

Near-Term Restoration Strategy

for the

Central Valley Project Improvement Act Fish Program

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In response to the 2008 Listen to the River report, the US Fish and Wildlife Service and the US Bureau of Reclamation have supported a Structured Decision Making (SDM) effort within the Fish Resource Area of the Central Valley Project Improvement Act (CVPIA), Title 34 of Public Law 102-575. SDM represents a collaborative process with agencies (State, Federal, and Local) and stakeholders (non-government organizations, Federal and State Water Contractors, etc).

SDM includes the use of numerical tools to facilitate analysis of data related to fisheries performance, mitigation actions, and habitat restoration. The result is a comprehensive, science-based approach that explicitly links activities with Program objectives. Output of SDM is intended to assist in prioritization of actions to achieve the anadromous fish doubling goal of the CVPIA and to document the best understanding of science affecting the Fish Resource Area.

Table of Contents

Introduction	4
Background	5
Structured Decision Making	5
Science Coordinator	5
Science Integration Team	6
SDM timeline and prior prioritization efforts	6
Uses for Near-term Restoration Strategy	7
Continuing role for SDM	7
Overview of prioritization process and results	8
Chinook salmon	8
O. mykiss and sturgeon	18
Results	18
Chinook salmon	19
Sensitivity analysis	26
Interpretation of results into a strategy	29
Areas of emphasis for restoration	31
Mainstem Sacramento above American River confluence	31
Non-natal rearing along mainstem Sacramento for winter-run Chinook salmon	32
Battle Creek	32
American River	32
Stanislaus River	33
Clear Creek	33
Butte Creek	33
Feather River below confluence with the Yuba River	33
Ongoing maintenance of spawning habitat	34
Information needs of the SIT	34
Chinook salmon research	34
Juvenile survival	34
Juvenile growth	35
Juvenile movement	35
Territory size	36
Southport levee setback	36
Chinook salmon monitoring	36
Habitat estimates	36
Habitat change over time	37

STRUCTURED DECISION MAKING - FINAL

Long-term monitoring	37
<i>O. mykiss</i> research and monitoring	39
Demographic information	39
Habitat estimates	39
Evaluate contrasting tributaries	39
Long-term monitoring	40
Sturgeon research and monitoring	41
Long-term needs	41
Short-term needs	41
Implementation	43
Identification and selection of charters	43
Implementation Guidance	43
Project development	43
Project design	44
Data	44
Monitoring	44
Research	44
Current restoration projects from prior funding cycles	44
Current monitoring efforts from prior funding cycles	45
Current research efforts from prior funding cycles	45
Process for review and revision	46
Literature cited	47
Appendix A Model Documentation	49
Appendix B Data Guidance	51
Appendix C Proposed CVPIA project related monitoring	53
Appendix D Central Valley Chinook Salmon & <i>O. mykiss</i> Recovery Plan	55

Introduction

In 2008, the US Bureau of Reclamation and the US Fish and Wildlife Service, in response to a request by the Secretary of the Interior, received an independent review of the Central Valley Improvement Act (Listen to the River, 2008). That report addressed four objectives:

- improve the effectiveness and efficiency of programs and implementation actions to achieve the fish restoration goals of the Act;
- enhance the agencies' ability to learn from and optimize program actions;
- improve the transparency and accountability of the fish restoration programs to management, stakeholders, and the public; and
- by achieving the first three objectives, enhance public understanding and support for the program and continuing restoration activities.

To address these objectives, the Bureau and the Service adopted a Structured Decision Making (SDM) process. SDM provides a formal, documented, open, and transparent process to develop quantifiable and measurable objectives and determine the best decision alternatives to achieve restoration objectives through the use of quantitative models. Decision-support models (DSMs) use the best available information to predict how actions might improve natural production for all four runs of Chinook salmon, *O. mykiss*, and sturgeon.

Development of the models was guided by an inter-agency, multi-stakeholder group of scientists and resource experts collectively referred to as the Science Integration Team (SIT). The models represent a current snapshot of the best collective understanding of population effects on anadromous fish in the Central Valley, and are subject to revision and refinement as that understanding improves. Reclamation and the Service seek broad support and buy-in for resource decisions by using the SDM process to prioritize restoration fund expenditures.

This Near-term Restoration Strategy based on the optimization of the current numerical models for fall-, spring-, and winter-run chinook salmon. Numerical optimization was reviewed and amended to account for local expertise in order to develop a strategy to build towards the goal of doubling anadromous fish populations in the Central Valley through the prioritization of restoration, research, and monitoring efforts that will be implemented over the next five year cycle.

