus spp.	Juvenile	7.948

- Timing, water volume, and water source for NDFS is not very accurate.
  - Timing: August 28 – September 23
  - Pulse water average flow: 500 cfs
  - Pulse water average volume: 28,000-acre feet
  - Sacramento River, but likely more reflective of agricultural releases

Figure A-3 Historical, no action, and NDFS action Toe drain flows for the Below Normal WYT simulations.



- For 2022 SDM, we are limited to using the outputs from the original model runs, because we do not have a funding mechanism in place to re-run the model at this time nor do we know if RMA staff are available.

Strengths: Why should the DCG use it?

- Models the NDFS action under different WYTs.
- Provides an upper bound or bookend for exploring potential effects of the NDFS action.
- Ambient zooplankton BPUE is based on the same monitoring data that is likely to be used for any data analyses.

Weaknesses:

- Only considers calanoid copepods.
- Is overly simplistic (treats zooplankton as particles) and relies on a number of concerning assumptions.

Data input requirements and computation time:

- As indicated above, we do not anticipate re-running this model for 2022 SDM scoring; if we choose to continue using this model in the future, we can check with RMA about model run time, staff availability, cost, etc.

Confidence and/or predictive accuracy: Low confidence in predictive accuracy; recommend using as an upper bookend if the scoring includes different levels of response to the NDFS action.

Links to documentation or papers written about the model:

- Copepod BPUE:
  - https://dshm.rmanet.app/overview/rma_calibration_reports/USBR_LTO_copepod_addendum.pdf
- Abiotic habitat simulations under different WYTs and action scenarios:
  - https://dshm.rmanet.app/overview/
  - https://dshm.rmanet.app/overview/rma_calibration_reports/USBR_LTO_Summer_Fall_Delta_Smelt_Habitat.pdf

Delta Coordination Group

SFHA Model Fact Sheet –Barros zoop models

Date: 02/10/2022

Point of contact: Rosie

Model: Zooplankton biomass regressions developed by Arthur Barros, CDFW

Objective: Delta Smelt food and habitat

Performance Measure: Zooplankton BPUE (regional)

Assumptions:

- X2 is the only major factor driving zooplankton distribution.
- Future zooplankton biomass will be similar to previous years.

Constraints:

- May not be useful in evaluating NDFA or SMSCGs that do not change X2.
- Looks one species at a time, more work needs to be done to roll up to a single metric.

Strengths: Why should the DCG use it?

- Models are available for all zooplankton taxa caught frequently in the estuary.
- Specific to different regions.

Weaknesses:

- Only assesses impact of change in X2

Data input requirements and computation time:

- All we need is X2, predictions in less than a minute

Confidence and/or predictive accuracy: Low predictive accuracy.

Links to documentation or papers written about the model:

Delta Coordination Group

SFHA Model Fact Sheet - Contaminant effect integration with IBMR

Date: 2/15/2022

Point of contact: Shawn Acuña

Model: Various; potentially SWAT/DSM2, Regression, or Constructed scale

Objective: Determine the effects of contaminants for integration into the IBMR.

Performance Measure: Survival

Conceptual model:

Proposed approaches

1. Constructed scale: Us the constructed scale to make predictions on the effect on concentrations of contaminants. Leverage the response curves from Landis Relative Risk Model to generate an estimated survival response for the IBMR.
2. Regression: Rely on contaminant survey data to develop response curves in response to the proposed action(s). Leverage the response curves from Landis Relative Risk Model to generate an estimated survival response for the IBMR.
3. SWAT/DSM2: Use pesticide use data and flow data to quantify the predicted contaminant loading into the Delta with the SWAT model. Use the DSM2 PTM for any further fine scale contaminant dynamics within the estuary. Leverage the response curves from Landis Relative Risk Model to generate an estimated survival response for the IBMR.

Assumptions:

- Approach 1) Constructed scale is a relatively accurate representation of the field.
- Approach 2) Relationships are simplistic and reasonably predictive.
- Approach 3) Standardized physical model for soil and water interaction. Assumes consistent dynamics interactions between the contaminants and media. Assumes a simplistic fate and transport in a tidal system.
- Contaminant effects: Assumes surrogate response is applicable to Delta smelt. Assumes only acute effects.

Constraints: It may be difficult to get someone up to speed on all of these models and may need to rely only on the Constructed scale. Limited to using DSM2 PTM for within Delta contaminant dynamics.

Strengths: Incorporates contaminant effects into decision making regarding listed species and water operations. Leverages a lot of data on contaminants in the estuary and exposure studies on a model estuary species. Options for approaches incorporating Contaminant effects on Delta smelt that range from simple to complex.

Weaknesses: May underestimate contaminant effects as it is limited to direct and acute impacts. Will need to explore whether indirect and sublethal impacts are worth integrating into the SDM process. Model may not be sensitive to minor changes in hydrology.

Data input requirements and computation time: Needs data on contaminant use on the landscape, concentration data in the Suisun Bay/ Delta, and distribution data for Delta smelt. It also requires data on soil types, precipitation, land use, flow, and hydrography.

Confidence and/or predictive accuracy: Leverages well accepted models but there are significant uncertainties regarding some of the models and their outputs such as using regression analyses or the accuracy of PTMs in the Delta.

Links to documentation or papers written about the model:

Reference Factsheets for SWAT, Wayne Landis Bayesian Network Relative Risk Model, DSM2.

SWAT model:

- https://swat.tamu.edu/
- Chen, H., Y. Luo, C. Potter, P. J. Moran, M. L. Grieneisen, and M. Zhang. 2017. Modeling pesticide diuron loading from the San Joaquin watershed into the Sacramento-San Joaquin Delta using SWAT. Water Research 121:374-385. doi:https://doi.org/10.1016/j.watres.2017.05.032

Relative Risk Model

- Landis, W. G. (2021). The origin, development, application, lessons learned, and future regarding the Bayesian network relative risk model for ecological risk assessment. Integrated Environmental Assessment and Management, 17(1), 79-94.
- Landis, W. G., Chu, V. R., Graham, S. E., Harris, M. J., Markiewicz, A. J., Mitchell, C. J., ... & Stark, J. D. (2020). Integration of chlorpyrifos acetylcholinesterase inhibition, water temperature, and dissolved oxygen concentration into a regional scale multiple stressor risk assessment estimating risk to Chinook salmon. Integrated Environmental Assessment and Management, 16(1), 28-42.
- Mitchell, C. J., Lawrence, E., Chu, V. R., Harris, M. J., Landis, W. G., von Stackelberg, K. E., & Stark, J. D. (2021). Integrating metapopulation dynamics into a Bayesian network relative risk model: Assessing risk of pesticides to Chinook salmon (Oncorhynchus tshawytscha) in an ecological context. Integrated Environmental Assessment and Management, 17(1), 95-109.

DSM2

- Methodology for Flow and Salinity Estimates in the Sacramento-San Joaquin Delta and Suisun Marsh - Datasets - California Natural Resources Agency Open Data

Delta Coordination Group

SFHA Model Fact Sheet – Landis relative risk model

Date: 2/7/2022

Point of contact: Rosie Hartman/Shawn Acuna

Model: Bayesian Network Relative Risk model for contaminant toxicity on Delta Smelt, developed by Dr. Wayne Landis, Western Washington University

Objective: Inform management of contaminants to reduce toxicity

Performance Measure: Contaminant toxicity. Identify priority contaminants.

Assumptions: Assumes Delta Smelt have similar responses to contaminants as Inland Silversides, which is a standard estuarine toxicity fish species. Assumes contaminant mixture effects are additive.

Constraints: Provides estimates of survival, but not growth. Does not include impacts of contaminants on zooplankton (although it does have benthic macroinvertebrates richness as a performance metric).

Strengths: May allow us to anticipate changes in toxicity due to a management action. Utilizes an abundance of data on contaminant monitoring in the estuary as well as new data improving the reliability of using inland silversides as a estuarine toxicity indicator species.

Weaknesses: May underestimate toxicity as it only includes a subset of common use or prevalent contaminants and it does not include multiplicative interactions.

Data input requirements and computation time: Requires estimates of contaminant concentrations for action versus no-action scenarios.

Confidence and/or predictive accuracy: Pending report due at the end of February 2022

Links to documentation or papers written about the model:

Landis, W. G. (2021). The origin, development, application, lessons learned, and future regarding the Bayesian network relative risk model for ecological risk assessment. Integrated Environmental Assessment and Management, 17(1), 79-94.

Landis, W. G., Chu, V. R., Graham, S. E., Harris, M. J., Markiewicz, A. J., Mitchell, C. J., ... & Stark, J. D. (2020). Integration of chlorpyrifos acetylcholinesterase inhibition, water temperature, and dissolved oxygen concentration into a regional scale multiple stressor risk assessment estimating risk to Chinook salmon. Integrated Environmental Assessment and Management, 16(1), 28-42.

Mitchell, C. J., Lawrence, E., Chu, V. R., Harris, M. J., Landis, W. G., von Stackelberg, K. E., & Stark, J. D. (2021). Integrating metapopulation dynamics into a Bayesian network relative risk model: Assessing risk of pesticides to Chinook salmon (Oncorhynchus tshawytscha) in an ecological context. Integrated Environmental Assessment and Management, 17(1), 95-109.

Delta Coordination Group

SFHA Model Fact Sheet – Histopathology

Date: 2/1/2022

Point of contact: Rosie/Matt

Model: Histopathology models similar to Hammock et al.

Objective: Delta Smelt Habitat

Performance Measure: Smelt health?

Assumptions: Depending on the endpoint, the histopathology assumes smelt have been in the habitat area for an extended period of time (a day to weeks), which may not be true.

Constraints: Data is very messy. Models show significant predictors but with extremely large variance. It's hard to use it for predictions. Relies on samples from wild collections.

Strengths: All of the other smelt habitat models have the implicit assumption that fish most frequently occur or are collected in highest numbers where habitat conditions are better than alternative locations. The histopathologic papers evaluate delta smelt tissues to ask the fish how they were doing when they were collected. This adds an important layer of information to our understanding of delta smelt habitat suitability. For instance, indications that feeding success is relatively high and contaminant stress relatively low in fish collected from Suisun Marsh played a major role in the development of the SFHA concept.

Weaknesses: Because this is more of a "frontier" like line of inquiry, the mechanistic linkages between some individual histopath metrics and their causes is still being worked out.

Data input requirements and computation time: Numerous biomarkers that function as indicators of feeding history and exposure to contaminants: location, year, fish length, time since last feeding.

Confidence and/or predictive accuracy: Low, hard to interpret.

Links to documentation or papers written about the model:

Hammock et al. 2015. https://doi.org/10.1016/j.scitotenv.2015.06.018

Teh et al. 2020. https://doi.org/10.1016/j.scitotenv.2020.138333

Hammock et al. 2020. https://doi.org/10.1371/journal.pone.0239358

Delta Coordination Group

SFHA Model Fact Sheet – Soil and Water Assessment Tool (SWAT)

Date: 2/7/2022

Point of contact: Rosie Hartman/Shawn Acuna

Model: Soil and Water Assessment Tool (SWAT)

Objective: Determine the fate and transport of contaminants. Reduce exposure to contaminants

Performance Measure: Contaminant fate and transport and concentration.

Assumptions: Standardized physical model for soil and water interaction. Assumes consistent dynamics interactions between the contaminants and media.

Constraints: Most of the technical support is for the FORTRAN version. It may be difficult to get someone up to speed on this. Figuring out which watershed area to use for the impact of X2 and the 100TAF may be difficult. Does not incorporate tidal dynamics therefore will require an in Delta model for fate and transport if that is needed.

Strengths: Can produce the fate and transport of contaminants. Allows some estimate of differences between the actions. Much of the individual properties of common use pesticides are known and can be easily adapted for varying use patterns in the estuary.

Weaknesses: It has not been used extensively in the Delta, so we don't know how well it will work for this purpose. Model may not be sensitive to minor changes in hydrology.

Data input requirements and computation time: Needs data on contaminant use on the landscape. This may be from pesticide application data and land use types or actual measurements of contaminants. It also requires data on soil types, precipitation, land use, flow, and hydrography. Most of this data is publicly available. Also relies on known toxicodynamics of the contaminant. The biggest time issue will be getting someone trained to use the model.

Confidence and/or predictive accuracy: Well accepted model around the world

Links to documentation or papers written about the model:

https://swat.tamu.edu/

Chen, H., Y. Luo, C. Potter, P. J. Moran, M. L. Grieneisen, and M. Zhang. 2017. Modeling pesticide diuron loading from the San Joaquin watershed into the Sacramento-San Joaquin Delta using SWAT. Water Research 121:374-385. doi:https://doi.org/10.1016/j.watres.2017.05.032

Delta Coordination Group

SFHA Model Fact Sheet – Expert Elicitation

Date: 2/9/2022

Point of contact: Jennie Hofmann (SDM facilitator)

Model: N/A

Objective: Any

Performance Measure: Any

Assumptions: Assumes experts know what they are talking about.

Constraints: Only as good as the data, knowledge, and experience of the available experts

Strengths:

- May be "best available" information when data are incomplete.
- Can provide added information on sources, magnitude, and consequences of uncertainty, including explicitly accounting for differences among experts.
- Can provide probability estimates on inherently stochastic variables.

Weaknesses:

- Not always seen as being as rigorous as mathematical models.
- If done poorly, may not be transparent or defensible.
- Not "reproducible" the way mathematical model outputs are.

Data input requirements and computation time: Requires multiple experts, and to do it well (structuring, eliciting, and synthesizing judgments) can take days to weeks (of non-continuous time) depending on level of agreement, number of variables being addressed, expert availability, etc.

Confidence and/or predictive accuracy: Variable

Links to documentation or papers written about the model:

Elicitations may be structured to generate responses that are qualitative (probability, odds, percentage, relative frequency, scalar quantity) or quantitative (binary, fill-in-the-blank, short answer).

Elicitation may use single point/value methods or continuous distribution methods. Typical elicitation is some version of lowest value, highest value, most likely value May bin responses and assign probabilities to bins (for likelihood point methods).

There are a variety of methods/protocols, but generally broad consensus on what is good practice. The steps are:

Step 1. Set-up before the actual elicitation: what to ask, who to ask.

Step 2. Prepare and “de-bias” the experts.

Step 3. Elicit and test judgments: select method, elicit individually then discuss, revise, and “aggregate” across experts, test for consistency and coherence.

Step 4. Document and synthesize.

Keeney, R. L., & Von Winterfeldt, D. (1991). Eliciting probabilities from experts in complex technical problems. IEEE Transactions on engineering management, 38(3), 191-201.

Martin, T. G., Burgman, M. A., Fidler, F., Kuhnert, P. M., Low-Choy, S., McBride, M., & Mengersen, K. (2012). Eliciting expert knowledge in conservation science. Conservation Biology, 26(1), 29-38.

Morgan, M. G. (2014). Use (and abuse) of expert elicitation in support of decision making for public policy. Proceedings of the National academy of Sciences, 111(20), 7176-7184.

O'Hagan,T.,et al.(2006) Uncertain Judgements: Eliciting Experts' Probabilities. John Wiley & Sons Ltd, West Sussex, England.

Runge MC, Converse SJ, Lyons JE. 2011b. Which uncertainty? Using expert elicitation and expected value of information to design an adaptive program. Biological Conservation 144:1214-1223

U.S. EPA (2001). Expert Elicitation Task Force White Paper. U.S. Environmental Protection Agency. Washington, DC.

Appendix B

Summer Fall Habitat Action (SFHA) Performance Metric InfoSheets

Compiled for SFHA Structured Decision Making 2022

PM Infosheet – Habitat Suitability Index

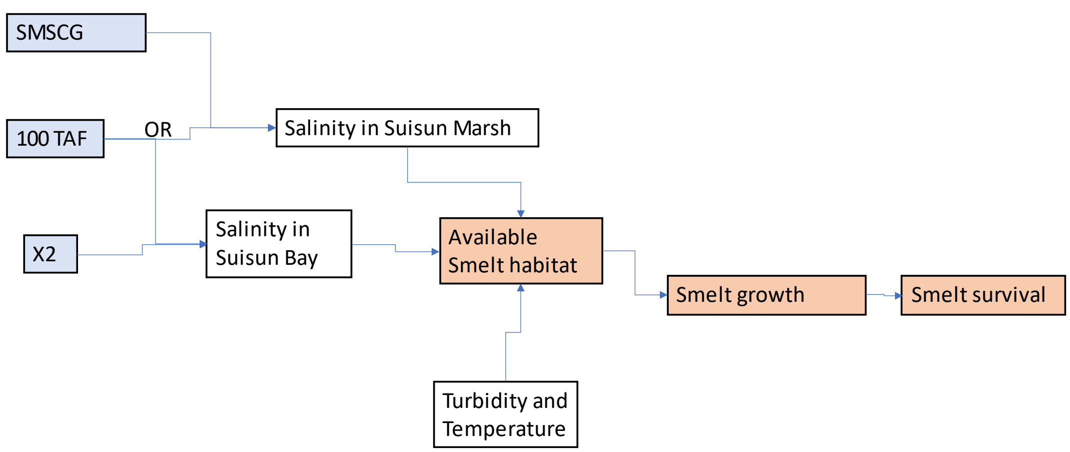
1. PM Summary

    A. Suitable habitat for Delta Smelt can be modeled based on appropriate ranges of temperature, turbidity, salinity, and current speed. Operation of the SMSCGs during the summer and fall is expected to increase suitable habitat in the Marsh by lowering salinity. Turbidity in the Marsh is more frequently in the range of suitable habitat for Delta Smelt, so Marsh habitat will be better than habitat in the Sacramento River. NDFS is not expected to have any measurable impact on available habitat.

    B. Final scores are average habitat suitability index for the summer (July-October) in Suisun Marsh, since that's where the largest change in HSI occurred.

2. Influence diagram

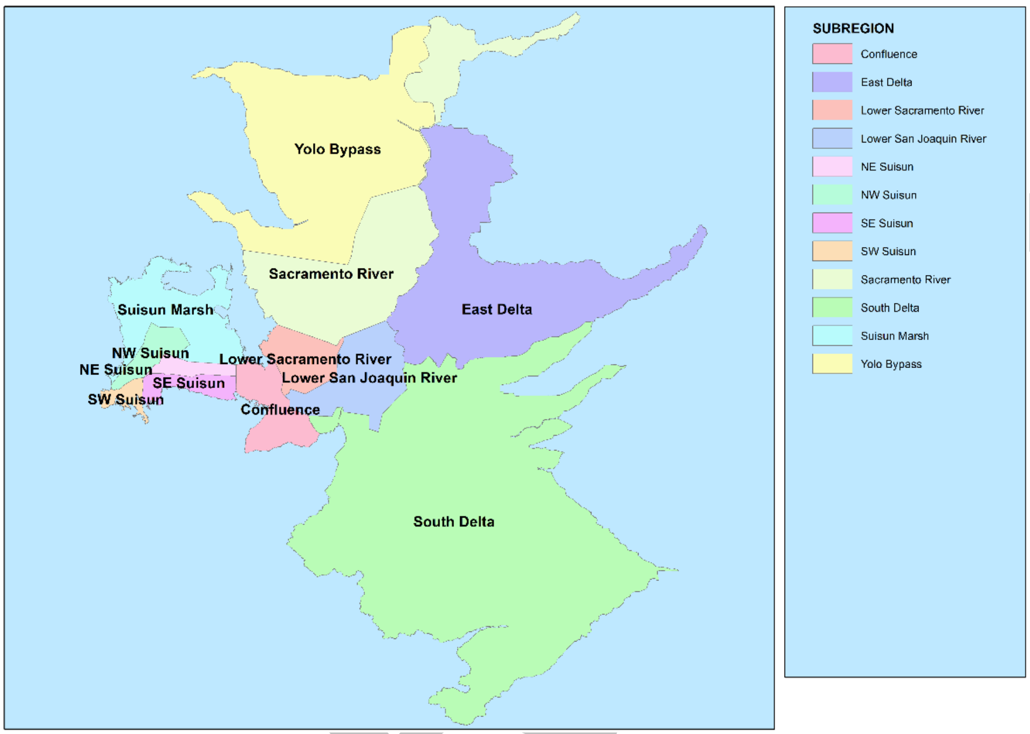
Figure B-1 Influence diagram for HSI PM



3. Calculations and/or scoring

Suitable Habitat Index was calculated using a methodology derived from Bever et al. (2016) and RMA (2021). The index represents spatially- and temporally-averaged suitability of habitats within the delineated subregions in the Bay-Delta shown in Figure B-2. Spatial averaging was performed both vertically over depth and horizontally over the area of each subregion. The temporal averaging was performed monthly from July to September. Habitat suitability was assessed only over the Below Normal years involving Suisun Marsh Salinity Control Gate actions.

Figure B-2 Subregions over which the Habitat Suitability Index was calculated



The habitat suitability index (HSI) is based on four abiotic variables: salinity, temperature, turbidity, and current speed. Two of the HSI variables, salinity and current speed, are readily calculated from results from the 3D Bay-Delta SCHISM model. Assuming that flow boundary conditions are available based on operational forecasts of flow, the model results are regarded to be spatially detailed and sufficiently accurate to inform the structured decision-making process.

Temperature and turbidity, by contrast, are highly dependent on atmospheric forcing, including air temperature, radiation and wind. In hindcasts, these variables are known and can be used directly in the Bever at al. (2016) and RMA (2021) formulas. In forecasts, however, the uncertainty regarding weather dominates the calculation and any small contribution that might result from individual actions.