Background

Following an independent review of CVPIA Fish Resource Area Activities, US Fish and Wildlife and US Bureau of Reclamation took action to develop a new comprehensive, science-based approach, and explicitly links activities with Program objectives. The new framework would also incorporate uncertainty and allow for integration of new information to improve scientific understanding and increase the effectiveness of Fish Resource Area activities. The CVPIA Fisheries Program identified Structured Decision Making (SDM) as a framework to allow decision-makers to identify Program objectives and guide planning of broad scale fisheries activities.

Structured Decision Making

Structured Decision Making (SDM) is an approach to decomposing and analyzing decisions to identify solutions that achieve the desired objectives, in a manner that is explicit and transparent. Based in decision theory and risk analysis, SDM is a concept that encompasses a very broad set of methods, not a prescription for a rigid approach for problem solving. SDM provides clear roles for stakeholders and scientists when working on problems at the interface of science and policy. Key SDM concepts include making decisions based on clearly articulated fundamental objectives, dealing explicitly with uncertainty, and responding transparently to legal mandates and public preferences or values in decision making; thus, SDM integrates science and policy explicitly. At a very basic level, SDM is about connecting decisions to objectives, and SDM is a formalized way of accomplishing that connection.

An SDM rapid prototyping process was initiated in January 2013 with a 2.5 day facilitated workshop that included CVPIA Fisheries Program managers and members from cooperating agencies. Participants included representatives from the US Fish and Wildlife Service (FWS), US Bureau of Reclamation, National Marine Fisheries Service, California Department of Water Resources, and California Department of Fish and Wildlife. Participants were provided with an overview of the SDM and ARM process and example case studies. Undertaking the SDM process by the agencies established a foundation to support engaging and incorporating stakeholders and scientific understanding into the CVPIA decision making process.

The SDM process continued with the formation of a CVPIA science integration team (SIT) that was open to the public and included members from state and federal agencies, municipalities, non-governmental organizations, and members of the general public. Over the course of five years, the SIT used the SDM process to refine objectives, expand and refine existing decision support models (DSM) and identified restoration priorities.

Science Coordinator

The Science Coordinator is responsible for ensuring the production of the periodic Technical Memoranda documenting the state of the DSMs, any changes that were made or recommended, and potential influence on the five year Strategy. The Science Coordinator is also the lead author for the Strategy that documents program priorities. The Strategy and

Technical Memoranda originate from the Science Coordinator, but are meant to serve as an accurate representation of the entire SDM process. SIT members are provided multiple opportunities for review, suggested edits, and provide written addenda when or if they disagree with the findings.

Science Integration Team

The SIT is a self-selected, collaborative team that uses the SDM method to make progress through scientific and technical discussions in support of ARM. Individual members express their own scientific viewpoints, and inform their various organizations of SIT processes and summaries. Collectively, these discussions are built into DSMs, which help focus the SIT's review of complex processes and are the subject of regular review and refinement. Members of the SIT participate in discussions and develop near-term (five year) priorities based on a combination of numerical modeling, literature review, monitoring results and professional judgement. The SIT is not a voting body or a consensus-based team, nor are its recommendations binding on the implementing agencies.

In summary, the SIT is a self-selected group composed of stakeholders and agency scientists with the responsibility of:

- Incorporating science and data to support ARM;
- Refining and revising DSMs with new and existing information;
- Recommending priorities for restoration, monitoring, and research;
- Reporting back to their agencies or constituents regarding updates or need for additional information related to prioritization.

SDM timeline and prior prioritization efforts

To date, the SDM progress has previously documented its prioritization process on an almost yearly basis through the preparation of two Tech Memos.

From April 2016 to February 2017, members of the SIT met during a series of 8 in-person workshops and 23 conference calls to complete a number of tasks, including identifying restoration scenarios. The purpose of these tasks were to:

1. Improve the existing DSM and use it to identify priorities; and
2. Use the information to initiate the integration of priorities for all the focal taxa, which include the following:
 - a. Fall-run Chinook salmon
 - b. Spring-run Chinook salmon
 - c. Winter-run Chinook salmon
 - d. *O. mykiss*
 - e. Green sturgeon
 - f. White sturgeon

STRUCTURED DECISION MAKING - FINAL

From the latter part of 2018 to February 2019, the SIT met during a series of in-person workshops and conference calls. The purpose of these tasks were to:

1. Improve the existing DSM and use it to identify priorities;
2. Use the information to initiate the integration of priorities for all focal taxa; and
3. Assess monitoring needs and address areas of uncertainty.