In order to accommodate this limitation, a method was developed that used historical quantiles, interpolated over space, to provide probable weighting of these atmospheric-dependent variables. First, we computed windowed (0.05, 0.25, 0.5, 0.75) quantiles at continuous stations for each day of the year, using the available record and a 19-day window around each date of interest. We verified that this produced results that were sensible with relatively low noise over time. We then interpolated the quantiles spatially using the method of Sangalli et al. (2013), a regularized spline method which respects islands and irregular domains. The interpolated quantiles consider only the distribution of the data, not the mixed distribution of the data and of the interpolation. The interpolator is based on unstructured meshes but is coarser (1km) than the Bay-Delta SCHISM mesh. Nearest neighbor interpolation was used to interpolate to the much more resolved SCHISM mesh.

Once the turbidity and temperature quantiles were available on the SCHISM mesh, marginal probabilities or factors based on the quantiles, in conjunction with the SCHISM-predicted salinity and current speed, were applied to the Bever et al. formulation at each mesh cell to determine the depth-averaged HSI for the cell. For instance, the Bever et al. formula is as follows,

$$S_i = 0.67S + 0.33V, \qquad \text{turbidity} \geq 12 \text{ NTU} \qquad (1a)$$

$$S_i = (0.67S + 0.33V)c_t, \qquad \text{turbidity} < 12 \text{ NTU} \qquad (1b)$$

where S is a suitability index based on the fraction of time salinity < 6 PSU (computed with SCHISM), V is a suitability index based on the maximum current speed (computed with SCHISM), and $c_t = 0.42$ is a penalty associated with low turbidity. Conventionally, one would use only one of the above equations depending on whether turbidity is above or below 12 NTU. However, to reconcile the formula with the turbidity quantiles for a given day, the quantile that was just higher or lower than the 12 NTU threshold was used to create a roughly discretized marginal probability and the two equations weighted accordingly. For instance, if q_{75} was the quantile just under 12 NTU for a given date and location, the formula would be weighted with a 0.75 weight on the penalized value (Eqn 1b) and a 0.25 weight on the unpenalized value (Eqn 1a), reflecting the assumption;

$$S_i = 0.75\times[\ (0.67S + 0.33V)\times0.42\ ] + 0.25\times[0.67S + 0.33V] \quad (2)$$

We similarly used quantiles for temperature to fit the RMA temperature addition to the Bever et al formula, which is simply a product of the original suitability index, S_i, and a temperature suitability factor. Looking up the quantiles bracketing the threshold value of 24 ºC, we determined the final suitability index at a given location and date as follows:

$$S_{i,final} = 1.00\times S_i, \quad q_{75} < 24ºC \quad (3a)$$
$$S_{i,final} = 0.75\times S_i, \quad q_{50} < 24ºC \leq q_{75} \quad (3b)$$
$$S_{i,final} = 0.50\times S_i, \quad q_{25} < 24ºC \leq q_{50} \quad (3c)$$
$$S_{i,final} = 0.25\times S_i, \quad q_{5} < 24ºC \leq q_{25} \quad (3d)$$
$$S_{i,final} = 0.05\times S_i, \quad 24ºC \leq q_{5} \quad (3e)$$

Finally, the daily depth-averaged suitability indices computed at the mesh cells were aggregated over subregion area and on a monthly basis from July to September.

1. Key assumptions and uncertainties
   A. Sources, types, magnitude of uncertainty
   B. Using historical turbidity and temperature values for a given water year type is the largest source of uncertainty. Salinity and velocity is relatively straightforward to model, but we have very poor predictive power for turbidity and temperature. Actual temperatures occurring in the summer and fall of 2022 may be quite different from previous years.
   C. Reducibility
2. Round 1 results

Action	Score	Comments/rationale
1. Dry Year. NDFA – Ag Flow - high magnitude, low duration	0.156	NDFA is not expected to change habitat suitability
2. Dry Year. NDFA – Ag Flow - low magnitude, high duration	0.156	NDFA is not expected to change habitat suitability
3. Below Normal Year. NDFA – Ag Flow - high magnitude, low duration	0.361	NDFA is not expected to change habitat suitability

Action	Score	Comments/rationale
4. Below Normal Year. NDFA – Ag Flow- low magnitude, high duration	0.361	NDFA is not expected to change habitat suitability
5. Below Normal Year. NDFA – Sac Flow- low magnitude, high duration	0.361	NDFA is not expected to change habitat suitability
6. Below Normal Year. NDFA – Sac Flow - high magnitude, low duration	0.361	NDFA is not expected to change habitat suitability
7. Below Normal Year. NDFA – Sac summer action + Fall ag action. Low magnitude, high duration	0.361	NDFA is not expected to change habitat suitability
8. . Below Normal Year. SMSCG – Nonconsecutive. Start when Beldon's >4ppt	0.505	Gates action increases HSI in the Marsh.
9. Below Normal Year. SMSCG – Nonconsecutive. Start when Beldon's >6ppt	0.419	Gates action increases HSI in the Marsh.
10. No action	0	

Additional information and context for interpreting results

Figure B-3 Plot of Habitat Suitability index by region, scenario, and month for below-normal years. The largest change in HSI was for Suisun Marsh, where gates actions increased HSI, especially in August and September. There wasn't much difference between the 4ppt and 6ppt scenarios.

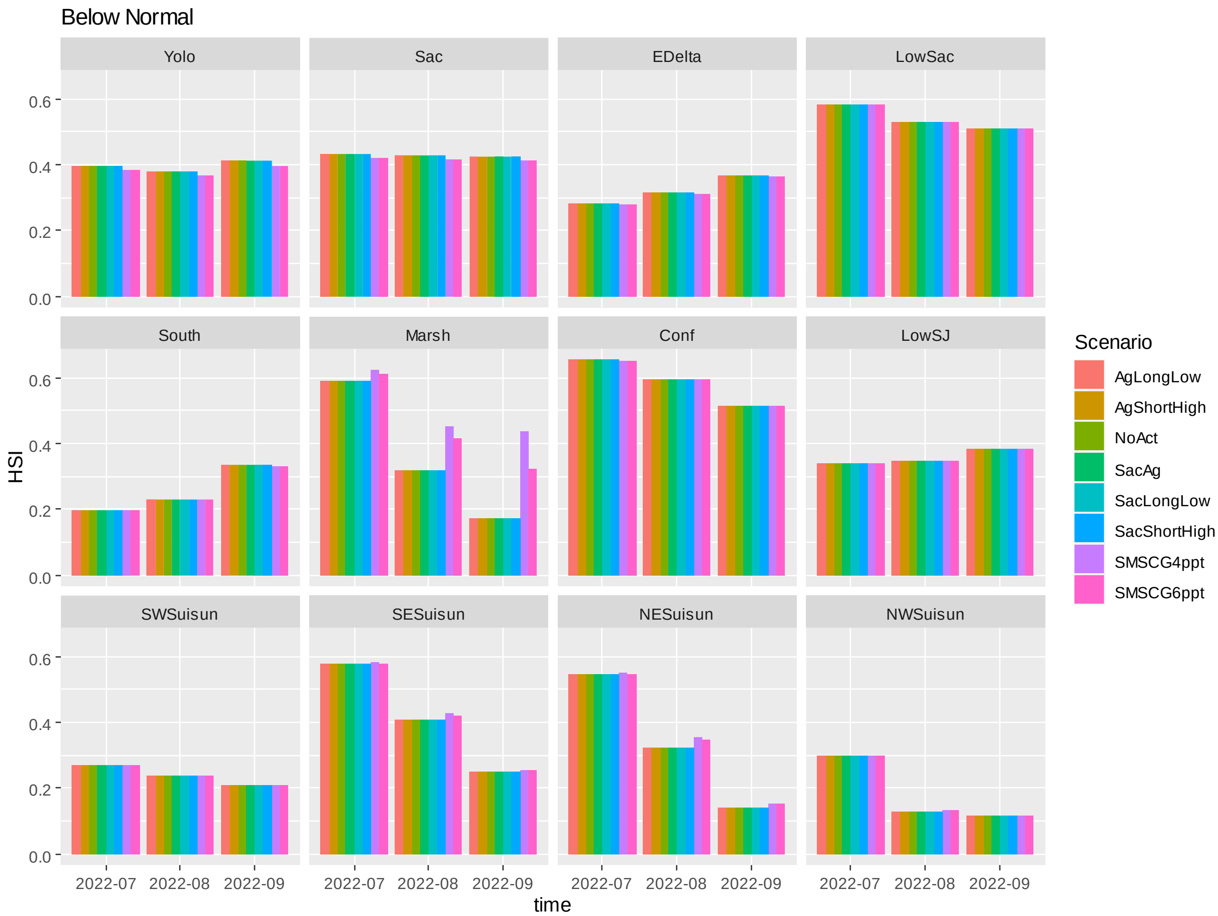
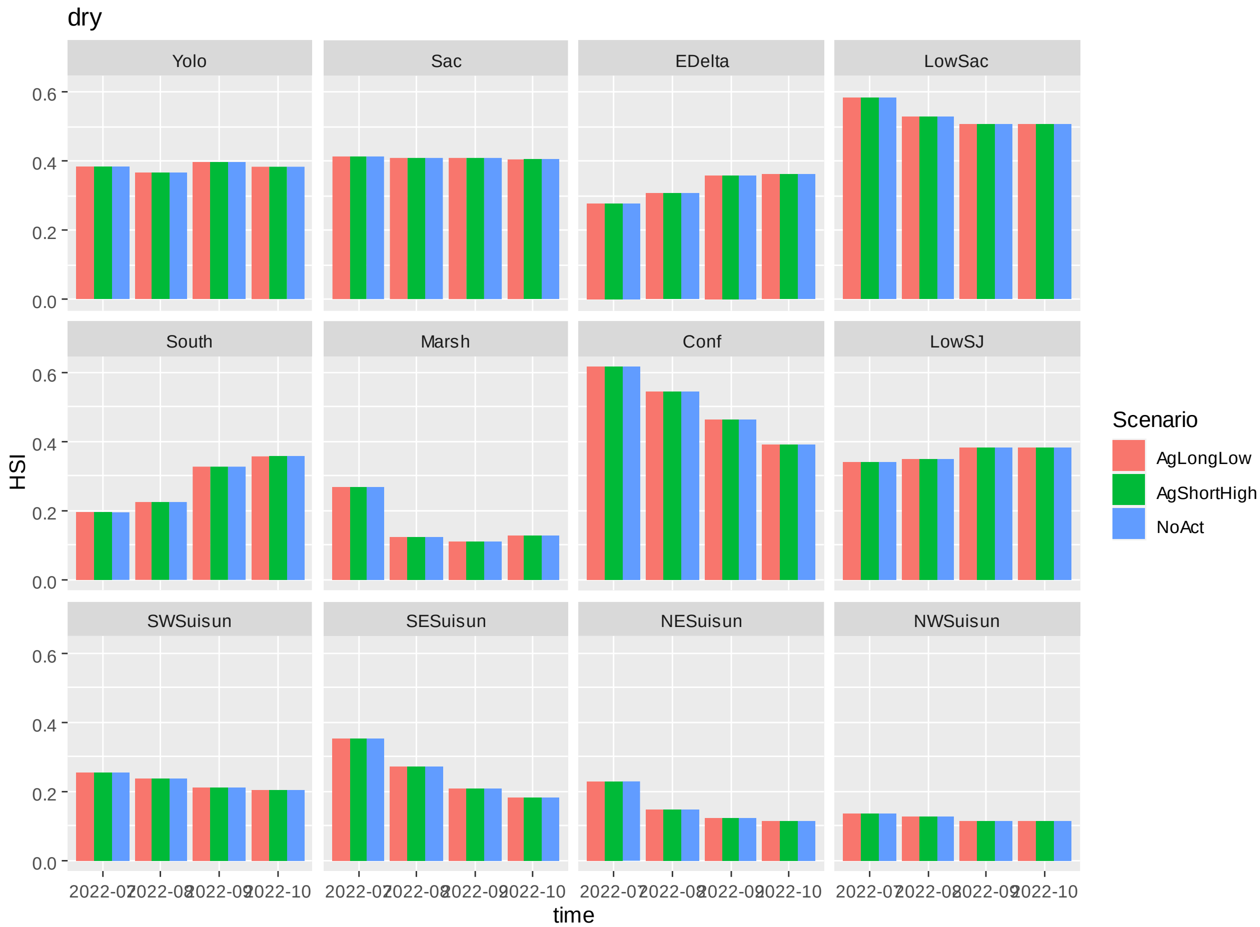


Figure B-4 Plot of habitat suitability index for dry year scenarios by month and region. There were no changes to HSI because there were no Gate actions included in the scenarios.



Summary table of calculated HSI for year type, action scenario, and subregion.

Yr_type	Scenario	Yolo	Sac	EDelta	LowSac	South	Marsh	Conf	LowSJ	SWSuisun	SESuisun	NESuisun	NWSuisun
Below Normal	AgLongLow	0.395	0.428	0.320	0.541	0.255	0.361	0.589	0.357	0.240	0.412	0.336	0.181
Below Normal	AgShortHigh	0.395	0.428	0.320	0.541	0.255	0.361	0.589	0.357	0.240	0.412	0.336	0.181
Below Normal	NoAct	0.395	0.428	0.320	0.541	0.255	0.361	0.589	0.357	0.240	0.412	0.336	0.181
Below Normal	SacAg	0.395	0.428	0.320	0.541	0.255	0.361	0.589	0.357	0.240	0.412	0.336	0.181
Below Normal	SacLongLow	0.395	0.428	0.320	0.541	0.255	0.361	0.589	0.357	0.240	0.412	0.336	0.181
Below Normal	SacShortHigh	0.395	0.428	0.320	0.541	0.255	0.361	0.589	0.357	0.240	0.412	0.336	0.181
Below Normal	SMSCG4ppt	0.383	0.416	0.317	0.540	0.253	0.505	0.586	0.357	0.240	0.421	0.353	0.183
Below Normal	SMSCG6ppt	0.383	0.414	0.328	0.533	0.280	0.419	0.547	0.364	0.231	0.362	0.290	0.164
Dry	AgLongLow	0.383	0.409	0.326	0.532	0.278	0.156	0.504	0.364	0.226	0.252	0.152	0.123
Dry	AgShortHigh	0.383	0.409	0.326	0.532	0.278	0.156	0.504	0.364	0.226	0.252	0.152	0.123
Dry	NoAct	0.383	0.409	0.326	0.532	0.278	0.156	0.504	0.364	0.226	0.252	0.152	0.123

References

Bever, Aaron J., MacWilliams, Michael L., Herbold, Bruce et al., 2016. Linking Hydrodynamic Complexity to Delta Smelt (*Hypomesus transpacificus*) Distribution in the San Francisco Estuary, USA. *San Francisco Estuary and Watershed Science*, 14(1).

RMA (2021). Numerical Modeling in Support of Reclamation Delta Smelt Summer/Fall Habitat Analysis, Technical Memo, Davis CA.

Sangalli, L.M., Ramsay, J.O. and Ramsay, T.O., 2013. Spatial spline regression models. Journal of the Royal Statistical Society: Series B (Statistical Methodology), 75(4), pp.681-703.

PM InfoSheet - Delta Smelt Growth

Kristi Arend, Brian Mahardja,
Matt Nobriga, and William Smith

20 April 2022

Summary

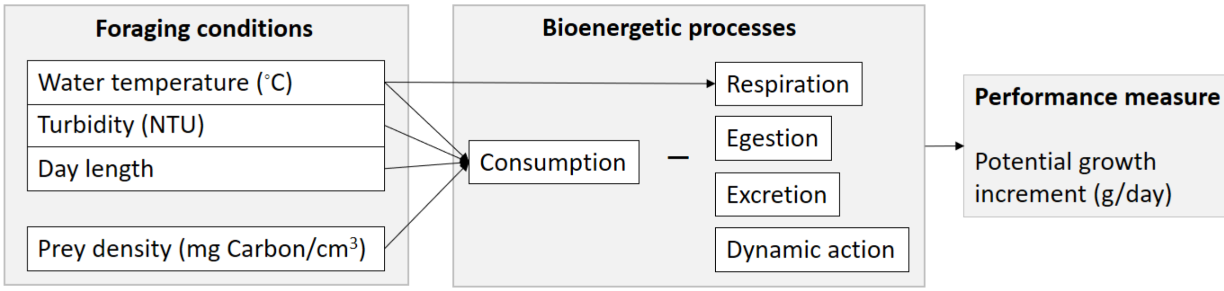
The bioenergetics model (BEM) presented by Rose et al. (2013) described the growth of delta smelt, given available prey and environmental constraints on foraging. For the Delta Coordination Group, delta smelt habitat suitability indices (HSI) were developed, based on the BEM, given bioenergetics constraints (BEM-based HSI). The BEM-based HSI was the cumulative growth increment of delta smelt, assuming occupancy of a given region of the estuary and a set of conditions influencing growth.

Regional conditions driving the expected growth of delta smelt were water temperature, turbidity, and prey density. BEM-based HSI, or growth potential, resulting from different summer-fall habitat actions were compared to an average rate of growth and the growth expected with no action. The average growth reference point was defined externally by fitting a von Bertalanffy growth model to size at age of wild delta smelt. If BEM-based growth was less than that associated with average growth, regional conditions were considered insufficient to support delta smelt growth. The difference between BEM-based growth, given no change to water temperature, turbidity, and prey density (no action) and given summer-fall habitat action effects, represented the expected benefit of the action.

The performance measure was a metric to evaluate whether simulated actions increased the bioenergetics-based suitability of a region. The performance measure was the difference in potential growth predicted by the bioenergetics model, between conditions representing no action and conditions representing the effects of a management action.

Influence diagram

Figure B-5 Influence diagram for Delta Smelt Growth PM



Bioenergetics model

Growth reference points

Potential delta smelt growth, given a set of limitations on the foraging arena described below, was compared to the mean growth estimated for the wild delta smelt population from length-at-age data (Appendix). Mean growth rates of wild fish from throughout the Delta, were used as reference points to evaluate the suitability of foraging arena conditions to support delta smelt growth. Specific foraging arena conditions (prey, temperature, and turbidity) representing management actions in the North Delta (Yolo, Lower Sacramento River, and Confluence) and Suisun Marsh strata (Fig. B-6), were used to simulate growth using the bioenergetics model, and the BEM-predicted growth was then compared to the growth reference points. The Fabens (1965) derivation of the von Bertalanffy growth model and parameters from a model fit to wild delta smelt length-at-age (Fig. B-10), was used to estimate the average monthly growth increment in fork length (FL)

(1) $$FL_m = FL_{m-1}(76.1 - FL_{m-1})\left(1 - e^{-2.98\left(\frac{n.days_m}{365}\right)}\right),$$

beginning with a July (m = 1) starting size of 30 mm. FL_m on month m were converted to weight W_m in grams using the length-weight equation provided by Kimmerer et al. (2005)

(2) $$W_m = 1.8 * 10^{-6} FL_m^{3.38}.$$

Growth

The bioenergetics growth model described by Rose et al. (2013) was a system of equations estimating daily delta smelt growth in body mass as a function of rates of consumption C_m, metabolism R_m, egestion F_m, excretion U_m, and activity SDA_m in month *m* (Eqs. 3-7). In this application, daily growth increments were scaled to monthly increments by multiplying by the number of days in each month. A set of bioenergetics model coefficients, specific to each life-stage *l* to model each rate were listed in Rose et al. (2013a) (Fig. B-8); in the notation below, these fixed coefficients are underlined to distinguish them from dynamic quantities that may vary by time period.

(3) $W_{\mathrm{m+1}} = W_{\mathrm{m}} * \left(1 + n.days_m * \frac{ep_{\mathrm{m}}}{4814} * (C_{\mathrm{m}} - R_{\mathrm{m}} - F_{\mathrm{m}} - U_{\mathrm{m}} - SDA_{\mathrm{m}})\right)$, where

(4) $R_{\mathrm{m}} = \underline{ar_{\mathrm{l}}} * W_{\mathrm{m}}^{\underline{br_{\mathrm{l}}}} * e^{\underline{RQ_{\mathrm{l}}} * Temp_{\mathrm{m}}}$,

(5) $F_{\mathrm{m}} = \underline{Fa_{\mathrm{l}}} * C_{\mathrm{m}}$,

(6) $U_{\mathrm{m}} = \underline{Ua_{\mathrm{l}}} * (C_{\mathrm{m}} - F_{\mathrm{m}})$, and

(7) $SDA_{\mathrm{ym}} = \underline{Sd_{\mathrm{l}}} * \left(C_{\mathrm{ym}} - F_{\mathrm{ym}}\right)$.

The conversion of prey to delta smelt biomass was expected to be less efficient for *Limnoithona* prey because of its lower energy density ed_{p}. The lower ed_{p} of *Limnoithona* was accounted by adjusting the efficiency at which simulated consumption was converted to delta smelt weight, represented by the ratio $ep_m/4814$ (Eq. 1). ep_m was the energy density of prey consumed, reduced by the fraction of consumed energy corresponding to *Limnoithona* (Eq. 8 and 9), and 4,814 J/g was the energy density of delta smelt. The energy density of *Limnoithona* (1,813 J/g) was assumed to be 30% less than that of all other prey items (2,590 J/g).

(8) $ep_{\mathrm{m}} = 1813 * Limno_{\mathrm{ym}} + 2590 * \left(1 - Limno_{\mathrm{ym}}\right)$, where

(9) $$Limno_{\mathrm{ym}} = \frac{1813 * Cmax_{\mathrm{m}} * \left(\frac{\frac{PD_{\mathrm{m(LImno)}} * \underline{\underline{V_{\mathrm{(Limno)l}}}}}{\underline{K_{\mathrm{(Limno)l}}}}}{\sum_{r=1}^{12} \frac{PD_{\mathrm{mr}} * \underline{\underline{V_{\mathrm{rl}}}}}{\underline{K_{\mathrm{rl}}}}} \right)}{\sum_{q=1}^{12} \underline{ed_{\mathrm{q}}} * Cmax_{\mathrm{ym}} * \left(\frac{\frac{PD_{\mathrm{mq}} * \underline{\underline{V_{\mathrm{ql}}}}}{\underline{K_{\mathrm{ql}}}}}{\sum_{r=1}^{12} \frac{PD_{\mathrm{mr}} * \underline{\underline{V_{\mathrm{rl}}}}}{\underline{K_{\mathrm{rl}}}}} \right)}$$

where PD_{mp} was the prey density of prey type *p*.

The maximum possible consumption rate $C_{\max_\mathrm{m}}$ was a measure of potential foraging rate, expressed as a proportion of body weight per day (Eqs. 10 and 11). Foraging arena theory suggests that fish reduce their time spent foraging to mitigate perceived risk of mortality, at the expense of forgone foraging and growth. Three environmental constraints on delta smelt foraging were considered: temperature $Temp_{\mathrm{ym}}$ effects ($KA_\mathrm{m} * KB_\mathrm{m}$), turbidity $Turb_{\mathrm{ym}}$ effects (KT_m), and day length effects (KL_m). Relationships between *Temp*, *C*, and *R* are shown in Fig. B-7.

(10) $$C_\mathrm{m} = C_{\max_\mathrm{m}} * \sum_{q=1}^{12}\left(\frac{\frac{PD_{\mathrm{mp}} * \underline{V_{\mathrm{pl}}}}{\underline{K_{\mathrm{ql}}}}}{\sum_{r=1}^{12}\frac{PD_{\mathrm{mp}} * \underline{V_{\mathrm{pl}}}}{\underline{K_{\mathrm{rl}}}}}\right)\text{, where}$$

(11) $$C_{\max_\mathrm{m}} = \underline{ac_\mathrm{l}} * W_\mathrm{m}^{\underline{bc_\mathrm{l}}} * KA_\mathrm{m} * KB_\mathrm{m} * KT_\mathrm{m} * KL_\mathrm{m}$$

Rose et al. (2013) assumed a *Temp*-*C*max model for delta smelt (KA_m and KB_m; Eq. 12 and13) that reduced foraging time as water temperatures increased above 23°C (Fig. B-7).

(12) $$KA_\mathrm{m} = \frac{\underline{CK1_\mathrm{l}} * e^{\frac{1}{\underline{T0_\mathrm{l}} - \underline{CQ_\mathrm{l}}} * ln\left(\frac{0.98*\left(1-\underline{CK1_\mathrm{l}}\right)}{0.02*\underline{CK1_\mathrm{l}}}\right) * \left(Temp_\mathrm{m} - \underline{CQ_\mathrm{l}}\right)}}{1 + \underline{CK1_\mathrm{l}} * \left(e^{\frac{1}{\underline{T0_\mathrm{l}} - \underline{CQ_\mathrm{l}}} * ln\left(\frac{0.98*\left(1-\underline{CK1_\mathrm{l}}\right)}{0.02*\underline{CK1_\mathrm{l}}}\right) * \left(Temp_\mathrm{m} - \underline{CQ_\mathrm{l}}\right)} - 1\right)}$$

(13) $$KB_\mathrm{m} = \frac{\underline{CK4_\mathrm{l}} * e^{\frac{1}{\underline{TL_\mathrm{l}} - \underline{TM_\mathrm{l}}} * ln\left(\frac{0.98*\left(1-\underline{CK4_\mathrm{l}}\right)}{0.02*\underline{CK4_\mathrm{l}}}\right) * \left(\underline{TL_\mathrm{l}} - Temp_\mathrm{m}\right)}}{1 + \underline{CK4_\mathrm{l}} * \left(e^{\frac{1}{\underline{TL_\mathrm{l}} - \underline{TM_\mathrm{l}}} * ln\left(\frac{0.98*\left(1-\underline{CK4_\mathrm{l}}\right)}{0.02*\underline{CK4_\mathrm{l}}}\right) * \left(\underline{TL_\mathrm{l}} - Temp_\mathrm{m}\right)} - 1\right)}$$

Forage fish, such as delta smelt, typically show a decrease in foraging rates as turbidity declines and the perceived risk of being detected by a predator increases (Pangle et al. 2012). The risk of predation and changes in delta smelt behavior in clear water were documented by Ferrari et al. (2014), though rates of predation may have been biased high because smelt could not effectively evade predators in laboratory conditions. The relationship between delta smelt foraging rate and turbidity reported by Hasenbein et al. (2016) was approximated using a simple logistic model (Fig. B-7), that increased from the lowest turbidities evaluated (5 NTU) to the turbidities associated with maximum foraging rate (25-80 NTU). Since turbidities greater than 80 NTU were rarely observed during the time period explored, foraging limitation at high turbidity was not modeled, i.e., using a dome-shaped double-logistic model. As turbidity declined, the effect of turbidity (*KT_{yms}*; Eq. 14) was assumed to reach some asymptotic minimum α_{FL}, and α_{FL} was assumed to increase linearly from 0.68 to 0.85 as fish grew from 20 to 45 mm FL, simulating a reduction in the turbidity effect on foraging as fish grew into the summer, corresponding with the historical season of declining inflow and turbidity.

$$(14) \quad KT_{\mathrm{m}} = \alpha_{FL} + (1 - \alpha_{FL}) / \left(1 + e^{0.1*(Turb_{\mathrm{m}} - 56.2)}\right)$$

Delta smelt only feed during daylight (Baskerville-Bridges 2004; Hobbs et al. 2006), so day length was considered as a third scalar of consumption (*KL_m*; Eq.15). The rationale for a daylight constraint was that the time available to acquire a daily ration, begins decreasing after the summer solstice in late June. From July 1 through October 31, daylight at San Francisco, CA ranges from a maximum of 884 min to a minimum of 758 min (https://www.esrl.noaa.gov/gmd/grad/solcalc/). As with temperature and turbidity effects, the effect of day length was represented by a scalar, from zero to one. The effect of day length equaled the daily fractional daylight hours divided by the maximum fractional daylight hours (887 minutes on the summer solstice). This approach ignored the potential effects of cloud cover on visibility, sensu Hansen and Beauchamp (2015), because summers in California's Central Valley tend to be sunny and dry.

$$(15) \quad KL_{\mathrm{m}} = \frac{day.length_{\mathrm{m}}}{887\ \text{minutes}}$$

Assumptions and Uncertainties

In this application, delta smelt are assumed to reside within a single stratum for the entire time period, and growth potential is cumulative within the July-October time frame modeled.

Uncertainty in inputs leads to uncertainty in outputs. BEMs depend upon externally-generated estimates of *Temp*, *Turb*, and *PD* that represent the expected effect of management actions on specific regions. Each of these predictions of environmental conditions is uncertain.

While the models used to simulate delta smelt bioenergetics dynamics are supported to varying degrees by experimental results, no experiment has directly quantified the parameters of a delta smelt bioenergetics model (i.e., from data collected during directed bioenergetics studies). Furthermore, the delta smelt model has not and cannot be validated empirically using data collected from wild delta smelt, because delta smelt catches and abundance are currently too low.

The temperature function that describes delta smelt's metabolic response to temperature (equations 11-12) is very uncertain. Though the model used here results in declining consumption at temperatures greater than 23°C, decreased delta smelt foraging rates were documented in laboratory conditions at temperatures as low as 20°C (Eder et al. 2014). If the Eder et al. study generated more accurate results than the parameterization of equations 11-12 chosen by Rose et al. (2013), then the predictions made here under-represent the effects of temperature and BEM-based growth estimates are positively biased.

Reproducibility

The model was implemented in the R statistical environment. Code to run the model is available on request or to reproduce modeling efforts in future years.

Results

Starting with a July 1 assumed length of 30 mm FL, it appeared that all combinations of conditions explored (region x year type x scenario) could produce at least an average growth rate by the end of October (Table B-1). With no simulated action, the difference between the most energetically favorable region (Marsh) and the least energetically favorable region (Lower Sacramento) was 3.4 mm of potential growth in a dry year and 3.6 mm of potential growth in a below normal year. The incremental benefit of each scenario (action – no action) was much smaller than the regional differences, ranging from zero to 0.43 (Table B-2). Predicted growth was highest in Suisun Marsh, with SMSCG4ppt.

Decomposition of the predicted foraging limitations into the three component effects due to temperature, turbidity, and day length demonstrated that the greatest predicted limitation resulted from low turbidity (Fig. B-9). Though turbidity declined over the time period analyzed, its effect was less in the fall than the summer because the model assumed that fish became less sensitive to turbidity during the same time period (as they grew from 30 to 45 mm FL; Fig. B-7).

References

Baskerville-Bridges, B., Lindberg, J. C., and Doroshov, S. L. 2004. The effect of light intensity, alga concentration, and prey density on the feeding behavior of delta smelt larvae. *In* American Fisheries Society Symposium 39: 219–227.

Eder, K. J., R. C. Kaufman, D. E. Cocherell, J. C. Lindberg, N. A. Fangue, and F. J. Loge. 2014. Longfin and delta smelt food consumption and bioenergetics assessments. Final Report to U.S. Bureau of Reclamation Project # R10AC20107.

Fabens, A. J. 1965. Properties and fitting of the von Bertalanffy growth model. Growth 29: 265–289.

Ferrari, M. C. O., L. Ranaker, K. L. Weinersmith, M. J. Young, A. Sih, and J. L. Conrad. 2014. Effects of turbidity and an invasive waterweed on predation by introduced largemouth bass. Environmental Biology of Fishes 97:79–90.

Hansen, A. G., and D. A. Beauchamp. 2015. Latitudinal and photic effects on diel foraging and predation risk in freshwater pelagic ecosystems. Journal of Animal Ecology 84:532–544.

Hasenbein, M., N. A. Fangue, J. Geist, L. M. Komoroske, J. Truong, R. McPherson, and R. E. Connon. 2016. Assessments at multiple levels of biological organization allow for an integrative determination of physiological tolerances to turbidity in an endangered fish species. Conservation Physiology 4(1). https://doi.org/10.1093/conphys/cow004

Hobbs, J. A., W. A. Bennett, and J. E. Burton. 2006. Assessing nursery habitat quality for native smelts (Osmeridae) in the low-salinity zone of the San Francisco estuary. Journal of Fish Biology 69: 907–922.

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

Pangle, K. L., T. D. Malinich, D. B. Bunnell, D. R. DeVries, and S. A. Ludsin. 2012. Context-dependent planktivory: interacting effects of turbidity and predation risk on adaptive foraging. Ecosphere 3(12): 1–18.

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

Table B-1 Bioenergetics model (BEM)-predicted and reference (external von Bertalanffy growth model) lengths at the end of October, assuming a July 1 length of 30 mm FL.

Region	**Year type = Below Normal**	
	BEM-based (No action)	**Reference**
Yolo	62.36	59.21
Lower Sac	62.07	59.21
Confluence	62.76	59.21
Marsh	65.64	59.21
	Year type = Dry	
Yolo	62.10	59.21
Lower Sac	61.81	59.21
Confluence	62.42	59.21
Marsh	65.24	59.21

Table B-2 Growth increment (performance measure) for each region-year type-scenario combination. Growth increment was the difference between BEM-predicted growth with simulated action minus predicted growth with no action (Table B-1).

Region	Year type = Below Normal						
	AgLong -Low	**AgShort -High**	**SacAg**	**SacLong -Low**	**SacShort-High**	**SMSCG -4ppt**	**SMSCG -6ppt**
Yolo	0.30	0.22	0.63	0.33	0.21	0	0
Lower Sac	0.05	0.05	0.07	0.05	0.05	0	0
Confluence	0	0	0	0	0	0	0
Marsh	0	0	0	0	0	0.43	0.34
Year type = Dry							
Yolo	0.42	0.34	--	--	--	--	--
Lower Sac	0.07	0.07	--	--	--	--	--
Confluence	0	0	--	--	--	--	--
Marsh	0	0	--	--	--	--	--

Figure B-6 Map of the Sacramento-San Joaquin Delta, showing the spatial strata used to model delta smelt spatial distributions. This map was reproduced from Rose et al. (2013a) and Peterson et al. (2019)

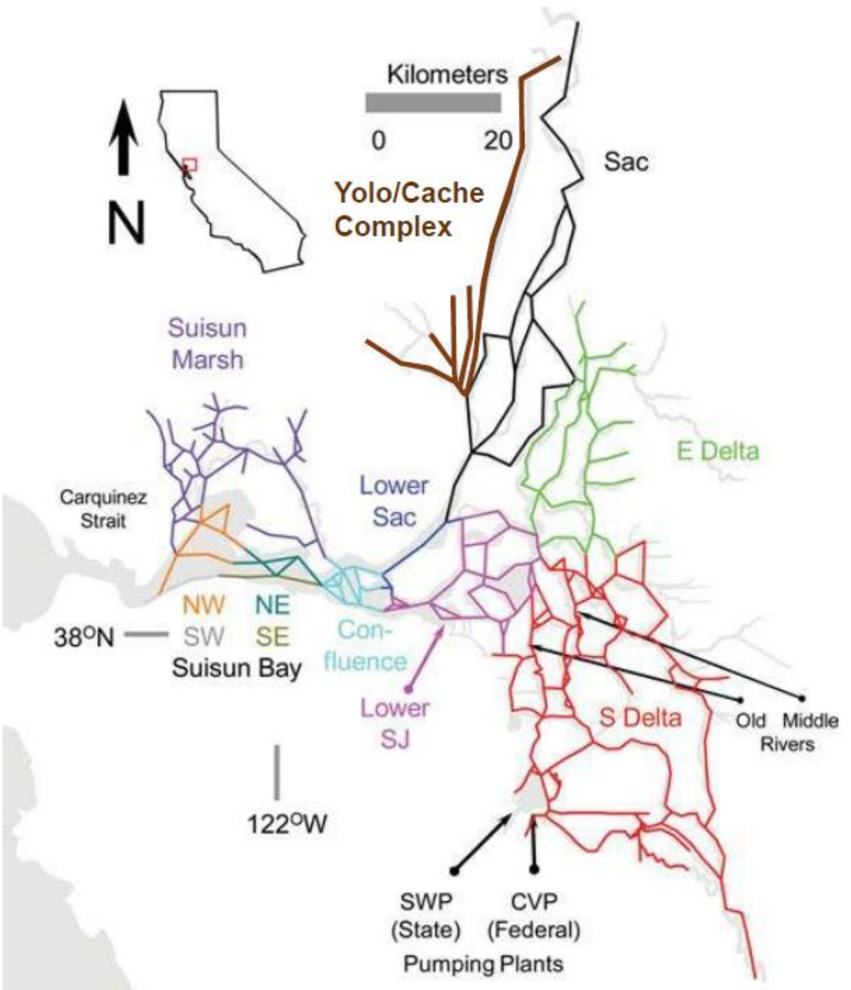


Figure B-7 Models of maximum consumption ($C_{\max}$) and respiration assumed by Rose et al. (2013a) (top row). In the bottom row are shown the model of temperature effects on $C_{\max}$ used in this application (the Rose et al. 2013a model) versus an alternate model based on sparse empirical data, and the model of the effect of turbidity on $C_{\max}$, suggested by data published by Hasenbein et al (2016).

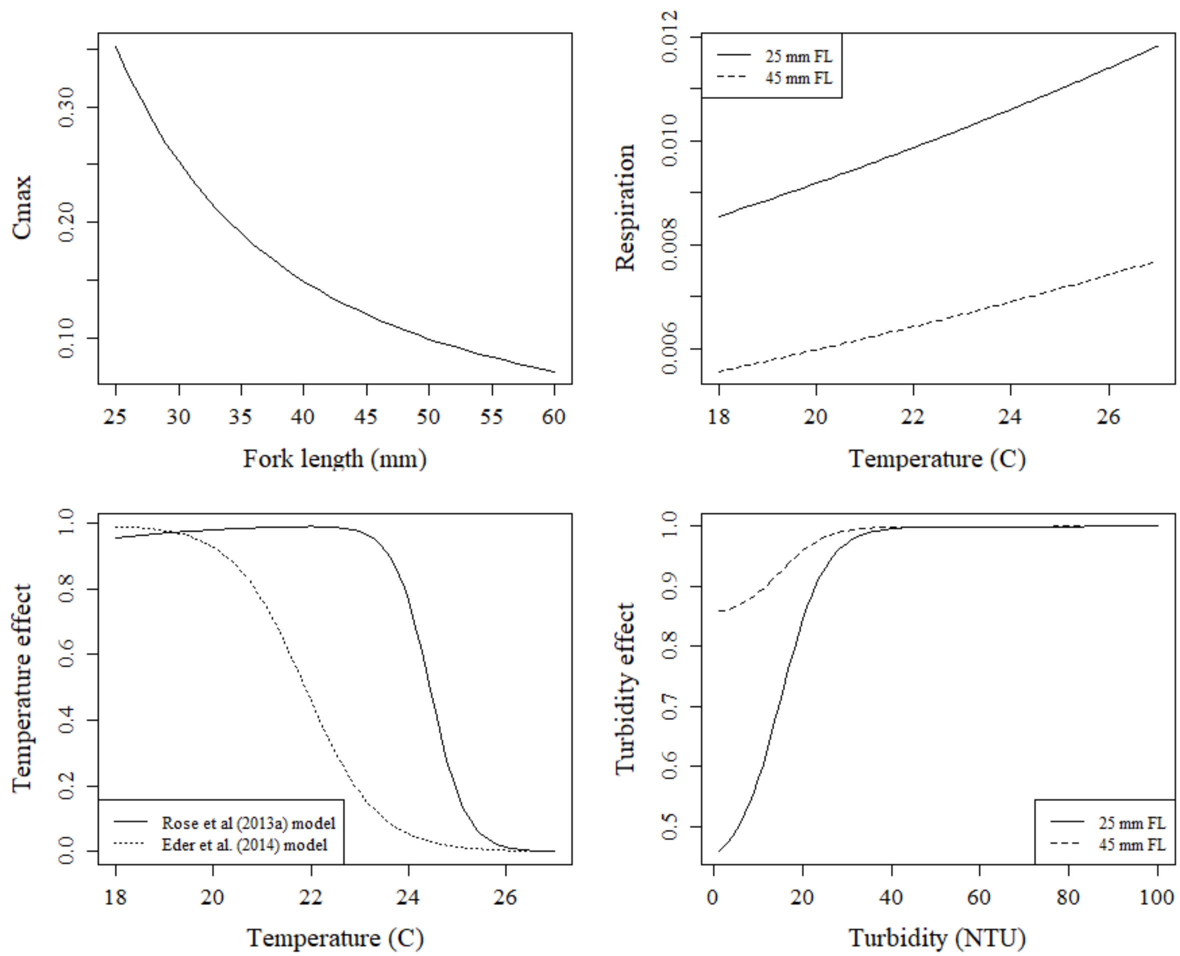
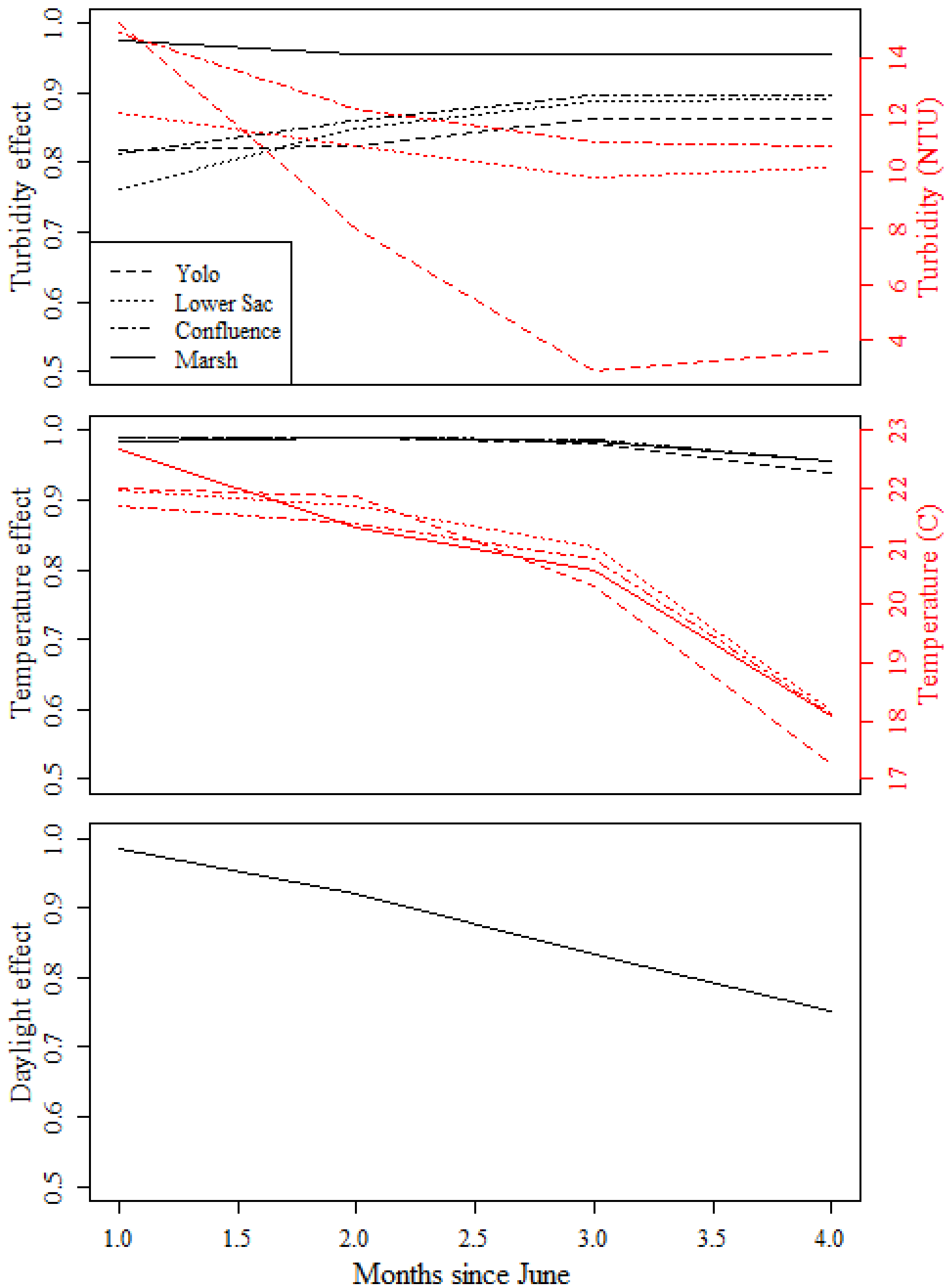


Figure B-8 Original image of a table from Rose et al. (2013a) showing fixed parameter values used to simulate Delta Smelt feeding and growth. For this application, fish were assumed to be of the juvenile (>25 mm FL) life stage.