Meeting minutes, presentations, DSMs, visualization tools, and other various support documents are available for review at: cvpia.scienceintegrationteam.com

Uses for Near-term Restoration Strategy

This Strategy outlines focused prioritizations that describe the best estimates of the SIT for investing CVPIA Restoration Funds to work towards anadromous fish doubling goals. The Strategy describes current efforts and future efforts, including restoration projects, monitoring programs, and targeted research. This Strategy is intended to be implemented over a five-year period so that the population-level effects on multiple anadromous fish species can be observed and large-scale restoration efforts can be planned, designed, and implemented.

Additionally, this Strategy can be used by other processes with an interest in improvements to anadromous species in California. The Strategy provides an organizational framework where multiple efforts can be recorded, analyzed, and repeated as appropriate for the benefit of anadromous species in the Central Valley.

Continuing role for SDM

During the implementation of the actions recommended in the current Strategy, the SDM process will continue to refine goals and objectives between 2020 and 2024. Specifically, the focus will be on improving existing DSMs, building new DSMs for *O. mykiss* and green sturgeon, review improvements and changes to model inputs and subsequent outputs, and assess knowledge gains that might result from monitoring or research projects.

These actions will occur over a regular schedule of bi-annual in-person workshops as well as regularly-scheduled teleconferences to review overall progress. Additionally, it is anticipated that numerous sub-groups and special focus meetings will occur to track issues relating to program administration, implementation of specific restoration, monitoring summaries, research progress, and technical development. All of these will be documented on the project website at: cvpia.scienceintegrationteam.com

Overview of prioritization process and results

The SDM process resulted in priorities for restoration efforts and monitoring / research efforts for Chinook salmon through updates to the existing fall-run DSM and development of DSMs for winter-run and spring-run. Chinook DSMs were used as a basis for evaluating various potential restoration strategies and to identify any potential trade-offs between results for the three salmon runs. The process and results of these efforts are described in more detail below.

There were multiple discussions about the value of developing a restoration strategy for sturgeon and *O. mykiss*. The discussions focused on the adequacy of the existing *O. mykiss* and sturgeon DSMs, the lack of data available to calibrate and run the models, and the general lack of knowledge about these taxa that would support development of a defensible, scientifically-based restoration strategy. The consensus was that these taxa would benefit most if efforts over the next 5 years focused on improving the state of knowledge for these taxa. Therefore, using information needs identified during previous prioritization efforts, the SIT worked with PTW members and other taxon-specific experts familiar with the Central Valley to identify and prioritize information needs for the next 5 years. The process used for each taxon is detailed below.

Chinook salmon

The SDM process resulted in the identification of priorities for the restoration strategy. The SDM process (Figure 1) includes the following steps:

1. defining the decision context (or decision situation) relating to the management problem;
2. identifying stakeholder fundamental objectives and their quantifiable attributes;
3. identifying candidate management actions;
4. developing DSMs that are used to predict the changes in quantifiable attributes that describe the state of fundamental objectives after implementing candidate actions; and
5. conducting sensitivity analyses to identify the uncertainties that are most influential candidate decisions based on the DSMs;
6. If the analysis is complete, implement the action.

The context and fundamental objectives remain unchanged from previous prioritization efforts. However, there were several modifications to Chinook salmon management attributes, the DSM model and inputs, and the process used to develop restoration scenarios. These changes were intended to increase transparency, simplify, and streamline the process and provide restoration and research / monitoring priorities with greater specificity based on what was learned during previous prioritization efforts. These modifications are highlighted in the overview below.