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

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

Figure B-9 Time series of temperature and turbidity used to predict delta smelt foraging limitations (red lines) and time series of predicted effects of each physical limitation on delta smelt foraging (black lines).



Delta Smelt Growth Appendix - Von Bertalanffy growth model fit to wild delta smelt length at age

Methods

Data

Delta smelt were collected from the San Francisco Estuary during June through September of 1999–2005 in the 20mm, Summer Townet, and Fall Midwater Trawl Surveys (ftp://ftp.dfg.ca.gov). Sagittal otoliths were sectioned, polished, and analyzed by the James Hobbs Lab (UC Davis). Daily rings from the otolith core to the edge were enumerated by two independent readers, and a dataset consisting of daily ages and associated fork lengths was provided to the US Fish and Wildlife Service, Bay-Delta Office on June 15, 2016.

Model

A von Bertalanffy growth model was fit to delta smelt length-at-age data. The growth model was defined as

(A1) $FL_a = FL_\infty * \left(1 - e^{-k*(a-t_0)}\right)$,

where fork length *FL* at age *a* were predicted from asymptotic length FL_∞, growth coefficient *k*, and age at *FL* = 0 t_0. *a* were represented as fractional years (*a* = daily age/365). By rearranging Equation 1 and substituting for FL_a a parameter for length at hatch (*a* = 0) FL_0, t_0 in Equation 1 can be calculated directly

(A2) $t_0 = \frac{1}{k} * \ln\left((FL_\infty - FL_0)/FL_\infty\right)$.

While FL_0 is not known for delta smelt, it can reasonably be assumed to be between 3 and 10 mm FL (Bennett 2005), so an informative uniform prior FL_0 was developed using bounds of 3 and 10 mm FL. Equations 1 and 2 were used to predict *FL* for each individual, assuming that observed lengths were normally distributed. Parameters FL_{∞}, k, FL_0, and error σ were estimated.

Model fitting

The model was fit using R package R2jags (R 2015) and Bayesian statistical software JAGS (Plummer 2003). A burn-in period of 25,000 was followed by 50,000 samples of posterior distributions. As preliminary analysis suggested high autocorrelation within posterior chains, posterior samples were thinned by 50. Model convergence was assessed by comparing the trace plots of six chains of each model parameter and using Gelman and Rubin's diagnostic (Gelman and Rubin 1992). Model convergence was reached if trace plots showed that both chains were sampling stationary parameter distributions that did not shift with additional samples and if Gelman and Rubin's statistic was less than 1.05 for all parameters.

Results and Discussion

A total of 823 delta smelt otoliths were examined and aged. Fitted von Bertalanaffy growth model parameters (Table B-3) indicated a mean asymptotic length of 76.1 mm FL and extremely rapid growth (k = 2.98). Diagnostics indicated adequate model fit; residuals appeared to be normally distributed around 0 at all but the youngest ages (Fig. B-10). The model appeared to overpredict lengths at ages below 0.1 years (less than 40 days), and most ages less than 40 days were observed in a single survey, the 20mm Survey, during a single year, 2000. It is possible that fish were larger at age during later spring of 2000 or that growth patterns changed subsequent to 0.1 years of age. Von Bertalanffy growth models may not be capable of consistently describing growth across early to late life stages; nevertheless, the fitted delta smelt model appeared to adequately describe growth after 0.1 years.

One major limitation of the data was the absence of larger fish sampled between January and May. This resulted from an inability to enumerate daily ages during the seasonal slow growth period, when otolith rings are closely spaced and difficult to distinguish. Presumably, the absence of these larger length samples limited the model's capability to estimate FL_{∞}, and inclusion of samples from older fish would improve estimation of this parameter.

References

Bennett, W. A. 2005. Critical assessment of the delta smelt population in the San Francisco Estuary, California. San Francisco Estuary and Watershed Science 3(2).

Gelman, A., and D. B. Rubin. 1992. Inference from iterative simulation using multiple sequences. Statistical Science 7: 457–511.

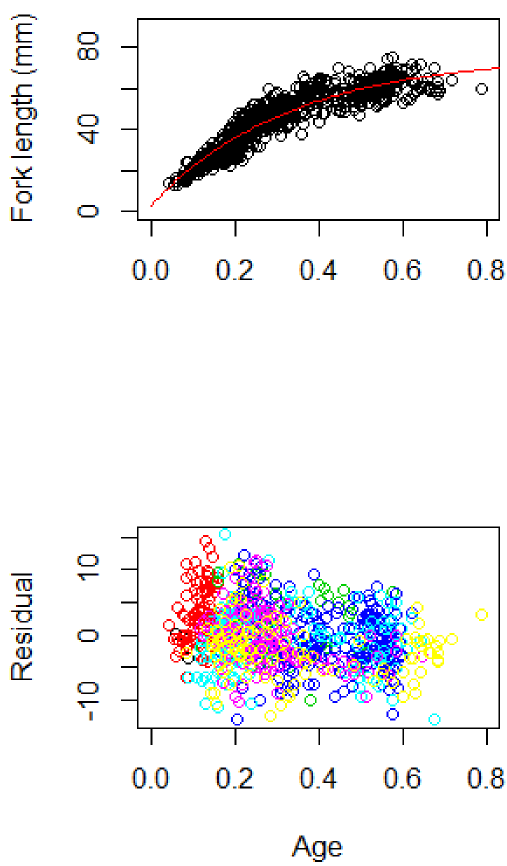
Plummer, M. 2003. JAGS: a program for analysis of Bayesian graphical models using Gibbs sampling. Proceedings of the 3rd International Workshop on Distributed Statistical Computing, Vienna, Austria.

R Development Core Team. 2015. R: A Language and Environment for Statistical Computing. version 3.2.2. Vienna: R Foundation for Statistical Computing. Available at: http://www.R-project.org.

Table B-3 Parameter estimates at 95% credible intervals.

Parameter	Posterior mean	95% credible interval
k	2.98	2.83 – 3.14
FL_∞	76.1	74.2 – 78.1
t_0	-0.014	-0.017 – 0.013
FL_0	3.18	3.05 – 3.67

Figure B-10 The top panel shows observed delta smelt length at age (black circles) and the predictions of the fitted von Bertalanffy growth model (red line). The bottom panel shows model residuals versus age, and residuals corresponding to each year of data are colored differently. Ages are represented in units of fractional years.



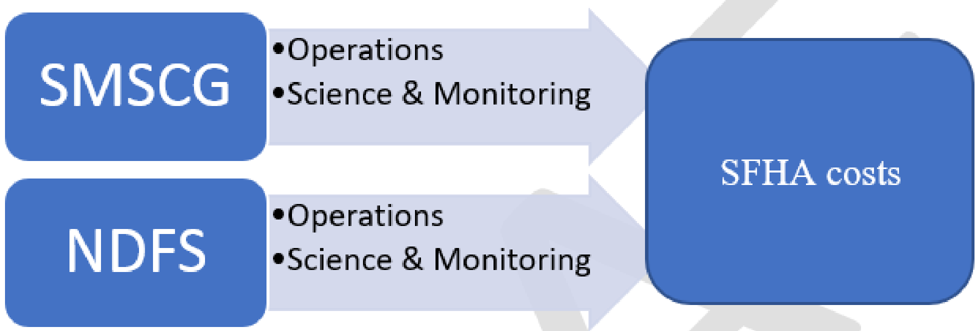
PM Infosheet –Resource Costs

1. PM Summary

Resource Costs were identified as a decision objective for the 2022 SFHA SDM. Costs include direct management costs for staff, operations used to implement actions, and science and monitoring including field and lab work, contracting costs, analysis, and reporting. The performance metric used for evaluating costs is USD/year.

2. Influence diagram

Figure B-11 Influence diagram for Resource Costs PM



3. Calculations and/or scoring

   A. Operations and science and monitoring costs were derived from DWR's PPM/RM platform for SMSCG and NDFS for 2022-2024 planning. Action planning, implementation, and reporting cross CY and FYs, therefore, estimated values were calculated using the average of Jul-Dec 22 + Jan-Jun 23 budgets (labor and OEE) and Jul-Dec 23 and Jan-Jun 24.

   B. Further discussion of costs across various scenarios occurred with project leads.

   C. Additional costs for scenarios not implemented previously were estimated (e.g. NDFS Sac+Ag action).

4. Key assumptions and uncertainties

   A. Assumptions

        i. Monitoring costs similar across water year types and no action (baseline monitoring)
        ii. PPM/RM budgets plan for maximum costs
    B. Uncertainties
        i. Resources available annually
            1. IEP long-term surveys
            2. Continued contract support
        ii. Monitoring improvement costs (e.g., AD MGT recommendations, directed studies, effects to other species monitoring)
        iii. NDFS operation costs similar for short or long duration
        iv. SMSCG boat lock operator staffing through summer or not
        v. Interagency costs for planning and coordination
5. Round 1 results

Action	**Difference from No-Action**	**Comments/rationale**
1. Dry Year. NDFA – Ag Flow - high magnitude, short duration	$100k	2022 (814k) 2023 (788k) Ave 801 for Science & Monitoring Difference from no-action includes increased coordination and planning - Uncertain KLOG, Wallace, FTC external costs?
2. Dry Year. NDFA – Ag Flow - low magnitude, long duration	$100k	assumes operation costs at KLOG are the same for long duration. 100k increase for coordination and planning of action
3. Below Normal Year. NDFA – Ag Flow - high magnitude, short duration	$100k	100k increase for coordination and planning of action
4. Below Normal Year. NDFA – Ag Flow- low magnitude, long duration	$100k	100k increase for coordination and planning of action

Action	Difference from No-Action	Comments/rationale
5. Below Normal Year. NDFA – Sac Flow- low magnitude, long duration	$250k	Ave. Ag costs + Sac operations (GCID/RD108 pumping) which can be ~150-200k +increased planning and coordination staff costs (~100k).
6. Below Normal Year. NDFA – Sac Flow - high magnitude, short duration	$250k	Uncertain duration costs - if GCID and RD108 pumping at lower rates for longer duration in #5, or stable pumping and Wallace/KLOG ops to increase pulse duration
7. Below Normal Year. NDFA – Sac summer action + Fall ag action. Low magnitude, high duration	$500k	Ave. Ag costs + Sac operations (GCID/RD108 pumping costs. $250k) + additional 2 months monitoring and science (labor & OEE, $250k)
8. Below Normal Year. SMSCG – Nonconsecutive. Start when Beldon's >4ppt	$250k	2022 (379k) 2023 (441k) Normal ops ($88.6k): flashboards taken out for boat passage. Removing flashboards cost 37k + 45k to put back in (covered w/ normal ops). Gates in summer (boards taken out in May), but if taken out in June not cost efficient so need a boat lock operator staff during all summer (~$104k). Currently Delta Field Division pays boat op staff through IEP FC not AM FC. Add potentially Smelt budget if cages deployed ($150-200k). Ave. Sci & Monit (410k baseline) +ops ($104k) + cages (150k)
9. Below Normal Year. SMSCG – Nonconsecutive. Start when Beldon's >6ppt	$250k	Same at 4ppt Ave. Sci & Monit (410k baseline) +ops ($104k) + cages ($150k)

Action	Difference from No-Action	Comments/rationale
11. No action	0	Total cost includes SMSCG and NDFS baseline monitoring costs. ~$1.2 mil planned in DWR PPM budgets. No-action may result in reduced planning and coordination costs. 2021 no action year spent ~1 mil (~200k less than planned).

6. Additional information and context for interpreting results
    A. No SFHA = $1 mil (baseline monitoring costs), set to 0 at the alternative scoring.
    B. SFHA (NDFS Ag + SMSCG) = ~$1.35 mil (same as no Action + special study and increased coordination (e.g. smelt cages))
    C. SFHA (NDFS Sac + SMSCG) = ~$1.5 mil
    D. SFHA (NDFS Sac/Ag + SMSCG) = ~$1.75 mil

7. References

PM Infosheet – Zooplankton availability

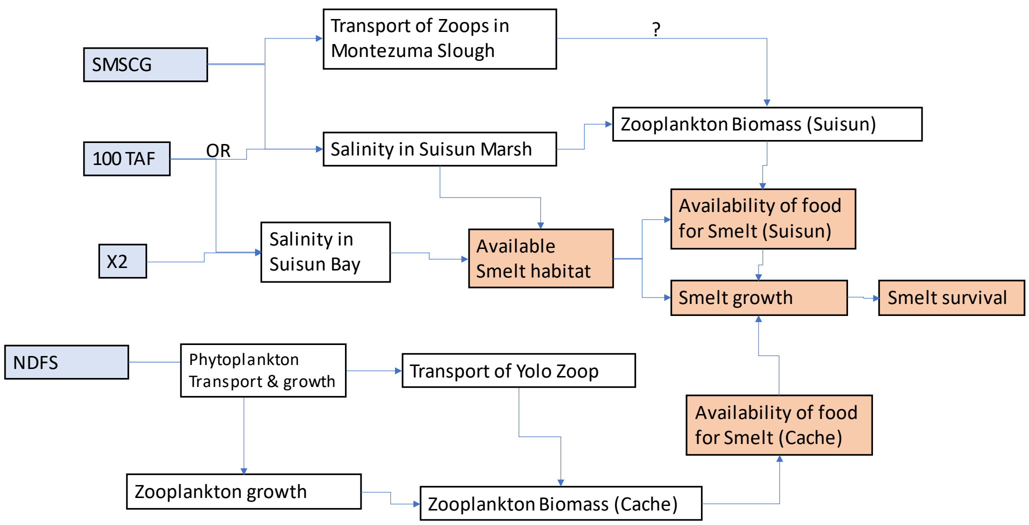
1. PM Summary

We broke this performance measure up into two parts, one for zooplankton in the Suisun area and one for zooplankton in the Cache Slough area. In Suisun, the SMSCG action will alter transport/residence time of zooplankton in Montezuma Slough, but we do not have enough baseline data to predict the impact on smelt food. However, the altered salinity in Suisun will definitely have impacts on biomass community composition in predictable ways (increased biomass of freshwater critters, decreased biomass of marine critters) (Kimmerer and Kayfetz 2017; Kimmerer et al. 2018; Barros et al. 2021). The most important food-related impacts of both a Gates action and an X2/outflow action will be increasing smelt occupancy in these areas (Sommer et al. 2020). Therefore, while zooplankton biomass may or may not change, availability of zooplankton in Suisun to smelt will change with the increase habitat suitability.

For the NDFS, the action is expected to transport phytoplankton from Yolo to zooplankton in Cache Slough and transport zooplankton from Yolo to Cache. Longer pulses with lower magnitude are expected to have the largest increase in zooplankton biomass due to increased residence time and longer periods of positive net flow. Sacramento river water is expected to have more positive impact on zooplankton than agricultural water because of lower contaminants, lower salinity, and higher dissolved oxygen. Previous flow actions have shown mixed results (Davis et al. 2022), however the highest response in downstream phytoplankton occurred during a Sacramento River action (Frantzich et al 2021), so this hypothesis is supported by some data.

2. Influence diagram

Figure B-12 Influence diagram for zooplankton availability PM



3. Calculations and/or scoring

A. The scoring was done in X steps:

B. 1. We used data from June-October of 2000-2020, that includes data collected by FMWT, and EMP, synthesized by the zooper package (Bashevkin et al. 2022). This incorporates data from the most recent ecological regime (post-POD). Data were summarized by region, month, water year type, and species, to develop a "baseline" for expected zooplankton biomass in each water year type. "Species" were the groups used by the IBMR (Smith et al. 2021), with the addition of mysids, due to their importance in smelt diets (Slater and Baxter 2014).

C. 2. We then used generalized additive models on historic data to model change in zooplankton biomass in Suisun (by taxonomic group) versus salinity. (description of models and code available here: https://sbashevkin.github.io/FLOATDrought/Zooplankton-salinity-relationships-in-Suisun.html) These models were then used to predict the change in zooplankton biomass expected in Suisun between the no-action and action scenarios. Individual models were run for each zooplankton taxa to account for differing responses to change in salinity.

D. To predict the change in zooplankton biomass cause by the NDFS, we used conceptual models of relative impact of different flow action types with the RMA copepod model to provide a 'best case scenario" estimate of change in biomass. These conceptual models provided a single value for "percent change" that was applied to the entire zooplankton community. Consultation with subject matter experts (the FLOAT Zooplankton team) resulted in the original values being reduced by ½, since use of the RMA model resulted in values of over 400% increase, which have never been seen during actual flow pulses.

E. Zooplankton IBMR input arrays were averaged by water year type (Dry – 2001, 2002, 2007, 2009, 2013, and Below Normal – 2004, 2010 2012). These values were then adjusted for each scenario using the models derived from steps 2 and step 3 (excluding mysids, which are not used in the IBMR).

F. To calculate a zooplankton performance metric, average zooplankton biomass in each region and month were multiplied by the habitat suitability index (including water velocity, temperature, turbidity, and salinity as developed by the outputs of the SCHSIM 3-D model run by E. Ateljavich) for each region and month to create a "weighted food availability score". This score was totaled across regions to develop a single metric for each scenario (Table B-5, Figure B-13). We then calculated the difference between the weighted score for each scenario and the 'no action' scenario for each water year type to develop the final score (Figure B-14). We also included the unweighted zooplankton biomass totals for comparison (Table B-5, Figure B-15)

4. Key assumptions and uncertainties

   A. Sources, types, magnitude of uncertainty

      i. The estimates of change in zooplankton biomass expected with the various NDFS scenarios are roughly based on expected change in chlorophyll seen in monitoring data collected during the actions, however the zooplankton biomass per change in chlorophyll biomass were based entirely on the RMA copepod model. Data collected during previous flow actions never showed changes as large as those expected in these models (Davis et al. 2022). Furthermore, change in biomass is likely to be different for different taxa, whereas a single value was used for all taxa in our model.

ii. The estimates of change in biomass with change in salinity used for the SMSCG action were based on a more comprehensive dataset than used for the IBMR. The IBMR input tables were developed by Wim Kimmerer several years ago (Rose et al. 2013; Smith 2021), and additional years of data are now available. We used the observed relationships between salinity and biomass in the more recent data and applied those relationships to data from previous years, since it would allow for greater continuity in running the IBMR. However, this could also have introduced error.

iii. Operation of the SMSCG may change zooplankton biomass in the Marsh by transporting them physically from the river into the Marsh, and may change the residence time and therefore growth potential of zooplankton once in the Marsh. We did not have mechanistic model for what the results of this would do to biomass, so did not include this effect in the model. Future iterations may want to include it.

B. Reducibility

i. The zooplankton biomass calculations, the habitat suitability index weighting, and the salinity/biomass relationships are all documented and reproducible. The effect of the different NDFS action types was based partially on expert judgement, and partially on a mechanistic model, so is less reproducible. Different experts may have arrived at different conclusions.

5. Round 1 results

Table B-4 Score for smelt food availability with each action.

Action	Newscore	Comments/rationale
1. Dry Year. NDFA – Ag Flow - high magnitude, low duration [AgShortHigh]	3	Agricultural water has poor water quality and higher contaminants, so not as much zoop growth. Higher magnitude flushes things down the system too quickly.
2. Dry Year. NDFA – Ag Flow -low magnitude, high duration [AgLongLow]	6	Agricultural water has poor water quality and higher contaminants, so not as much zoop growth. Lower magnitude allows longer residence time for growth.