STRUCTURED DECISION MAKING - FINAL

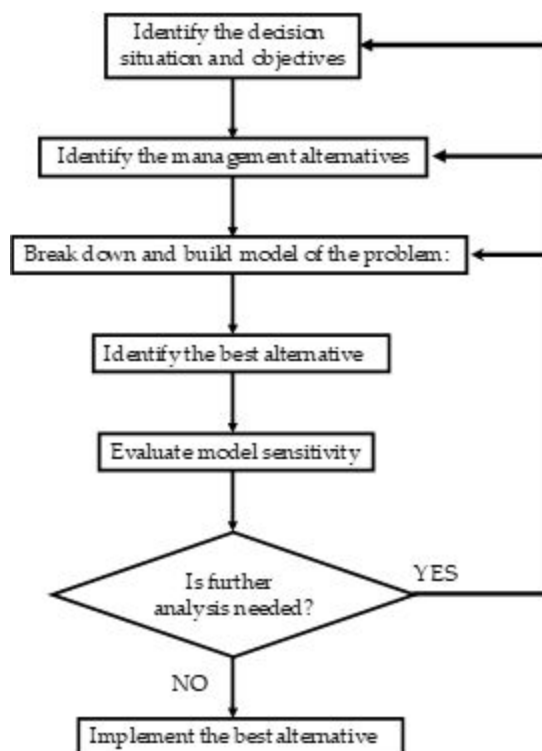


Figure 1. Steps in the structured decision making process

During the first step in the prioritization process, the DSMs output key population attributes, which allow the SIT to evaluate relative achievement of objectives. Population attributes are defined as quantifiable measures of progress toward the fundamental objective of achieving strong, self-sustaining populations of anadromous fishes. The SIT originally had five valley-wide and four tributary scale objectives for Chinook salmon that were difficult to use for identifying priorities because they resulted in too many combinations to evaluate. For example, during the FY17 prioritization, the SIT needed to review 125 DSM outputs (5 valley wide + 4 tributary scale * 30 tributaries & mainstem segments) for *each* restoration scenario. To streamline the effort, the SIT identified three valley wide objectives: total juvenile biomass at Chipps Island, natural adult production, and spatial diversity and two tributary objectives: total juvenile biomass at Chipps Island and natural adult production. The SIT was provided with DSM outputs for all 5 metrics, but focused on valley-wide total juvenile biomass at Chipps Island and valley-wide natural adult production during the scenario evaluations. In addition, spring-run fish from the Yuba and Feather were not included in the juvenile biomass and natural production metrics used in the development of the strategy due to a decision made by the SIT prior to the FY17 prioritization.

The second step in the prioritization process was to identify candidate restoration strategies that could lead to achieving the fundamental objective of achieving strong, self-sustaining populations of winter, spring, and fall Chinook salmon. Contrary to previous prioritizations, the

SIT used a two-phase process to develop alternative restoration strategies. The first phase used the fall-run DSM and optimal policy plots (described below) to simulate seven, 20-year long scenarios designed to contrast strategies that focused on implementing restoration actions across various areas in the basin. All of the strategies were compared to a No action / No restoration strategy to develop measurements of relative effect. These Phase 1 strategies included:

- A. Implement 5 optimal actions a year that maximized natural adult production valley wide.
- B. Implement 5 optimal actions a year with at least one action from a tributary in each diversity group as defined by NOAA fisheries (see Table 2 and Appendix D) that maximized natural adult production valley wide.
- C. Implement 5 optimal actions a year that that maximized natural adult production valley wide, but only work in non-hatchery streams.
- D. Implement 5 optimal actions a year that that maximized natural adult production valley wide, but only work in hatchery streams.
- E. Implement 5 optimal actions that resulted in the smallest increase in natural adult production valley wide.
- F. Implement 5 optimal actions a year with at least one action from a tributary in each diversity group as defined by NOAA fisheries (see Table 2 and Appendix D) that resulted in the smallest increase in natural adult production valley wide.

The results of the Phase 1 strategies are presented in Table 1 as changes from a model run that did not take any measures to improve conditions for salmon. The results of Phase 1 strategies also focused attention on a subset of watersheds that were consistently correlated with the greatest improvements to measurable attributes. These watersheds informed the selection of watersheds in Phase 2 and also facilitated a more focused discussion during the consideration of winter- and spring-run DSMs. Additional information regarding specific actions in specific watershed is available at <https://flowwest.shinyapps.io/DSM-results/>

Table 1. Results of Phase 1 Strategies (Fall-run DSM)

Scenario	Description	Juvenile Biomass at Chipps	Natural Spawners
A	Maximum Adults	61.9 %	97.6 %
B	Maximum Adults with No Hatchery Streams	44.8 %	93.2 %
C	Maximum Adults with Only Hatchery Streams	17.5 %	6.1 %
D	Maximum Adults with Diversity Groups	64.2 %	139.2 %
E	Minimum Adults	2.2 %	0.4 %
F	Minimum Adults with Diversity Groups	-0.2 %	-0.6 %

Table 2 presents a breakdown of the Diversity Groups used in the DSMs. Diversity Groups were used to evaluate spatial diversity among different strategies.

Table 2. Diversity groups and tributaries

Diversity Group	Tributaries
Basalt and Porous Lava	Upper Sacramento River, Cow Creek, Bear Creek, Battle Creek
Northwestern California	Clear Creek, Cottonwood Creek, Thomes Creek, Elder Creek, Stony Creek
Northern Sierra 1	Antelope Creek, Deer Creek, Mill Creek, Big Chico, Butte Creek Paynes Creek
Northern Sierra 2	Feather River, Yuba River, Bear River, American River, Consumnes River, Mokelumne River
Southern Sierra Nevada	Calaveras River, Merced River, Stanislaus River Tuolumne River

The results of the first phase were reviewed. Patterns that emerged from the analysis and potential anomalies were discussed (i.e., unexpected benefits of restoration actions in certain tributaries). Using this information, a revised list of 14 candidate restoration strategies (Table 3) was developed for further consideration. Two strategies were developed specifically pertaining to winter-run Chinook salmon: improving habitat in Battle Creek; and improving connectivity between the mainstem Sacramento and ephemeral non-natal tributaries that would have

required significant modifications to the DSM. However, there was insufficient time to complete the modifications to the DSM and inputs, so these strategies remained qualitative strategies that could be informed by the quantitative output of DSMs when formulating the final restoration strategy.