Action	Newscore	Comments/rationale
3. Below Normal Year. NDFA – Ag Flow - high magnitude, low duration [AgShortHigh]	3	Agricultural water has poor water quality and higher contaminants, so not as much zoop growth. Higher magnitude flushes things down the system too quickly.
4. Below Normal Year. NDFA – Ag Flow- low magnitude, high duration [AgLongLow]	6	Agricultural water has poor water quality and higher contaminants, so not as much zoop growth. Lower magnitude allows longer residence time for growth.
5. Below Normal Year. NDFA – Sac Flow- low magnitude, high duration [SacLongLow]	13	Sac water has better water quality and lower contaminants, so more zoop growth. Lower magnitude allows longer residence time for growth.
6. Below Normal Year. NDFA – Sac Flow - high magnitude, low duration [SacShortHigh]	7	Sac water has better water quality and lower contaminants, so more zoop growth. Higher magnitude flushes things down the system too quickly.
7. Below Normal Year. NDFA – Sac summer action + Fall ag action. Low magnitude, high duration [SacAg]	22	A longer, low magnitude flow pulse allows higher residence time for growth but also more time to transport food into Cache Slough and downstream.
8. Below Normal Year. SMSCG – Nonconsecutive. Start when Beldon's >4ppt [SMSCG4ppt]	66	Food in the marsh (which is pretty high) overlaps with good habitat for longer. Lower salinity means more Pseudodiaptomus and mysids.
9. Below Normal Year. SMSCG – Nonconsecutive. Start when Beldon's >6ppt [SMSCG6ppt]	33	Food in the marsh (which is pretty high) overlaps with good habitat. Lower salinity means more Pseudodiaptomus and mysids, though not as much as the 4ppt scenario.
10.		
11. No action [NoAct]		

6. Additional information and context for interpreting results

Table B-5 Results of zooplankton modeling. Unweighted biomass is the average total zooplankton biomass across the Delta based on historical data in ug/L. Weighted biomass is the unweighted biomass multiplied by the habitat suitability index for each region and then added across months and regions. Scenario abbreviations are listed in Table B-4.

Scenario	Yr_type	Weighted BPUE	Unweighted BPUT	Difference in Weighted BPUE	Difference in unweighted BPUT
AgLongLow	Below Normal	251.39	692.82	5.52	13.25
AgShortHigh	Below Normal	249.31	687.77	3.43	8.19
NoAct	Below Normal	245.88	679.58	0.00	0.00
SacAg	Below Normal	267.36	733.28	21.49	53.70
SacLongLow	Below Normal	258.82	711.90	12.95	32.32
SacShortHigh	Below Normal	252.37	695.58	6.50	16.00
SMSCG4ppt	Below Normal	311.61	783.53	65.73	103.95
SMSCG6ppt	Below Normal	279.19	737.99	33.32	58.41
AgLongLow	Dry	181.84	626.28	6.06	15.12
AgShortHigh	Dry	179.23	619.70	3.45	8.54
NoAct	Dry	175.77	611.16	0.00	0.00

Figure B-13 Predicted biomass of each zooplankton taxa by month in Suisun Marsh for each action.

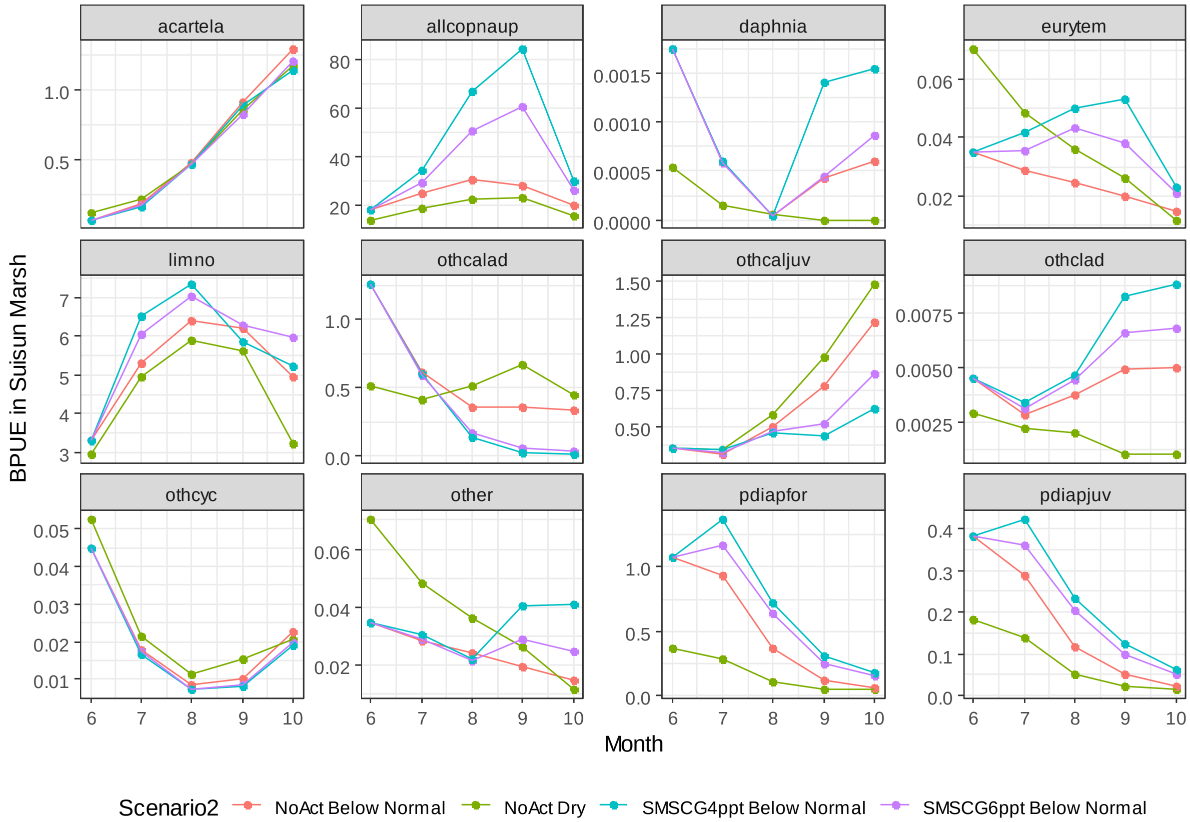


Figure B-14 Change in zooplankton biomass with different scenarios in the Yolo region.

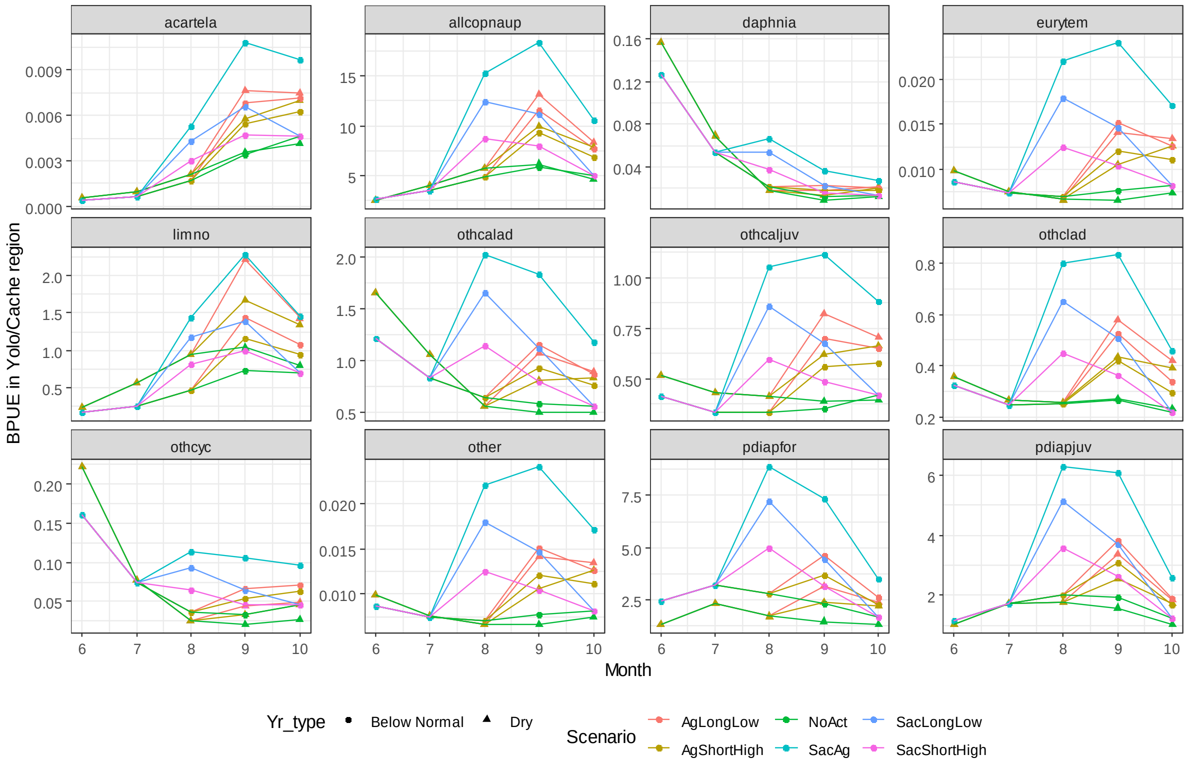


Figure B-15 Total weighted zooplankton biomass for each scenario. Zooplankton biomass was weighted by multiplying by the Habitat Suitability Index (including velocity, temperature, turbidity, and salinity). HSI was higher in Suisun Marsh than other regions, so food is more available to fish with the Gate actions.

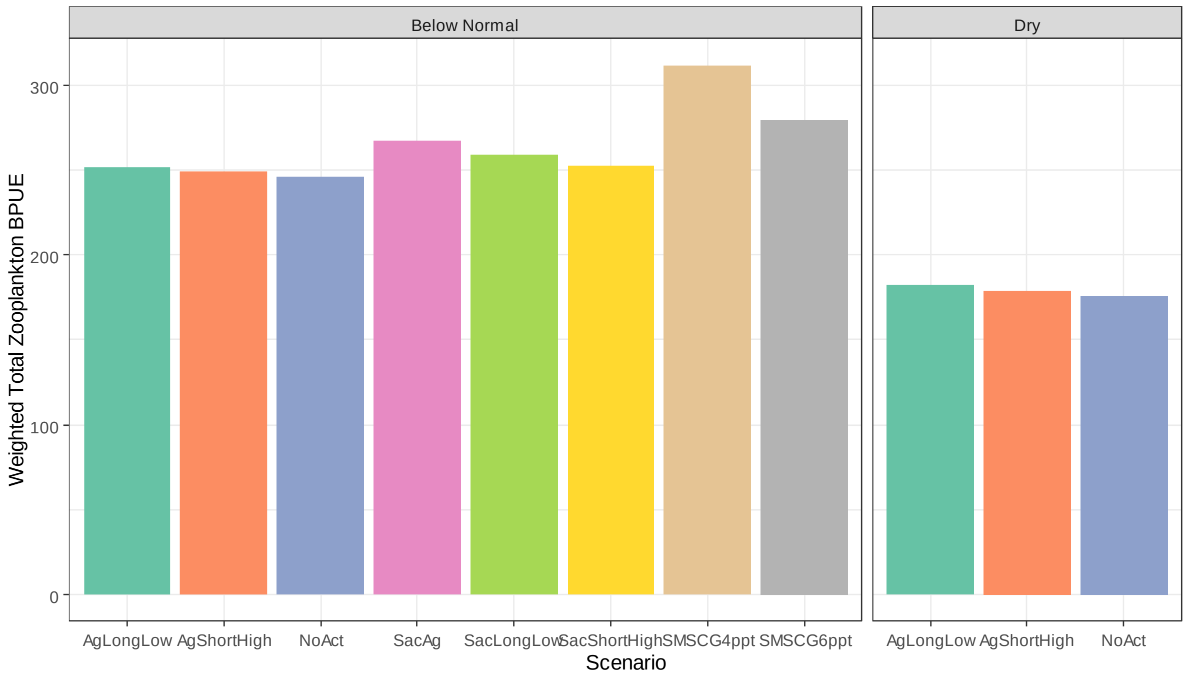


Figure B-16 Difference in weighted zooplankton BPUE between a no-action scenario and scenarios with each action. Zooplankton biomass was weighted by multiplying by the Habitat Suitability Index (including velocity, temperature, turbidity and salinity). HSI was higher in Suisun Marsh than other regions, so food is more available to fish with the Gate actions. Notice that while zooplankton biomass as a whole is higher during Below Normal years than Dry years (Fig B-13), there is a greater improvement in zooplankton biomass with NDFS actions in Dry years.

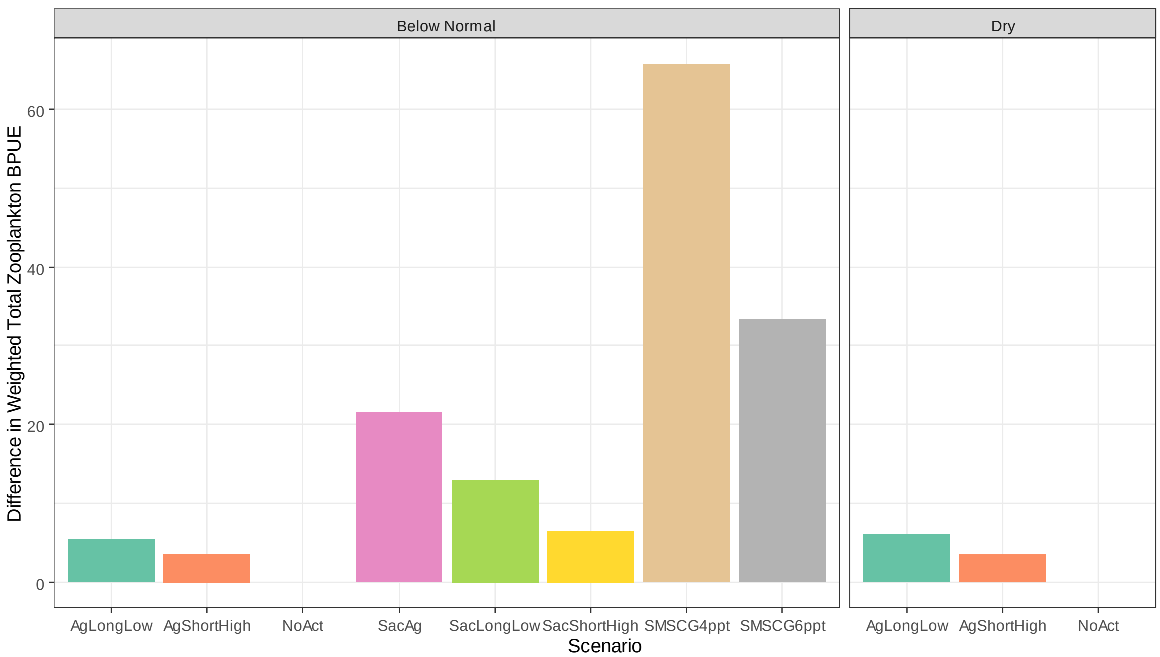
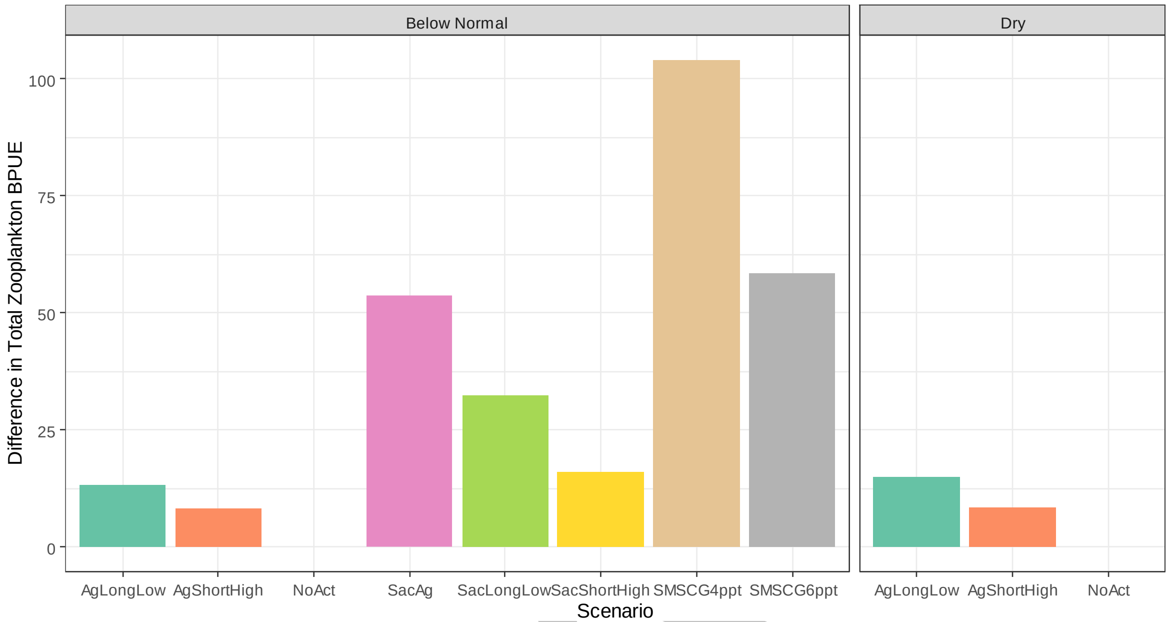


Figure B-17 Difference in unweighted zooplankton BPUE between a no-action scenario and scenarios with each action. Without weighting zooplankton biomass by HSI, the SMSCG actions are lower in comparison to the NDFS actions versus the weighted metric.



7. References

Barros, A. 2021. Zooplankton Trends in the Upper SFE, 1974-2018. IEP Newsletter 40(1):5-14.

Bashevkin, S.M., R. Hartman, M. Thomas, A. Barros, C.E. Burdi, A. Hennessy, T. Tempel, and K. Kayfetz. 2022. Interagency Ecological Program: Zooplankton abundance in the Upper San Francisco Estuary from 1972-2020, an integration of 5 long-term monitoring programs ver 3. Environmental Data Initiative. https://doi.org/10.6073/pasta/89dbadd9d9dbdfc804b160c81633db0d

Davis et al. 2022. North Delta Food Subsidy Synthesis: Evaluating Flow Pulses from 2011-2019. Department of Water Resources, Division of Integrated Science and Engineering. Draft.

Frantzich, J., B. E. Davis, M. MacWilliams, A. Bever, and T. Sommer. 2021. Use of a Managed Flow Pulse as Food Web Support for Estuarine

Habitat. San Francisco Estuary and Watershed Science 19(3):art3. doi:https://doi.org/10.15447/sfews.2021v19iss3art3

Kayfetz, K., and W. Kimmerer. 2017. Abiotic and biotic controls on the copepod *Pseudodiaptomus forbesi* in the upper San Francisco Estuary. Marine Ecology Progress Series 581:85-101. doi:https://doi.org/10.3354/meps12294

Kimmerer, W. J., T. R. Ignoffo, K. R. Kayfetz, and A. M. Slaughter. 2018. Effects of freshwater flow and phytoplankton biomass on growth, reproduction, and spatial subsidies of the estuarine copepod *Pseudodiaptomus forbesi*. Hydrobiologia 807(1):113-130. doi: https://doi.org/10.1007/s10750-017-3385-y

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

Slater, S. B., and R. D. Baxter. 2014. Diet, prey selection and body condition of age-0 Delta Smelt, *Hypomesus transpacificus*, in the upper San Francisco Estuary. San Francisco Estuary and Watershed Science 14(4). doi:http://dx.doi.org/10.15447/sfews.2014v12iss3art1

Smith, W. 2021. A Delta Smelt Individual-Based Life Cycle Model in the R Statistical Environment. V3. Software documentation.

Sommer, T., R. Hartman, M. Koller, M. Koohafkan, J. L. Conrad, M. MacWilliams, A. Bever, C. Burdi, and M. P. Beakes. 2020. Evaluation of a large-scale flow manipulation to the upper San Francisco Estuary: Response of habitat conditions for an endangered native fish. Plos ONE 15(10). doi:https://doi.org/10.1371/journal.pone.0234673

Twardochleb, L., A. Maguire, L. Dixit, M. Bedwell, J. Orlando, M. MacWilliams, A. Bever, and B. Davis. 2021. North Delta Food Subsidies Study: Monitoring Food Web Responses to the North Delta Flow Action, 2019 Report. Department of Water Resources, Division of Environmental Services, West Sacramento, CA.