The third step in the process was to evaluate the effectiveness of each candidate restoration strategy to improve measurable attributes and best achieve SDM objectives using the DSMs. Policy plots were used to evaluate strategies requiring optimization, while the other strategies focused restoration into the various geographic areas.



Figure 2. Locations of Tributaries

Table 3. Phase 2 Strategies evaluated during SDM process.

Strategy	Description	Geographic Focus ¹
0	Implement no restoration	None
1	Juvenile perennial habitat restoration	Upper Sacramento River Lower-mid Sacramento River Butte Creek Deer Creek Battle Creek Stanislaus River Feather River
2	Juvenile perennial habitat restoration	Upper Sacramento River Lower-mid Sacramento River Butte Creek Deer Creek Clear Creek Stanislaus River Feather River
3	Juvenile perennial habitat restoration	Upper Sacramento River Lower-mid Sacramento River Butte Creek Clear Creek Stanislaus River Feather River Mokelumne River
4	Juvenile perennial habitat restoration	Sacramento River (all reaches) San Joaquin River (from confluence with Merced to Vernalis)
5	Juvenile perennial habitat restoration	Upper Sacramento River Lower-mid Sacramento River Cow Creek Clear Creek
6	Juvenile perennial habitat restoration and selected maintenance	Restore: Upper Sacramento River Lower-mid Sacramento River

¹ Locations of tributaries are in Figure 2.

STRUCTURED DECISION MAKING - FINAL

		American River Maintain: Butte Creek Clear Creek
7	Juvenile seasonally-inundated habitat restoration	Sacramento River (all reaches) San Joaquin River (from confluence with Merced to Vernalis)
8	Optimize* habitat restoration actions for winter-run Chinook salmon	Sacramento River (all reaches) More emphasis: Below Red Bluff
9	Optimize* habitat restoration actions for spring-run Chinook salmon	More emphasis: Upper-mid Sacramento River Lower Sacramento River Battle Creek Butte Creek Clear Creek Less emphasis: Lower-mid Sacramento River Deer Creek Mill Creek Antelope Creek
10	Optimize* habitat restoration actions for spring-run Chinook salmon	Upper-mid Sacramento River Battle Creek Butte Creek Clear Creek Deer Creek Mill Creek Antelope Creek Feather River
11	Optimize habitat restoration actions for fall-run Chinook salmon	One action per diversity group per year: Basalt and Porous Lava Northwestern California Northern Sierra 1 Northern Sierra 2 Southern Sierra Nevada Once action per year: Sacramento River San Joaquin River

12	Optimize* habitat restoration actions for fall-run Chinook salmon	Upper Sacramento River Lower Sacramento River American River Stanislaus River Calaveras Rivers
13	Optimize* habitat restoration actions for fall-run Chinook salmon	Upper Sacramento River Lower Sacramento River American River Stanislaus River Mokelumne Rivers
*See Figure 3 and associated discussion for description of optimization process		

Policy plots are graphical representations of state-dependent, globally optimal policies, which determine the optimal restoration actions for any condition that arises in the simulation. In the example policy plot presented in Figure 3, if a given reach has a monthly juvenile survival between 0.5-0.6, then the optimum solution is determined by the relative amount of spawning habitat per redd compared to the perennial rearing habitat per redd. In this example, different combinations result in the recommendations to:

1. increase juvenile rearing habitat (dark gray); or
2. increase spawning habitat (light gray); or
3. increase juvenile survival (black)

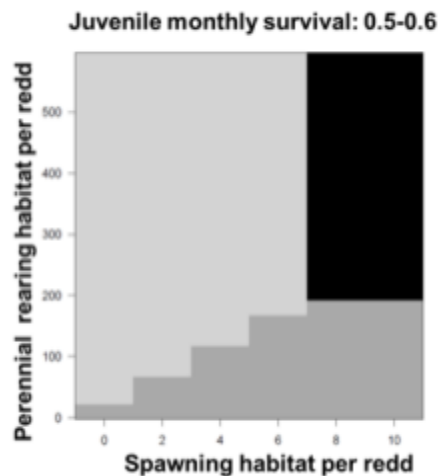


Figure 3. Example policy plot

STRUCTURED DECISION MAKING - FINAL

For the Phase 2 strategies that included the implementation of optimal restoration actions (strategies 8, 9, 10, 11, 12, and 13, in Table 3), policy plots were used to identify the optimal state-dependent restoration action at each time step for each tributary. In each modeled year of the 20-year scenario, restoration units were allocated to optimize model output subject to any constraint(s) described in the strategies.

For the remaining candidate strategies, only the DSM was used to simulate the implementation of strategy specific actions for the 20-year period. During each simulated year, five restoration actions were implemented at each location as required by the rules of the scenario. This annual level of effort was roughly estimated from the number of restoration projects implemented by CVPIA each year. Use of consistent units of effort ensured that restoration was equal across candidate strategies. Table 4 presents the units of effort used in the Phase 2 strategies. Simulations were run for each candidate strategy and Chinook salmon run and the five SDM objectives (metrics) were output for each year.

Table 4. Units of effort for restoration in Phase 2 strategies.

Restoration Action	Unit of effort
Spawning habitat	1 acre
Perennially inundated juvenile rearing habitat	2 acres
Seasonally inundated juvenile rearing habitat	3 acres
Juvenile survival	Increase 0.5%

The fourth step in the process was to identify the best-performing restoration strategies. This was accomplished by providing the results of the simulations in an Excel workbook and through the project website (fall-run, spring-run, and winter-run DSM results are available to review at <http://cvpia.scienceintegrationteam.com/#tools>). The candidate strategies were ranked from best to worst based on valley-wide estimates of total juvenile biomass at Chipps Island and natural production objectives. To facilitate comparisons across runs, the mean objective value across years was calculated and used to calculate utilities for each objective using proportional scoring (Conroy and Peterson 2013) that resulted in scores that ranged from 0 (worst strategy) to 1 (best strategy). The loss of implementing a candidate strategy relative to the best strategy also was calculated using the mean value as:

$$RL_i = \frac{Max(X) - X_i}{Max(X)}$$

Where, for strategy i , RL is relative loss of objective X (i.e., natural production and juvenile biomass). For relative loss, scores range from 0 (best strategy, least loss) to 1 (worst strategy, greatest loss).

The fifth step in the SDM process was sensitivity analyses. One-way sensitivity analysis was used to identify the model components or inputs that had the greatest effect on valley wide natural production. Response profile sensitivity analysis (Conroy and Peterson 2013) was used to evaluate the sensitivity of the rankings of the candidate strategies to the model components and inputs. Similar to one-way sensitivity analysis, one component or input was varied at a time to evaluate the change in the estimated score. Unlike one-way sensitivity analysis, the estimated natural production for each strategy is recorded. These values then are then plotted to examine how rankings of the scenarios change over the range of values for the model component. See Figure 4 for an example of how the selection of a best strategy may change based on the assumed value for a component or input. In Figure 4, the best strategy is the one with the highest natural production. Here, the rankings of strategy changes twice (arrows) across the range of prespawn mortality, which means that the best strategy depends on the estimated prespawn mortality.

Figure 4. Example sensitivity analysis for three restoration strategies

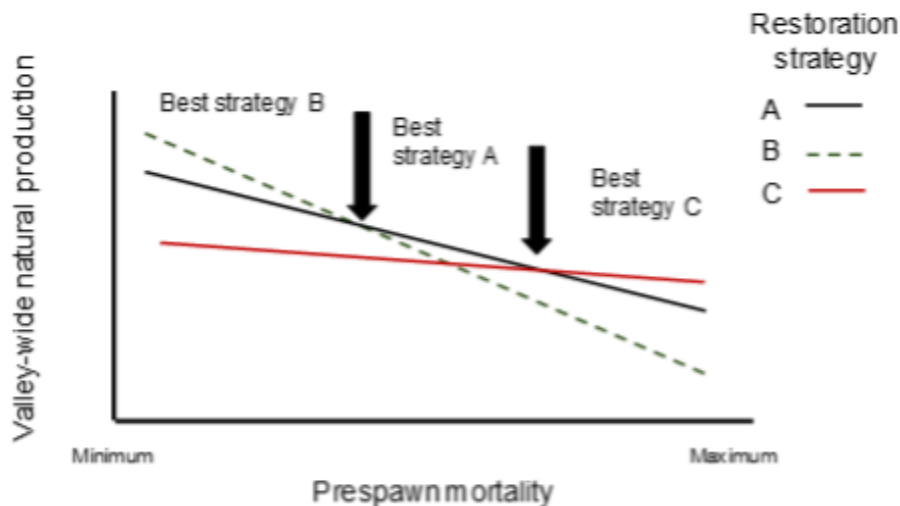


Figure 4. Example sensitivity analysis for three restoration strategies.