PM Infosheet - Water Cost (TAF)

1. PM Summary

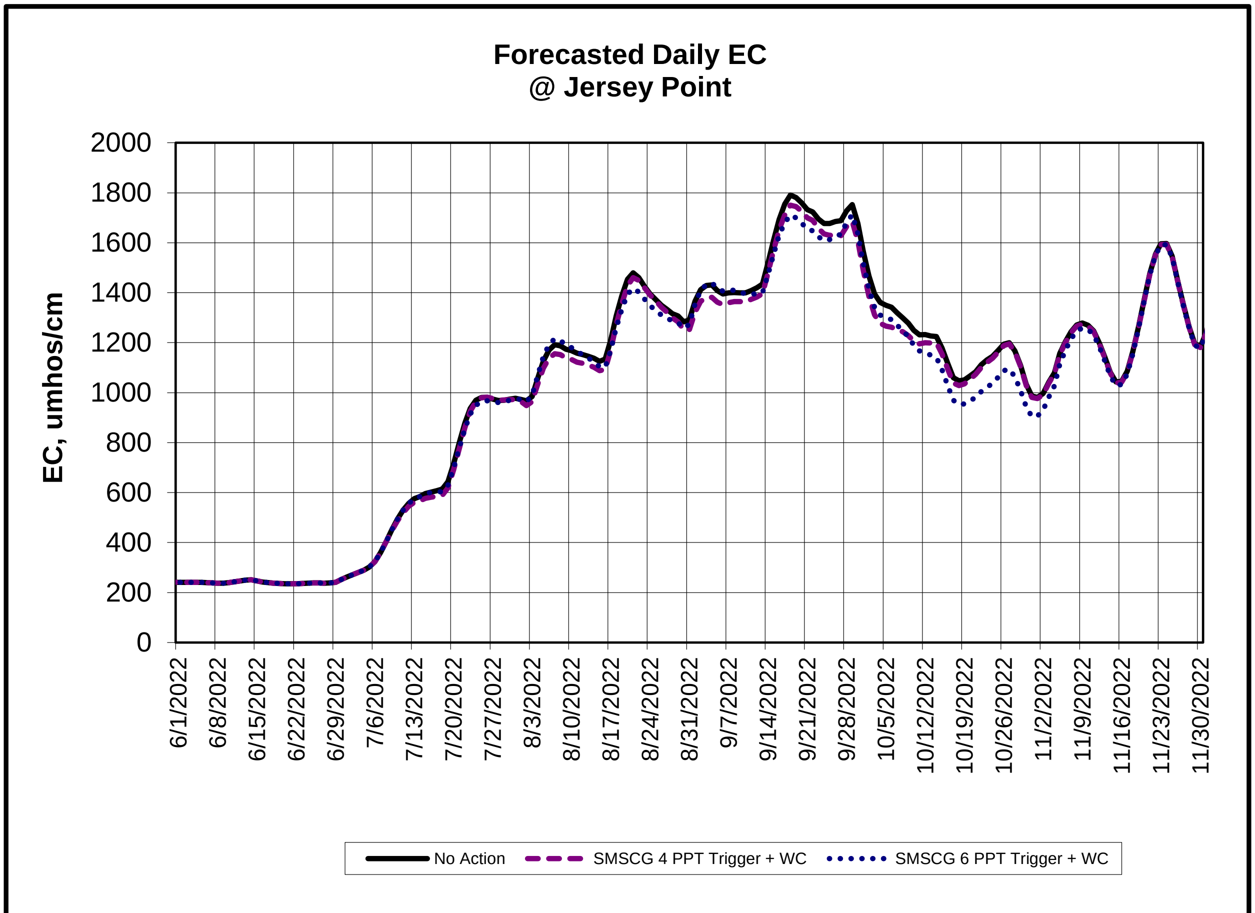
A volume of outflow needed to offset the degradation to a controlling location can be quantified. Units in TAF

2. Influence diagram
3. Calculations and/or scoring:

See Operational Impact of SMSCG_HOWG.pdf

DSM2 used to assess a case where no action is present and compared to a case where the SMSCG is operated, with additional outflow added to offset degradation from operating the gates to the control location. See graphs below of DSM2 Results:

Figure B-18 Forecasted daily electrical conductivity at the Jersey Point station, June – November 2022.



4. Key assumptions and uncertainties:

Jersey point used as a control location as that would be likely to control operations during this period.

5. Round 1 results

Action	Score	Comments/rationale
1. Dry Year. NDFA – Ag Flow - high magnitude, low duration	0 TAF	NDFA is a flow re-route, with minimal difference in losses between the paths, thus water cost is inconsequential
2. Dry Year. NDFA – Ag Flow -low magnitude, high duration	0 TAF	NDFA is a flow re-route, with minimal difference in losses between the paths, thus water cost is inconsequential

Action	Score	Comments/rationale
3. Below Normal Year. NDFA – Ag Flow - high magnitude, low duration	0 TAF	NDFA is a flow re-route, with minimal difference in losses between the paths, thus water cost is inconsequential
4. Below Normal Year. NDFA – Ag Flow- low magnitude, high duration	0 TAF	NDFA is a flow re-route, with minimal difference in losses between the paths, thus water cost is inconsequential
5. Below Normal Year. NDFA – Sac Flow- low magnitude, high duration	0 TAF	NDFA is a flow re-route, with minimal difference in losses between the paths, thus water cost is inconsequential
6. Below Normal Year. NDFA – Sac Flow - high magnitude, low duration	0 TAF	NDFA is a flow re-route, with minimal difference in losses between the paths, thus water cost is inconsequential
7. Below Normal Year. NDFA – Sac summer action + Fall ag action. Low magnitude, high duration	0 TAF	NDFA is a flow re-route, with minimal difference in losses between the paths, thus water cost is inconsequential
8. . Below Normal Year. SMSCG – Nonconsecutive. Start when Beldon's >4ppt	69 TAF	Operation of the gates corresponds with times of greatest exports, resulting in a higher water cost.
9. Below Normal Year. SMSCG – Nonconsecutive. Start when Beldon's >6ppt	63 TAF	Lower Exports in October made the operation more efficient as it operates the gates for some of the allotted 60 days during this period.
11. No action	0TAF	No action results in no water cost

6. Additional information and context for interpreting results

See Operational Impact of SMSCG_HOWG.pdf

7. References: See Operational Impact of SMSCG_HOWG.pdf

Appendix C

Summer Fall Habitat Action (SFHA) Expert Elicitations

Compiled for SFHA Structured Decision Making 2022

Contaminant Elicitation

Materials Shared

Background: The Summer Fall Habitat Action (SFHA) includes a suite of actions intended to improve habitat and food in the estuary, thereby improving Delta Smelt growth, survival, and recruitment. While the proposed Actions are aimed to benefit Delta Smelt, they may unintentionally result in negative effects such as increased or mobilized contaminants; however, these effects are largely uncertain.

Purpose: To elicit expert judgment on how the proposed Action Alternatives (described below) for the 2022 SFHA year will affect contaminant concentrations, including scores to feed into a consequences table, to provide the rationale behind those scores, and to describe sources, magnitude, and reducibility of uncertainty to inform both this year's decision and future research or elicitation processes.

Approach: Two groups will be formed to 1) formulate the questions and provide descriptions of the 2022 proposed Action and their potential effects on contaminant concentrations, and 2) review the actions and provide responses to what effect if any would occur on the Performance Metrics on Delta Smelt and Zooplankton.

Proposed Actions:

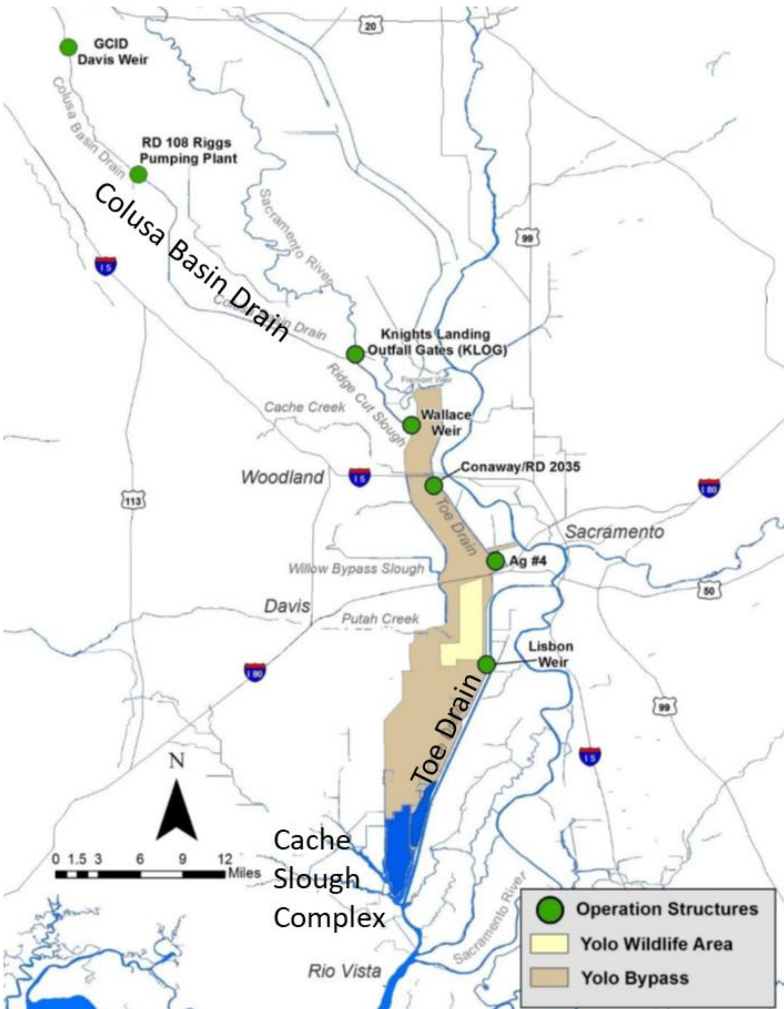
- North Delta Food Subsidy (NDFS) Action
  - The NDFS action uses existing infrastructure to redirect water (~20-25 TAF) down the Yolo Bypass in effort to restore net positive flow and improve plankton in downstream Delta Smelt habitat.
  - The NDFS action relies on the coordination of water operations upstream of the Delta either to implement a Sacramento River Action or Agricultural drainage Action.
    - The Sacramento Action: Redirects Sacramento River water during summer through Glenn-Colusa Irrigation District and the Reclamation District 108 to pass the water into the Yolo Bypass and downstream to Cache Slough Complex
    - The Agriculture Action: Redirects agricultural return water mostly from rice fields in the Colusa Basin Drain through

the Ridge Cut Slough and down the Yolo Bypass that would otherwise be drained into the mainstem Sacramento River.
    - Operationally, the Sacramento River and Agriculture actions can be implemented in a number of ways; either high intensity (800cfs) short duration (2 weeks) or low intensity (400 cfs) long duration (4 weeks) to provide positive tidally averaged flow from the Toe Drain.
    - A third type of action that has not yet been experimented but is operationally feasible is a summer Sacramento River action followed by a fall Agriculture action to generate a longer duration pulse (60 days) and time period with net positive flow.

- Suisun Marsh Salinity Control Gate (SMSCG) Action
  - Operating the SMSCGs allows fresh water from the Sacramento River to entire the Marsh on the ebb tide while preventing brackish water from Grizzly Bay from entering on the flood tide.
  - The Summer-fall SMSCG action includes operating the gates for 60 days between June 1 and October 31 in order to increase low salinity zone habitat in the Marsh for Delta smelt.
  - This will allow Delta Smelt to occupy the Marsh which is hypothesized to provide better habitat than the Sacramento River due to increased hydrodynamic complexity and higher turbidity.
  - The DCG is considering two scenarios for gate operations:
    - Begin operations after June 1st when Belden’s landing is >4 ppt. Operate for 60 days to maximize time that Belden’s is at or below 4ppt.
    - Begin operations after June 1st when Belden’s landing is >6 ppt. Operate for 60 days to maximize time that Belden’s is at or below 4ppt.

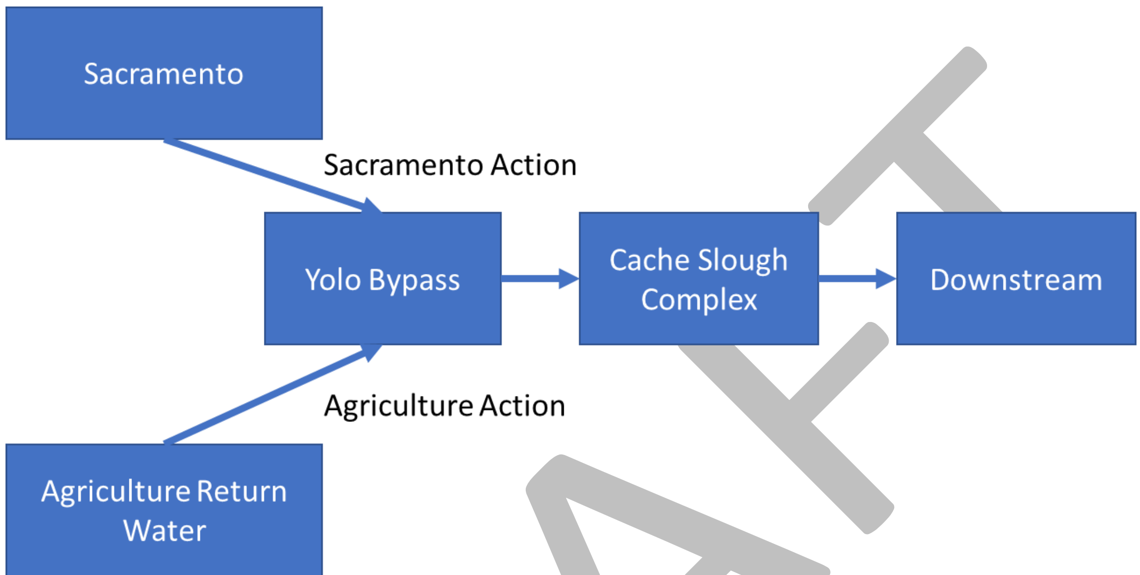
Proposed assumptions and effect of Actions on contaminants

Figure C-1 Map of the North Delta Foodweb Action area, including the Colusa Basin Drain, Yolo Bypass, Toe Drain and the into the Cache Slough Complex



NDFA Assumptions on Contaminants

Figure C-2 Box model for the North Delta Foodweb Action. Sacramento Action model begins with the water from the upper Sacramento to the Yolo Bypass to Cache Slough Complex and then Downstream. The Agriculture Action begins with the agricultural return water to the Yolo Bypass to Cache Slough Complex and then Downstream.



- Compared to No Action Alternative the contaminants in the Cache Slough Complex will change based on how much is entering the Cache Slough Complex and how much is exiting the Cache Slough Complex.
- The Contaminants entering from the Agriculture Action is of higher concentration and number than in the Cache Slough Complex
- The Contaminants entering from the Sacramento Action is of lower concentration and number than in Cache Slough Complex
- The High Intensity/ Low Duration action may mobilize contaminants compared to a Low Intensity/ Short Duration action.

SMSCG Assumptions on contaminants

- ○ There are more contaminants in Suisun Bay and the Confluence than Suisun Marsh

Performance Metrics

- All performance metrics will be contrasted with a No Action Alternative. The Respondent will provide their opinion on whether there is a significant change due to the action in comparison to the No Action Alternative.
- Delta smelt metrics for **Survival** and **Growth** should reflect only the **direct acute term effects** of contaminants on Delta smelt.
- Delta smelt **Recruitment** should reflect only the **direct long-term effects** on DS Recruitment from sublethal effects from contaminants.
- Zooplankton **Abundance** should reflect only the **direct acute effects** of contaminants on survival.
- Zooplankton **Quality** should reflect only the **direct acute effects** on the composition of zooplankton that would lead to a change in availability of preferred prey for Delta smelt.

Questions based on the action in Summer/Fall of 2022 either as a Below Normal Year or Dry Year.

- What will be the change in performance metric (Delta smelt growth, survival, and recruitment and Zooplankton survival and quality) in the Cache Slough Complex in response to:
    1. NDFS with Agriculture Action in August/September with high intensity, short duration?
    2. NDFS with Agriculture Action in August/September with low intensity, long duration?
    3. NDFS with Sacramento Action in August with high intensity, short duration?
    4. NDFS with Sacramento Action in August with low intensity, long duration?
    5. NDFS with sequential implementation of the Sacramento Action in August and Ag Action in August/September with low intensity, long duration?

- What will be the change in Performance Metrics (Delta smelt growth, survival, and recruitment and Zooplankton survival and quality) in the Suisun Marsh in response to:
    1. Suisun Marsh Salinity Control Gate action after June 1st at >4 ppt at Belden's Landing?
    2. Suisun Marsh Salinity Control Gate action after June 1st at >6 ppt at Belden's Landing?

Response

- Experts will be solicitated independently to respond to the above questions regarding the actions effect on Performance Metric relative to No Action
- The experts will respond to each question (using the provided tables) with a score from 1- to 1 with
    - -1 = significant reduction in performance metric relative to the No Action Alternative
    - 0 = insignificant effect on performance metric relative to the No Action Alternative
    - 1 = significant increase in performance metric relative to the No Action Alternative
- Experts will be asked to provide written response to provide clarification on why they scored the way they did and to provide what information would be needed if they did not provide a score.
- After the first round of scoring, anonymized results (scores and reasoning) will be shared with all Respondents, who will be given an opportunity to revise their scores or provide additional reasoning and sources.

Expert Responses and Mean Scores for SDM

Table C-1a Expert responses for contaminant effects on Delta Smelt recruitment.

Action Scenario	Expert 1	Expert 2	Expert 3	Expert 4	Expert 5	Mean	SD
NDFS with Ag- Action in Aug/Sep with high intensity, short duration	-1	-1	-1	0	0	-0.75	0.5
NDFS with Ag- Action in Aug/Sept with low intensity, long duration	-1	-1	1	0	0	-0.25	0.957
NDFS with Sac- Action in Aug with high intensity, short duration	0	0	-1	0	0	-0.25	0.5
NDFS with Sac- Action in Aug with low intensity, long duration	1	0	1	0	0	0.5	0.577
NDFA with sequential implementation of the Sac- Action in Aug and Ag- Action in Aug/Sep with low intensity, long duration	-1	0	1	0	0	0	0.816
SMSCG action after June 1st at >4 ppt at Belden's Landing	0	1	0	0	0	0.25	0.5
SMSCG action after June 1st at >6 ppt at Belden's Landing	0	1	1	0	0	0.5	0.577

Table C-1b Expert responses for contaminant effects on Delta Smelt survival

Action Scenario	Expert 1	Expert 2	Expert 3	Expert 4	Expert 5	Mean	SD
NDFS with Ag- Action in Aug/Sep with high intensity, short duration	-1	Can't answer	-1	0	0	-0.67	0.58
NDFS with Ag- Action in Aug/Sept with low intensity, long duration	-1	Can't answer	1	0	0	0.00	1.00
NDFS with Sac- Action in Aug with high intensity, short duration	0	Can't answer	-1	0	0	-0.33	0.58
NDFS with Sac- Action in Aug with low intensity, long duration	1	Can't answer	1	0	0	0.67	0.58
NDFA with sequential implementation of the Sac- Action in Aug and Ag- Action in Aug/Sep with low intensity, long duration	-1	Can't answer	1	0	0	0.00	1.00
SMSCG action after June 1st at >4 ppt at Belden's Landing	0	1	0	0	0	0.25	0.50
SMSCG action after June 1st at >6 ppt at Belden's Landing	0	1	1	0	0	0.50	0.58

Table C-1c Expert responses for contaminant effects on Delta Smelt growth

Action Scenario	Expert 1	Expert 2	Expert 3	Expert 4	Expert 5	Mean	SD
NDFS with Ag-Action in Aug/Sep with high intensity, short duration	-1	-1	-1	-1	0	-1	0
NDFS with Ag-Action in Aug/Sept with low intensity, long duration	-1	-1	1	0	0	-0.25	0.957
NDFS with Sac-Action in Aug with high intensity, short duration	0	0	-1	-1	0	-0.5	0.577
NDFS with Sac-Action in Aug with low intensity, long duration	1	0	1	0	0	0.5	0.577
NDFA with sequential implementation of the Sac- Action in Aug and Ag- Action in Aug/Sep with low intensity, long duration	-1	0	1	0	0	0	0.816
Suisun Marsh Salinity Control Gate action after June 1st at >4 ppt at Belden's Landing	0	1	0	-1	1	0	0.816
Suisun Marsh Salinity Control Gate action after June 1st at >6 ppt at Belden's Landing	0	1	1	-1	1	0.25	0.957

Table C-1d Expert responses for contaminant effects on zooplankton survival

Action Scenario	Expert 1	Expert 2	Expert 3	Expert 4	Expert 5	Mean	SD
NDFS with Ag-Action in Aug/Sep with high intensity, short duration	-1	-1	-1	-1	0	-1	0
NDFS with Ag-Action in Aug/Sept with low intensity, long duration	-1	-1	1	-1	0	-0.33	1.155
NDFS with Sac-Action in Aug with high intensity, short duration	-1	1	-1	-1	0	-0.5	1
NDFS with Sac-Action in Aug with low intensity, long duration	1	1	1	-1	0	0.5	1
NDFA with sequential implementation of the Sac- Action in Aug and Ag- Action in Aug/Sep with low intensity, long duration	-1	1	1	-1	0	0	1.16
Suisun Marsh Salinity Control Gate action after June 1st at >4 ppt at Belden's Landing	0	0	0	0	0	0	0
Suisun Marsh Salinity Control Gate action after June 1st at >6 ppt at Belden's Landing	0	0	1	0	0	0.25	0.5

Table C-1e Expert responses for contaminant effects on zooplankton quality

Action Scenario	Expert 1	Expert 2	Expert 3	Expert 4	Expert 5	Mean	SD
NDFS with Ag-Action in Aug/Sep with high intensity, short duration	-1	0	-1	-1	0	-0.75	0.5
NDFS with Ag-Action in Aug/Sept with low intensity, long duration	-1	0	1	-1	0	-0.25	0.96
NDFS with Sac-Action in Aug with high intensity, short duration	-1	0	-1	-1	0	-0.75	0.5
NDFS with Sac-Action in Aug with low intensity, long duration	1	0	1	-1	0	0.25	0.957
NDFA with sequential implementation of the Sac- Action in Aug and Ag- Action in Aug/Sep with low intensity, long duration	-1	0	1	-1	0	-0.25	0.957
Suisun Marsh Salinity Control Gate action after June 1st at >4 ppt at Belden's Landing	0	0	0	0	0	0	0
Suisun Marsh Salinity Control Gate action after June 1st at >6 ppt at Belden's Landing	0	0	1	0	0	0.25	0.5

Salmonids & Sturgeon Elicitation

Material Shared

Delta Coordination Group Expert Elicitation for Effects to other Native Species (Salmonids) Resulting from Implementation of SFHA for WY 2022

Thank you for volunteering to participate in WY 2022's Summer Fall Habitat Action expert elicitation. One of the DCG's decision objectives is to minimize effects of the Sumer Fall Habitat Action (SFHA) action on other native species, specifically spring run Chinook salmon, fall run Chinook salmon, winter run Chinook salmon, and steelhead. Because there are no existing models the DCG is comfortable using to predict the consequences of different alternatives for salmonids, we are taking an expert elicitation approach to predicting the performance of different alternatives. We have created two sets of alternatives: one for a dry water year type and one for a below normal water year type. However, current forecasts are trending towards a dry year, and it's likely no SFHA may be implemented in WY 2022 due to prevailing circumstances. However, the DCG still recognizes the importance of conducting the elicitation with the purpose of informing future actions and elicitations.