The final step was implementing the Strategy. The SIT recognized the importance of providing habitat to promote connectivity among the different locations throughout the Central Valley as a means to benefit all three runs of chinook salmon, through increased production and spatial diversity.

STRUCTURED DECISION MAKING - FINAL

The results of the simulated strategies were reviewed during in-person meetings on November 20-21, 2019 and characterized the actions that were to make up the Strategy using the following criteria:

1. Does the action contribute to connectivity?
2. Does the action contribute to spatial diversity?
3. Does the action contribute significantly to natural production?
4. Was the proposed action evaluated in any of the simulated strategies? If so, was the proposed action supported by the simulation results?

Additional considerations included the potential risks associated with an action and the opportunities to reduce the critical uncertainties identified during the sensitivity analysis. Critical uncertainties and high priority areas for research and monitoring also informed the recommendations. Research and monitoring priorities are intended to reduce uncertainties for future iterations of the DSM.

Finally, Chinook salmon DSM inputs and model components were qualitatively assessed in order to develop a path for improving critical elements of the DSM. Model components were identified that had been improved or modified since the previous evaluation which could be improved further as well as elements that had not been addressed since previous iterations. Model components were graded for their degree of empirical support and identified submodels that were published or parameterized with empirical data. The assessments can be found in Appendices B and C.

***O. mykiss* and sturgeon**

As discussed above, several SIT members who were also experts on Sturgeon or *O. mykiss* in the Central Valley recommended that -- in the near term, restoration efforts for these taxa would best be served by focusing efforts at reducing key uncertainties. Thus, the SIT worked with PWT members and other taxon-specific experts familiar with the Central Valley to identify and prioritize information needs for the next five years. The experts were provided with an overview of previous priorities from FY19 and FY20 efforts and information on what critical data and information were lacking to support the DSM and inputs. The discussions identified near-term (within five years) and long-term information needs focusing on the information needed by the SIT to improve and calibrate the taxon-specific DSM.

Results

Quantitative results from the DSMs were evaluated and provided a mechanism to focus discussion across complex geographies and taxa. The resulting strategy is informed by the DSM output and interpreted by the subject matter expertise of SIT participants.

Chinook salmon

The results of the DSM simulations indicated that for each salmon run there was a unique strategy that resulted in the best results across time, but they were different strategies for each run (see Figure 5). DSM outputs for fall-run and winter-run also revealed a pattern that was primarily due to the water years that were used as DSM inputs, 1980-2000. The large decrease in fall-run and winter-run natural production in years 10-16 correlates with the simulated effects on subsequent adult returns after the six-year drought that occurred from late 1986 through late 1992. Adults spawning in drought conditions and their resulting juveniles were subject to greater mortality, which would manifest in lower subsequent adult returns, even though the drought may have ended.

Assessment of relative utilities in Figure 6 show a much clearer contrast between the strategies. Strategies 5, 6, 7, and 10 were the best for winter, fall, and spring-runs, respectively based on natural production (Figure 6). Strategies 5 and 6 were also among the best for fall-run Chinook salmon based on natural production. Both strategies involved perennially inundated juvenile habitat restoration focused on the mainstem Sacramento River, the American River and Clear and Cow Creeks. Strategy 7 focused on creating seasonally inundated juvenile habitats in the mainstem Sacramento and San Joaquin Rivers, whereas strategy 10 implemented the optimal actions (based on previous optimized simulations) for spring-run Chinook salmon in the upper-mid Sacramento River and several tributaries in the upper Sacramento Basin. Interestingly, spring and fall-run natural production under strategy 8 -- the optimal winter-run strategy, was less than the no action strategy (0).

In contrast, the output for juvenile biomass revealed different patterns. Here strategies 9 and 10 produced the greatest juvenile biomass for winter and fall-run Chinook salmon, while strategy 2 produced the greatest biomass for spring-run Chinook salmon (Figure 6). Strategies 9 and 10 focused on implementing the optimal spring-run actions, while strategy 2 involved perennially inundated juvenile habitat restoration focused on the mainstem Sacramento River, the Feather and Stanislaus Rivers and several tributaries in the upper Sacramento Basin.