This elicitation has two purposes:

First, we are asking you to use your judgment to score each of a set of alternative relative to their effect on the salmonids of interest using the coarse scale we have developed.

Second, we are seeking input to improve this elicitation in future years. For example, are we asking about the most informative effects? We are likely to repeat such elicitations when different aspects of the SFHA are implemented for the first time, and thus the feedback received on this process will help to streamline future efforts.

The actions we are considering are:

1. North Delta Food Subsidies:

DWR proposes to implement actions to improve flow conditions in the North Delta in summer and fall, thereby facilitating downstream transport of phytoplankton and zooplankton. While the Cache Slough Complex and the lower Yolo Bypass are known to have relatively high levels of food resources, local water diversions create net negative flows during summer and fall that may inhibit downstream food transport. Enhancement of summer and fall flows through the Yolo bypass could improve the transport of food downstream.

DWR and partners would test two different ways to improve flow conditions in the North Delta. For the first approach, water would be provided by Sacramento River water districts, such as Reclamation District 108 and Glenn Colusa Irrigation District, during the summer. The water districts would use their facilities to move freshwater into Colusa Drain. By adjusting the operations of Knights Landing Outfall Gates and Wallace Weir, much of this water would be routed into the Yolo Bypass.

The second approach would use agricultural drain water in fall, when valley rice fields discharge irrigation water at the end of the growing season. Agricultural drain water would be routed into the Yolo Bypass via Knights Landing Ridge Cut.

DWR proposes flow pulses would include summer actions using fresh Sacramento River water and fall actions using agricultural drain water from Colusa Drain. Initial results suggest that a target pulse of 27 TAF over a 4-week period would improve downstream transport of phytoplankton. This flow volume is not sufficient to inundate the floodplain in the Yolo Bypass, nor would it constitute a consumptive use of water because the water used for this action would be allowed to move through the North Delta and contribute to Delta outflow.

2. Operation of the Suisun Marsh Salinity Control Gates (June – October):

The Suisun Marsh Salinity Control Gates (SMSCG) are located on Montezuma Slough about 2 miles downstream from the confluence of the Sacramento and San Joaquin rivers, near Collinsville. The objective of Suisun Marsh Salinity Control Gate operation is to decrease the salinity of the water in Montezuma Slough. The gates control salinity by restricting the flow of higher salinity water from Grizzly Bay into Montezuma Slough during incoming tides and retaining lower salinity Sacramento River water from the previous ebb tide. Operation of the gates in this fashion lowers salinity in Suisun Marsh channels and results in a net movement of water from east to west through Suisun Marsh.

The SMSCG are historically operated during the salinity control season, which spans from October to May. Operational frequency is affected by salinity at Water Rights Decision-1641 (D-1641) compliance stations, hydrologic conditions, weather, Delta outflow, tide, fishery considerations, and other factors. The boat lock portion of the gate is now held partially open during SMSCG operation to allow an opportunity for continuous salmon passage.

The action would be conducted as directed based on the current water year's forecast. For 2022, the operation of the SMSCG would only occur if the water year would be determined as Below Normal by May. The use of the SMSCG within the Summer/Fall Habitat Action is through operation of the gates during the historical "operational off-season" (June – September). In Above Normal and Below Normal water years, ITP (2020) requires operation of the SMSCG for up to 60 days between June 1 to Oct. 31 to maximize the number of days that the three-day average salinity at Beldon's landing in Suisun Marsh is less than 4ppt.

It is expected that operation of these gates during dry summer months will Improve habitat suitability for Delta Smelt such that they will make more use of this area, where conditions tend to be more favorable during the driest part of the year. The SMSCG action will be similar to the initial pilot effort DWR completed in August 2018. The action included operation of the SMSCG for the entirety of August, during which an additional 28 thousand acre-feet of Delta outflow was provided to maximize the action's efficacy (GEI 2018). It is assumed that to achieve 60 days of SMSCG operation, that the water cost would be approximately double what was provided in 2018.

What is your conceptual model for how the actions would affect salmonids?

Think about the pathways through which you think the actions could affect salmonids. Review the attached conceptual model (Salmon EE Influence Diagram.ppt), which was developed by a small group of biologists to provide a starting point for this elicitation.

Does the conceptual model capture your understanding of pathways of action? Is there anything you would change? Any effect pathways that aren't captured?

Make note of any changes and provide any additional thoughts.

Now we are going to ask you about how each of the alternatives would affect the salmonids in question.

1. We are asking for you best judgment; we recognize that there are many unknowns.
2. We are asking you to think about the effects on two levels: the individual and the population.

Refer to the consequences table we have provided (Salmon Scoring Matrix.xlsx). You will see a row for each alternative action, a pair of columns for each salmonid of interest (one for individual-level assessment, one for population-level; these are the cells in which you will enter your scores), a column in which to document your rationale for each scoring, and a column in which to note resources on which you drew, if any.

First, think about the effects of the alternative at the level of individual salmonids, referring to the conceptual model as needed. If you wouldn't expect that salmonid to be exposed to the action, note with an "X". For the fish that may be exposed to the alternative, would you expect that:

Score	Description of Individual Effect Score
1	Overall, the action would benefit the salmonid in question.
0	Overall, the action would not affect the salmonid in question.
-1	Overall, the action would negatively affect the salmonid in question, with minor sublethal effects (occurring in up to 100% of exposed individuals) and/or low likelihood (occurring in <10% of exposed individuals) of serious sublethal or lethal effects.
-2	Overall, the action would negatively affect the salmonid in question, with intermediate likelihood (occurring in 10%-50% of exposed individuals) of serious sublethal or lethal effects.
-3	Overall, the action would negatively affect the salmonid in question, with high likelihood (occurring in >50% of exposed individuals) of serious sublethal or lethal effects.

Put the score in the appropriate box. Document your rationale, including assumptions you made, along with the key studies or data on which you drew, to the best that you can.

Second, think about the effects of the alternative at the level of salmonid populations, referring to your conclusion about effects at the individual level. For the purpose of this evaluation, consider the population to refer to the "annual cohort" (either of up-migrating BY 2022 adults or out-migrating juveniles from BY 2021 or earlier). For example, if you expect the action to affect all up-migrating winter-run Chinook salmon adults, that would be an effect to 100% of the "population", rather than to ~33% of the population (assuming a 3-year average age of return and thus that ~2/3 of the overall adult population is in the ocean). For the population of the salmonid in question, would you expect that:

Score	Description of Population Effect Score
1	Overall, the action would benefit the salmonid in question.
0	Overall, the action would not affect the salmonid in question.
-1	Overall, the action would negatively affect the salmonid in question, with minor sublethal effects (occurring in up to 10% of the population) and very low likelihood (occurring in <1% of the population) of serious sublethal or lethal effects.
-2	Overall, the action would negatively affect the salmonid in question, with minor sublethal effects (occurring in up to 50% of the population) and/or low likelihood (occurring in <10% of the population) of serious sublethal or lethal effects.
-3	Overall, the action would negatively affect the salmonid in question, with minor sublethal effects (occurring in >50% of the population) and/or intermediate to high likelihood (occurring in >50% of the population) of serious sublethal or lethal effects

Put the score in the appropriate box and document your rationale, including assumptions you made, along with the key studies or data on which you drew.

For both efforts, there are companion documents which provide more detailed information related to the pilot efforts for both actions. These are attached simply to provide more information for those who may seek it.

Once you have filled out the consequence table with all the appropriate scores and rationales, please return the scoring matrix to Michael Eakin (Michael.eakin@wildlife.ca.gov) by **close of business April 1st 2022.**

If you have questions or need assistance in understanding how to score these actions, please reach out to me.

Influence Diagrams

Figure C-3 Influence Diagram for Summer Fall Habitat Actions Effect on Salmonids

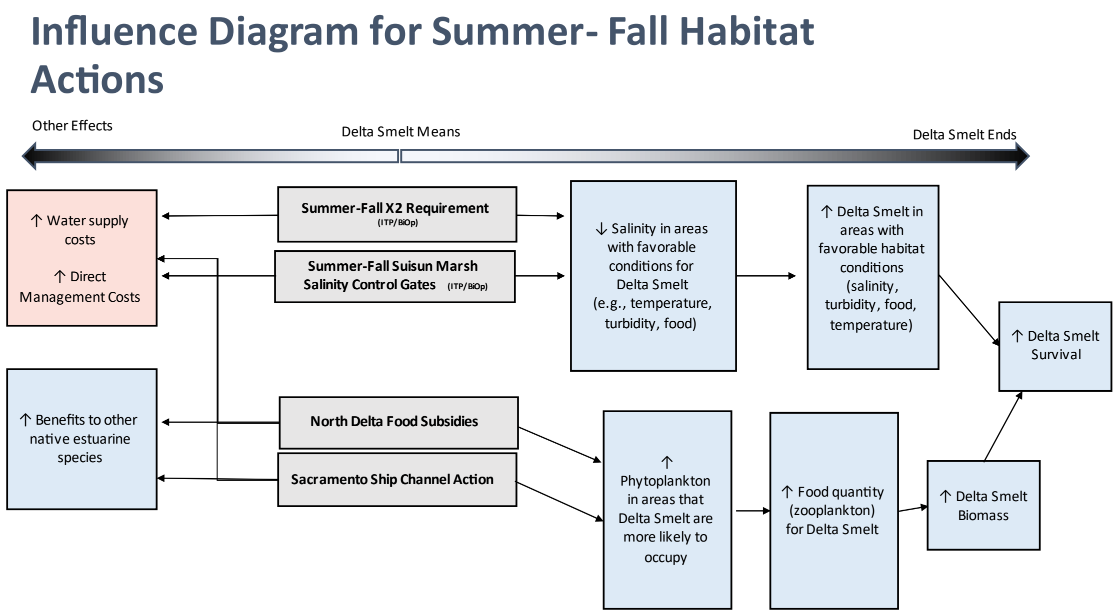


Figure C-4 Influence diagram for Suisun Marsh Salinity Control Gate Summer Operation Effect on Salmonids

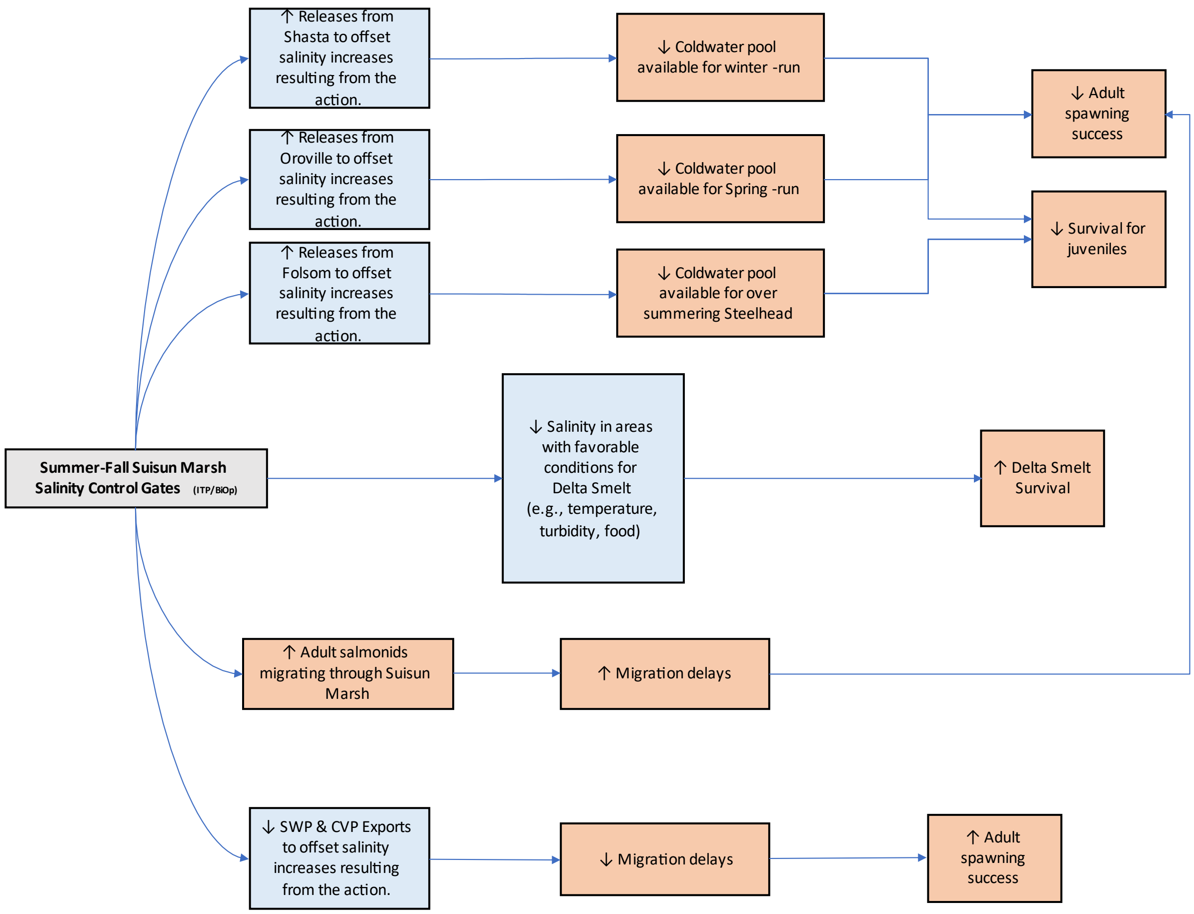
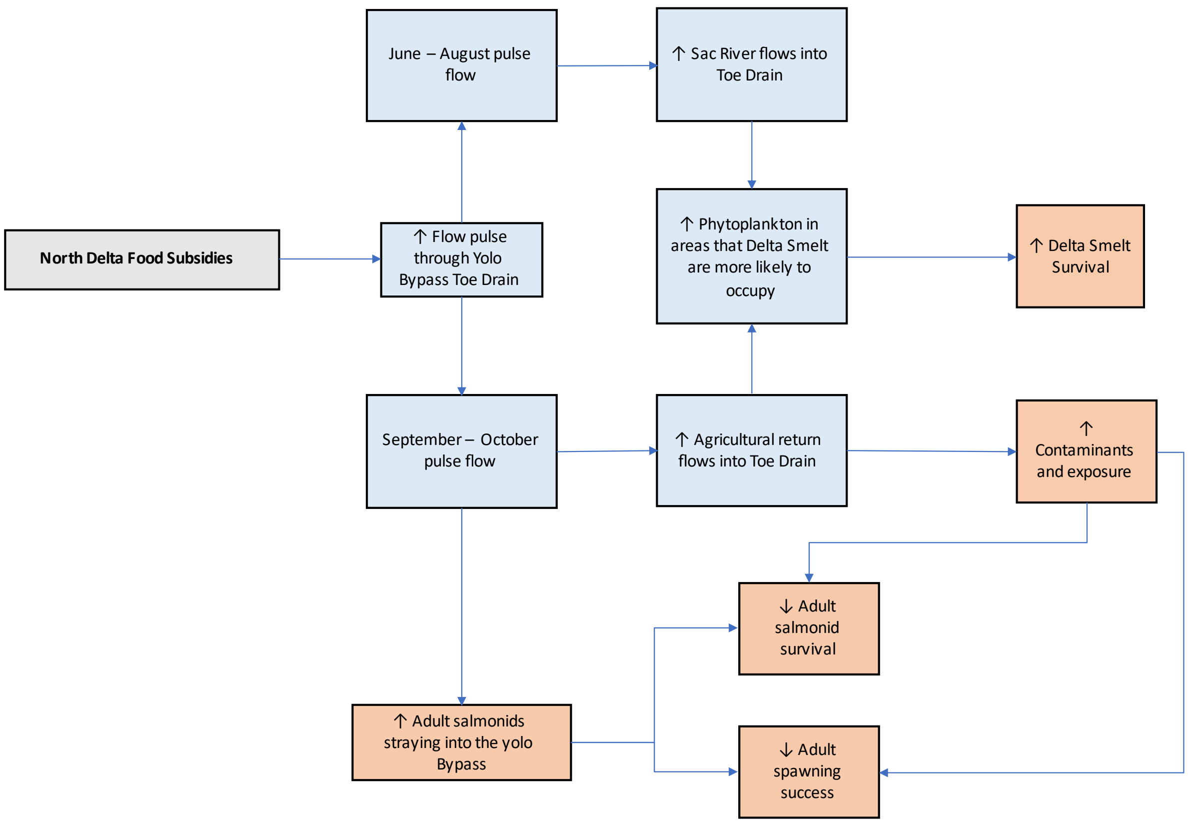


Figure C-5 Influence diagram for North Delta Food Subsidies Effect on Salmonids



Expert Responses and Scores for SDM

Table C-2a CDFW Scores and Rationales

Question #	Action(s) implementation approaches	Months of Action	Spring Run		Fall Run		Steelhead		Winter Run		Rationale for Spring Run	Rationale for Fall Run	Rationale for Steelhead	Rationale for Winter Run	Sources
			Ind	Pop	Ind	Pop	Ind	Pop	Ind	Pop					
	Dry Water Year Type														
	North Delta Food Subsidy (NDFS)														
1	NDFS - **4 week pulse** into the toe drain. uses **agriculture return flows**	September, October	-1	0	-3	-2	-3	-2	0	0	Although very unlikely, there is a chance that yearling spring-run might be impacted by this project as they outmigrate. Yearlings might get drawn into the Cache Slough Complex during outmigration and become exposed to poor water quality conditions as a result of the action.	The score is based on fish presence at Wallace Weir and increased exposure to the following stressors: high water temperatures, low DO concentrations, high contaminant concentrations and handling effects from fish rescues. Individually and combined these factors impact immediate or delayed survival, reduce overall fitness and reduce likelihood of successful reproduction. The flow action affects how far up the Yolo Bypass salmon are migrating, thus reducing the chance of those fish turning around on their own volition and increasing exposure to the impacts mentioned above. Without comprehensive monitoring throughout the Yolo Bypass (daily	The score is based on fish presence at Wallace Weir and increased exposure to the following stressors: high water temperatures, low DO concentrations, high contaminant concentrations and handling effects from fish rescues. Individually and combined these factors impact immediate or delayed survival, reduce overall fitness and reduce likelihood of successful reproduction. The flow action affects how far up the Yolo Bypass salmon are migrating, thus reducing the chance of those fish turning around on their own volition and increasing exposure to the impacts mentioned above. Without comprehensive monitoring throughout the Yolo Bypass (daily straying surveys), it	Winter-run adults are unlikely to be in the vicinity of the action. Early arriving young-of-year (YOY) juveniles may be in the vicinity of the Cache Slough Complex, but at very low numbers. Knights Landing catch data shows winter-run LAD fish occurring as early as August, but in low numbers.	1) EPA Temp. thresholds for salmon: <68°F (<20°C) for salmon and trout migration - generally in the lower part of river basins that likely reach this temperature naturally, if there are cold-water refugia available. 2)Wallace Weir fish collection data: www.calfish.org 3) Scott G. Hinch, Nolan N. Bett, Erika J. Eliason, Anthony P. Farrell, Steven J. Cooke, and David A. Patterson. Exceptionally high mortality of adult female salmon: a large-scale pattern and a conservation concern. Canadian Journal of Fisheries and Aquatic Sciences. 78(6): 639-654. https://doi.org/10.1139/cjfas-2020-0385 4) Cumulative Effects of Thermal and Fisheries Stressors Reveal Sex-Specific Effects on Infection Development and Early Mortality of Adult Coho Salmon (Oncorhynchus kisutch) Amy Kathryn Teffer, Scott Hinch, Kristina Miller, Kenneth Jeffries, David Patterson, Steven Cooke, Anthony Farrell,

Question #	Action(s) implementation approaches	Months of Action	Spring Run		Fall Run		Steelhead		Winter Run		Rationale for Spring Run	Rationale for Fall Run	Rationale for Steelhead	Rationale for Winter Run	Sources
			Ind	Pop	Ind	Pop	Ind	Pop	Ind	Pop					
												straying surveys), it is unclear what percent of the population is affected by this proposed action. Also, see rationale for spring-run regarding yearling presence. There can potentially be fall-run yearling presence at this time as well.	is unclear what percent of the population is affected by this proposed action.		Karia H. Kaukinen, Shaorong Li, and Francis Juanes Physiological and Biochemical Zoology 2019 92:5, 505-529 5) Amy K. Teffer, Arthur L. Bass, Kristi M. Miller, David A. Patterson, Francis Juanes, and Scott G. Hinch. Infections, fisheries capture, temperature, and host responses: multistressor influences on survival and behaviour of adult Chinook salmon. Canadian Journal of Fisheries and Aquatic Sciences. 75(11): 2069-2083. https://doi.org/10.1139/cjfas-2017-0491 6) Allison, A., S. Holley, L. McNabb, V. Kollmar, K. Kundargi, L. Linander, B. Serup, J. Julienne, M. Johnson, C. Purdy, M. R. Harris, S. Tsao, T. Nguyen and B. Jacobs (2020). Attachment 8: State Water Project effects on winter-run and spring-run Chinook Salmon. In State Water Project 2020 Incidental Take Permit (No. 2081- 2019-066-00). California Department of Fish and Wildlife, Water Branch, West Sacramento, CA.
	Below Normal Water Year Type														
	Suisun Marsh Salinity Control Gate (SMSCG) Operation														

Question #	Action(s) implementation approaches	Months of Action	Spring Run		Fall Run		Steelhead		Winter Run		Rationale for Spring Run	Rationale for Fall Run	Rationale for Steelhead	Rationale for Winter Run	Sources
			Ind	Pop	Ind	Pop	Ind	Pop	Ind	Pop					
2	SMSCG, non consecutive 60 days of operation, start when Beldon's Landing salinity > 4ppt. Water is released from **Shasta**.	June, July, August, September	-1	0	1	0			-1	0	June through September is a long timeframe for releasing up to 60 thousand acre-feet of water for this action. It is unclear how this would differ or correlate with current operations and water transfers that occur during this same timeframe. It is assumed that the releases would be within current operations or there will be a water cost associated with this action. Spring-run adults will be spawning in September with juveniles emerging potentially in September. Yearling spring-run will also be present. There could cause potential stranding and redd dewatering depending on how the flows are released (e.g., ramping rates). This may also deplete cold water pool management earlier in the season if cool water is being released. If warm	Fall-run adults will be moving up the Sacramento River beginning around mid-September and may benefit from experiencing increased flows through the river. However, if warmer water is released this can be harmful.		June through September is a long timeframe for releasing up to 60 thousand acre-feet of water for this action. It is unclear how this would differ or correlate with current operations and water transfers that occur during this same timeframe. It is assumed that the releases would be within current operations or there will be a water cost associated with this action. Winter-run adults will be spawning through September with juveniles emerging. There could cause potential stranding and redd dewatering depending on how the flows are released (e.g., ramping rates). This may also deplete cold water pool management earlier in the season if cool water is being released. If warm water is released, this can be detrimental.	There is no empirical data to evaluate for this action as no specific studies for salmonids have occurred during the pilot study in 2018 (or at least not to my knowledge). All information documented is related to timing of fish presence. Presence data can be found on SacPas and within the SWP ITP Salmon Effects Analysis. Allison, A., S. Holley, L. McNabb, V. Kollmar, K. Kundargi, L. Linander, B. Serup, J. Julienne, M. Johnson, C. Purdy, M. R. Harris, S. Tsao, T. Nguyen and B. Jacobs (2020). Attachment 8: State Water Project effects on winter-run and spring-run Chinook Salmon. In State Water Project 2020 Incidental Take Permit (No. 2081- 2019-066-00). California Department of Fish and Wildlife, Water Branch, West Sacramento, CA.

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			Ind	Pop	Ind	Pop	Ind	Pop	Ind	Pop					
											water is released, this can be detrimental				

Question #	Action(s) implementation approaches	Months of Action	Spring Run		Fall Run		Steelhead		Winter Run		Rationale for Spring Run	Rationale for Fall Run	Rationale for Steelhead	Rationale for Winter Run	Sources
			Ind	Pop	Ind	Pop	Ind	Pop	Ind	Pop					
3	SMSCG, non consecutive 60 days of operation, start when Beldon's Landing salinity > 4ppt. Water is released from **Oroville**.	June, July, August, September	-1	0	1	0			0	0	June through September is a long timeframe for releasing up to 60 thousand acre-feet of water for this action. It is unclear how this would differ or correlate with current operations and water transfers that occur during this same timeframe. It is assumed that the releases would be within current operations or there will be a water cost associated with this action. Spring-run adults will be spawning in September with juveniles emerging potentially in September. Yearling spring-run will also be present. There could cause potential stranding and redd dewatering depending on how the flows are released (e.g., ramping rates). This may also deplete cold water pool management earlier in the season if cool water is being released. If warm	Fall-run adults will be moving up the Sacramento River beginning around mid-September and may benefit from experiencing increased flows through the river. However, if warmer water is released this can be harmful.		Winter-run adults will be present in the upper Sacramento River and juveniles are unlikely to experience flow increases as they move downstream based on very low abundance in the vicinity of the action area (downstream of Oroville). Winter-run do not spawn or rear in the Feather River (there might be very low numbers rearing near the confluence of the Feather River and Sacramento River).	See above

Question #	Action(s) implementation approaches	Months of Action	Spring Run		Fall Run		Steelhead		Winter Run		Rationale for Spring Run	Rationale for Fall Run	Rationale for Steelhead	Rationale for Winter Run	Sources
			Ind	Pop	Ind	Pop	Ind	Pop	Ind	Pop					
											water is released, this can be detrimental.				

Question #	Action(s) implementation approaches	Months of Action	Spring Run		Fall Run		Steelhead		Winter Run		Rationale for Spring Run	Rationale for Fall Run	Rationale for Steelhead	Rationale for Winter Run	Sources
			Ind	Pop	Ind	Pop	Ind	Pop	Ind	Pop					
4	SMSCG, non consecutive 60 days of operation, start when Beldon's Landing salinity > 4ppt. Water is released from **Folsom**.	June, July, August, September	0	0	1	0			0	0	Spring-run adults are not present in the American River. It is very unlikely that any spring-run juveniles will be in the area of the releases as they will likely still be in the redds on natal tributaries.	Fall-run adults will be moving up the Sacramento River beginning around mid-September and may benefit from experiencing increased flows through the river. However, if warmer water is released this can be harmful.		Winter-run adults are not present in the American River. It is very unlikely that any winter-run juveniles will be in the area of the release or the confluence of the American and Sacramento rivers during this timeframe (only potentially at very low numbers).	See above
5	SMSCG, non consecutive 60 days of operation, start when Beldon's Landing salinity > 4ppt. Water is achieved through **SWP/CVP export reduction.**	June, July, August, September	1	0	1	0			1	0	Reducing exports from June-September will coincide with the very tail-end of spring-run YOY outmigrants (in June) and the beginning of yearling outmigrants (September). Reducing exports during this time will benefit both Sacramento and San Joaquin origin spring-run. Reducing exports can improve conditions during outmigration by reducing the risk of juvenile entrainment. On the San Joaquin River, reducing exports can increase outmigration of juveniles and provide a more direction attraction	Reducing exports from June-September will coincide with adult fall-run returning the rivers (August/September) and can improve their routing to either the Sacramento River or San Joaquin River.		Reducing exports from June-September will coincide with the very tail-end of winter-run YOY outmigrants (in June). Reducing exports can improve conditions during outmigration by reducing the risk of juvenile entrainment. There is also some overlap with reducing exports and adult winter-run upstream migration through June. Reducing exports may help with reducing adult straying through the interior Delta.	See above

Question #	Action(s) implementation approaches	Months of Action	Spring Run		Fall Run		Steelhead		Winter Run		Rationale for Spring Run	Rationale for Fall Run	Rationale for Steelhead	Rationale for Winter Run	Sources
			Ind	Pop	Ind	Pop	Ind	Pop	Ind	Pop					
											flow for returning adults (which may be in the Delta through September).				
	North Delta Food Subsidy (NDFS)														

Question #	Action(s) implementation approaches	Months of Action	Spring Run		Fall Run		Steelhead		Winter Run		Rationale for Spring Run	Rationale for Fall Run	Rationale for Steelhead	Rationale for Winter Run	Sources
			Ind	Pop	Ind	Pop	Ind	Pop	Ind	Pop					
6	NDFS - **4 week pulse** into the toe drain. uses **agriculture return flows**	September, October	-1	0	-3	-2	-3	-2	0	0	Although very unlikely, there is a chance that yearling spring-run might be impacted by this project as they outmigrate. Yearlings might get drawn into the Cache Slough Complex during outmigration and become exposed to poor water quality conditions as a result of the action.	The score is based on fish presence at Wallace Weir and increased exposure to the following stressors: high water temperatures, low DO concentrations, high contaminant concentrations and handling effects from fish rescues. Individually and combined these factors impact immediate or delayed survival, reduce overall fitness and reduce likelihood of successful reproduction. The flow action affects how far up the Yolo Bypass salmon are migrating, thus reducing the chance of those fish turning around on their own volition and increasing exposure to the impacts mentioned above. Without comprehensive monitoring throughout the Yolo Bypass (daily straying surveys), it is unclear what percent of the population is affected by this proposed action.	The score is based on fish presence at Wallace Weir and increased exposure to the following stressors: high water temperatures, low DO concentrations, high contaminant concentrations and handling effects from fish rescues. Individually and combined these factors impact immediate or delayed survival, reduce overall fitness and reduce likelihood of successful reproduction. The flow action affects how far up the Yolo Bypass salmon are migrating, thus reducing the chance of those fish turning around on their own volition and increasing exposure to the impacts mentioned above. Without comprehensive monitoring throughout the Yolo Bypass (daily straying surveys), it is unclear what percent of the population is affected by this proposed action.	Winter-run adults are unlikely to be in the vicinity of the action. Early arriving young-of-year (YOY) juveniles may be in the vicinity of the Cache Slough Complex, but at very low numbers. Knights Landing catch data shows winter-run LAD fish occurring as early as August, but in low numbers.	See sources listed above for a dry water year.

Question #	Action(s) implementation approaches	Months of Action	Spring Run		Fall Run		Steelhead		Winter Run		Rationale for Spring Run	Rationale for Fall Run	Rationale for Steelhead	Rationale for Winter Run	Sources
			Ind	Pop	Ind	Pop	Ind	Pop	Ind	Pop					
												Also, see rationale for spring-run regarding yearling presence. There can potentially be fall-run yearling presence at this time as well.			

Question #	Action(s) implementation approaches	Months of Action	Spring Run		Fall Run		Steelhead		Winter Run		Rationale for Spring Run	Rationale for Fall Run	Rationale for Steelhead	Rationale for Winter Run	Sources
			Ind	Pop	Ind	Pop	Ind	Pop	Ind	Pop					
7	NDFS - **4 week pulse** into the toe drain. uses water from the Sacramento River. Water provided by Glen Colusa Irrigation District & Reclamation District 108.	June, July, August	0	0	0	0			0	0	There is the potential to improve Cache Slough Complex rearing habitat for late outmigrating juveniles (young-of-year) in June; however, these fish are smolts and are unlikely to experience the benefit of the improved rearing habitat. There is also the potential to attract adults in June-August (at very low numbers) into the Yolo Bypass, where the only route back to the Sacramento River is to turn around or be salvaged (when Wallace Weir is operated). As mentioned earlier, it is unclear what percent of the population is impacted without comprehensive monitoring. This impact can be perceived as potentially neutral due to uncertainty.	There is the potential to improve Cache Slough Complex rearing habitat for late outmigrating juveniles (young-of-year) in June; however, these fish are smolts and are unlikely to experience the benefit of the improved rearing habitat. As mentioned earlier, it is unclear what percent of the population is impacted without comprehensive monitoring. This impact can be perceived as potentially neutral due to uncertainty.		There is the potential to improve rearing habitat for late outmigrating juveniles in June; however, these fish are smolts and are unlikely to experience the benefit of the improved rearing habitat. There is also the potential to attract adults in June-July (at very low numbers) into the Yolo Bypass, where the only route back to the Sacramento River is to turn around or be salvaged (when Wallace Weir is operated). As mentioned earlier, it is unclear what percent of the population is impacted without comprehensive monitoring. This impact can be perceived as potentially neutral due to uncertainty.	Presence data can be found on SacPas and within the SWP ITP Salmon Effects Analysis. Allison, A., S. Holley, L. McNabb, V. Kollmar, K. Kundargi, L. Linander, B. Serup, J. Julienne, M. Johnson, C. Purdy, M. R. Harris, S. Tsao, T. Nguyen and B. Jacobs (2020). Attachment 8: State Water Project effects on winter-run and spring-run Chinook Salmon. In State Water Project 2020 Incidental Take Permit (No. 2081- 2019-066-00). California Department of Fish and Wildlife, Water Branch, West Sacramento, CA.

Table C-2b. NMFS Scores

Question #	Action(s) implementation approaches	Months of Action	Spring Run		Fall Run		Steelhead		Winter Run		Green Sturgeon		Score
			Ind	Pop	Ind	Pop	Ind	Pop	Ind	Pop	Ind	Pop	
	Dry Water Year Type												
	North Delta Food Subsidy (NDFS)												
1	NDFS - **4 week pulse** into the toe drain. uses **agriculture return flows**	September, October	0	0			-2	-1	0	0	-3	0	-6
	Below Normal Water Year Type												
	Suisun Marsh Salinity Control Gate (SMSCG) Operation												
2	SMSCG, non consecutive 60 days of operation, start when Beldon's Landing salinity > 4ppt. Water is released from **Shasta**.	June, July, August, September											
3	SMSCG, non consecutive 60 days of operation, start when Beldon's Landing salinity > 4ppt. Water is released from **Oroville**.	June, July, August, September											
4	SMSCG, non consecutive 60 days of operation, start when Beldon's Landing salinity > 4ppt. Water is released from **Folsom**.	June, July, August, September											
5	SMSCG, non consecutive 60 days of operation, start when Beldon's Landing salinity > 4ppt. Water is achieved through **SWP/CVP export reduction.**	June, July, August, September											
	North Delta Food Subsidy (NDFS)												
6	NDFS - **4 week pulse** into the toe drain. uses **agriculture return flows**	September, October	0	0			-2	-1	0	0	-3	0	-6
7	NDFS - **4 week pulse** into the toe drain. uses water from the Sacramento River. Water provided by Glen Colusa Irrigation District & Reclamation District 108.	June, July, August	0	0			0	0	0	0	0	0	0

Table C-2c. NMFS Rationales. Contaminants have been observed to exceed both acute and chronic levels with some pesticides during ag flow action in fall than with Sac River Water redirected during summer action. Extent of exposure for fish may be dependent on duration. Acute exposure can result in physiological stress or possibly death. Chronic exposure can result in physiological stress. Stress can lead to reduced fitness and/or survival. **Water quality** shows observed increases in water temps and low DO as a result of fall action, not sure about summer. Temperatures above 20 degrees C or below 5 mg/l DO can result in injury or death to fish. Injury includes reduced fitness and survival. **Stranding/delayed migration:** adults may follow false attraction flows into the toe drain during pulses. Stressors include delay in migration (holding or high energy expenditures to navigate back out). Fish that hold or continue to swim up to Wallace Weir may be exposed to poor water quality conditions, stress during handling, reduced fitness and survival upon release back into Sac River (recovery time).

	Stressor	JUNE	JULY	AUG	SEPT	OCT	individual	population	individual	population
WR		**occurrence**					**Fall**		**Summer**	
juvenile	contaminants, WQ	no	no	no	no	low	0	0	0	0
adult	cont., WQ, straying	med	no	no	no	no	0	0	0	0
SR										
juvenile	contaminants, WQ	no	no	no	no	no	0	0	0	0
adult	cont., WQ, straying	med	no	no	no	no	0	0	0	0
FR										
juvenile	contaminants, WQ									
adult	cont., WQ, straying									
STEEL										
juvenile	contaminants, WQ	low	low	no	low	no	0	0	0	0
adult	cont., WQ, straying	low	no	med	high	low	-2	-1	0	0
GS										
sub-adult	contaminants, WQ	high	high	high	high	high	-2	0	0	0
adult	contaminants, WQ	med	med	med	med	med	-1	0	0	0

Table C-2d Cramer Fish Sciences Scores and Rationales

Question #	Action(s) implementation approaches	Months of Action	Spring Run		Fall Run		Steelhead		Winter Run		Rationale for Spring Run	Rationale for Fall Run	Rationale for Steelhead	Rationale for Winter Run	Sources
			Ind	Pop	Ind	Pop	Ind	Pop	Ind	Pop					
	Dry Water Year Type														
	North Delta Food Subsidy (NDFS)														
1	NDFS - **4 week pulse** into the toe drain. uses **agriculture return flows**	September, October	0	0	-1	0	0	0	0	0	Adults not present in the project area (for months indicated). Yearlings are very unlikely to be in the project area (for months indicated).	Overlaps with fall-run immigration timing. Some risk of increased adult straying into the project area, but such straying occurs regularly w/o the action.	Adults and smolts not expected to occur in the project area (for months indicated).	Adults not present in the project area (for months indicated). Juveniles are very unlikely to be in the project area (for months indicated).	
	Below Normal Water Year Type														
	Suisun Marsh Salinity Control Gate (SMSCG) Operation														

Question #	Action(s) implementation approaches	Months of Action	Spring Run		Fall Run		Steelhead		Winter Run		Rationale for Spring Run	Rationale for Fall Run	Rationale for Steelhead	Rationale for Winter Run	Sources
			Ind	Pop	Ind	Pop	Ind	Pop	Ind	Pop					
2	SMSCG, non-consecutive 60 days of operation, start when Beldon's Landing salinity > 4ppt. Water is released from **Shasta**.	June, July, August, September	0	0	0 to -1	0 to -1	0	0	0 to -3	0 to -3	Action will occur after spring-run adult migration. Sacramento River mainstem spring-run are rare, not viable because of introgression with fall-run.	Action may occur during adult immigration, but delay effects will likely impact small fraction of the population. Cold-water pool availability less of an issue for fall-run because of spawn timing and water temps cool naturally after October, latter half of egg incubation period most sensitive to water temperatures.	Action does not occur when steelhead are present in the affected area. Shasta cold-water availability will not affect steelhead (spawn in winter)	Impact depends on if, how much, and when cold-water pool in Shasta is depleted. Could be no impact, or could contribute to very substantial loss of incubating eggs.	Egg incubation stage dependent temperature mortality: Geist et al. (2005)

Question #	Action(s) implementation approaches	Months of Action	Spring Run		Fall Run		Steelhead		Winter Run		Rationale for Spring Run	Rationale for Fall Run	Rationale for Steelhead	Rationale for Winter Run	Sources
			Ind	Pop	Ind	Pop	Ind	Pop	Ind	Pop					
3	SMSCG, non-consecutive 60 days of operation, starts when Beldon's Landing salinity > 4ppt. Water is released from **Oroville**.	June, July, August, September	0	0	0 to -1	0 to -1	0	0	0	0	Action will occur after spring-run adult migration. River valve on Lake Oroville means cold-water pool is not as limited as other CV rivers.	Action may occur during adult migration, but delay effects or straying will likely impact small fraction of the population. River valve on Lake Oroville means cold-water pool is not limited like other CV rivers. Cold-water pool availability less of an issue for fall-run because of spawn timing and water temps cool naturally after October, latter half of egg incubation period most sensitive to water temperatures. However, effect of cold-water pool depletion cannot be assessed without more specific information (see winter-run for Shasta operation).	Action does not occur when steelhead are present in the affected area. Oroville cold-water availability will not affect steelhead (spawn in winter)	No effect if we assume Oroville releases do not affect Shasta cold water pool or carry over storage.	Egg incubation stage dependent temperature mortality: Geist et al. (2005)

Question #	Action(s) implementation approaches	Months of Action	Spring Run		Fall Run		Steelhead		Winter Run		Rationale for Spring Run	Rationale for Fall Run	Rationale for Steelhead	Rationale for Winter Run	Sources
			Ind	Pop	Ind	Pop	Ind	Pop	Ind	Pop					
4	SMSCG, non-consecutive 60 days of operation, start when Beldon's Landing salinity > 4ppt. Water is released from **Folsom**.	June, July, August, September	0	0	0 to -1	0 to -1	0	0	0	0	Action will occur after spring-run adult migration through the Delta. Spring-run do not occur in the American River.	Action may occur during adult migration, but delay effects will likely impact small fraction of the population. Cold-water pool availability less of an issue for fall-run because of spawn timing and water temps cool naturally after October, latter half of egg incubation period most sensitive to water temperatures. However, effect of cold-water pool depletion cannot be assessed without more specific information (see winter-run for Shasta operation).	Action does not occur when steelhead are present in the affected area (the Delta). Temperature changes (should they occur) are unlikely to affect steelhead, which spawn in winter (juveniles and adults are more tolerant of warmer waters). American River steelhead (including fish spawning and rearing in-river) are a non-native stock (Eel River strain) and therefore should be of reduced conservation concern.	No effect if we assume Folsom releases do not affect Shasta cold water pool or carry over storage.	Egg incubation stage dependent temperature mortality: Geist et al. (2005). For American River steelhead genetics, see genetic analyses reported by Pearse and Garza (2015) which shows ostensibly natural (unclipped) O. mykiss from the lower American River are much more closely related Nimbus Hatchery steelhead (i.e. Eel River strain) than to any other CV steelhead stocks.
5	SMSCG, non-consecutive 60 days of operation, start when Beldon's Landing salinity > 4ppt. Water is achieved through **SWP/CVP export reduction.**	June, July, August, September	0	0	1	1	0	0	0	0	Does not overlap with adult or juvenile migration	Does not overlap juvenile migration. Some possible benefits to adult fall-run are that they are less likely to stray toward the South	Does not overlap with adult or juvenile migration	Does not overlap with adult or juvenile migration	

Question #	Action(s) implementation approaches	Months of Action	Spring Run		Fall Run		Steelhead		Winter Run		Rationale for Spring Run	Rationale for Fall Run	Rationale for Steelhead	Rationale for Winter Run	Sources
			Ind	Pop	Ind	Pop	Ind	Pop	Ind	Pop					
												Delta, but unlikely to be significant.			
	North Delta Food Subsidy (NDFS)														
6	NDFS - **4-week pulse** into the toe drain. uses **agriculture return flows**	September, October	0	0	-1	0	0	0	0	0	Does not overlap with adult or juvenile migration	Action may occur during adult migration, but delay effects or straying will likely impact small fraction of the population.	Does not overlap with adult or juvenile migration	Does not overlap with adult or juvenile migration	
7	NDFS - **4-week pulse** into the toe drain. uses water from the Sacramento River. Water provided by Glen Colusa Irrigation District & Reclamation District 108.	June, July, August	0	0	-1	0	0	0	0	0	Does not overlap with adult or juvenile migration	Action may occur during adult migration, but delay effects or straying will likely impact small fraction of the population.	Does not overlap with adult or juvenile migration	Does not overlap with adult or juvenile migration	