DSM output was also converted to a relative loss metric in order to determine the decrease in production any run would experience compared to the benefit accrued to another run. Zero loss indicates no cost in production relative to other runs. For this metric higher values are worse for the specific run. The relative loss metric suggested that decreases in natural production relative to the best strategy was relatively minor and did not vary greatly among runs and scenarios (Figure 7). The notable exception was for spring Chinook salmon under strategy 8, optimal winter-run strategy. winter-run Chinook salmon natural production relative loss was also greatest under Scenarios 0, 9 and 10. Relative loss in juvenile biomass revealed a different pattern with loss generally high for winter and spring-runs under scenarios 0, 2, and 11-13 (Figure 7). The last of the strategies (11-13) focused on implementing optimal fall-run actions in various configurations of tributaries.

STRUCTURED DECISION MAKING - FINAL

The DSM outputs allowed the SIT to focus on a subset of actions and locations and debate the relative merits of a comprehensive strategy that would benefit all three runs. During discussion, the concept of connectivity between habitats was identified as a valuable principle to organize and develop the final recommended strategy. Following that discussion, the SIT focused on strategies 8-13.

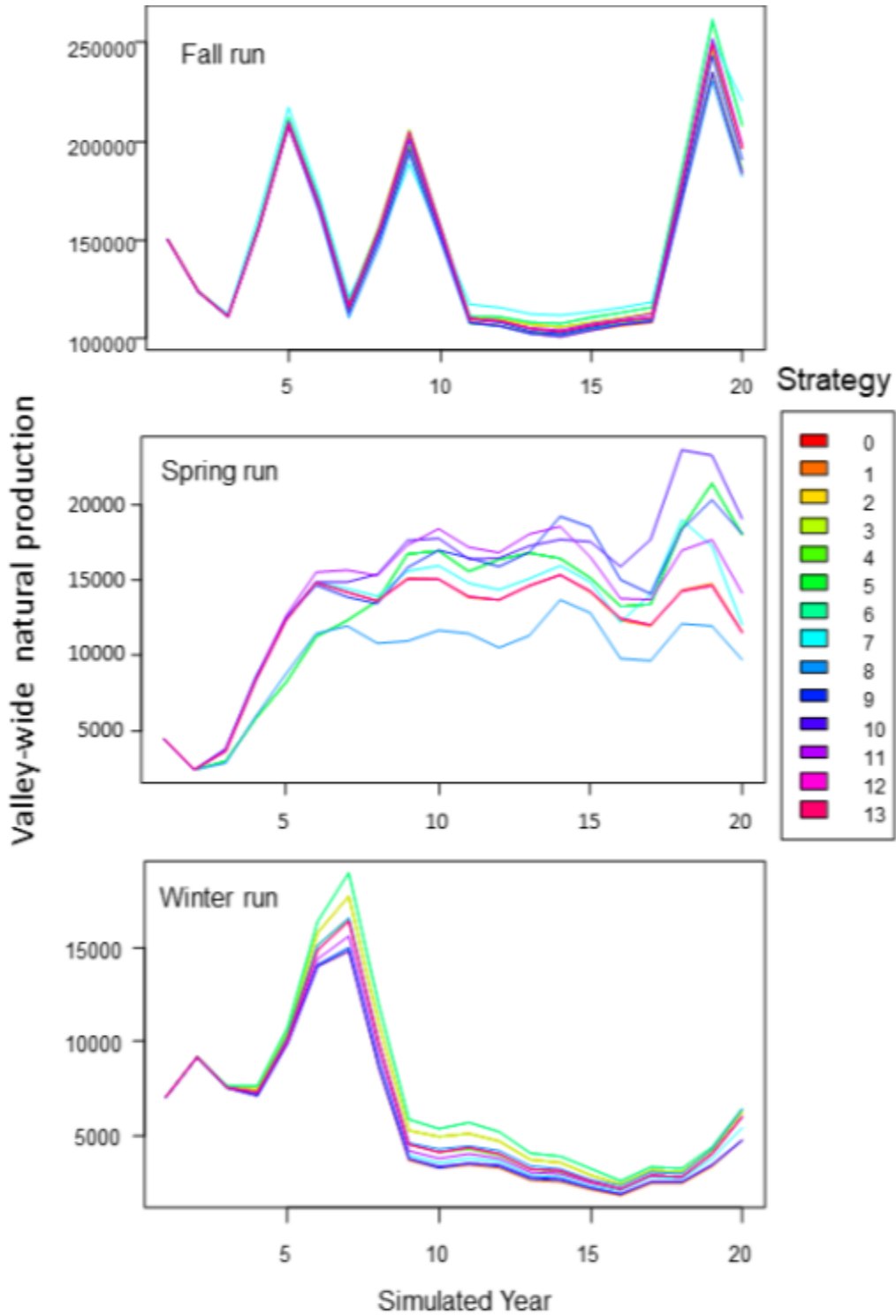


Figure 5. Modeled Chinook salmon natural production.

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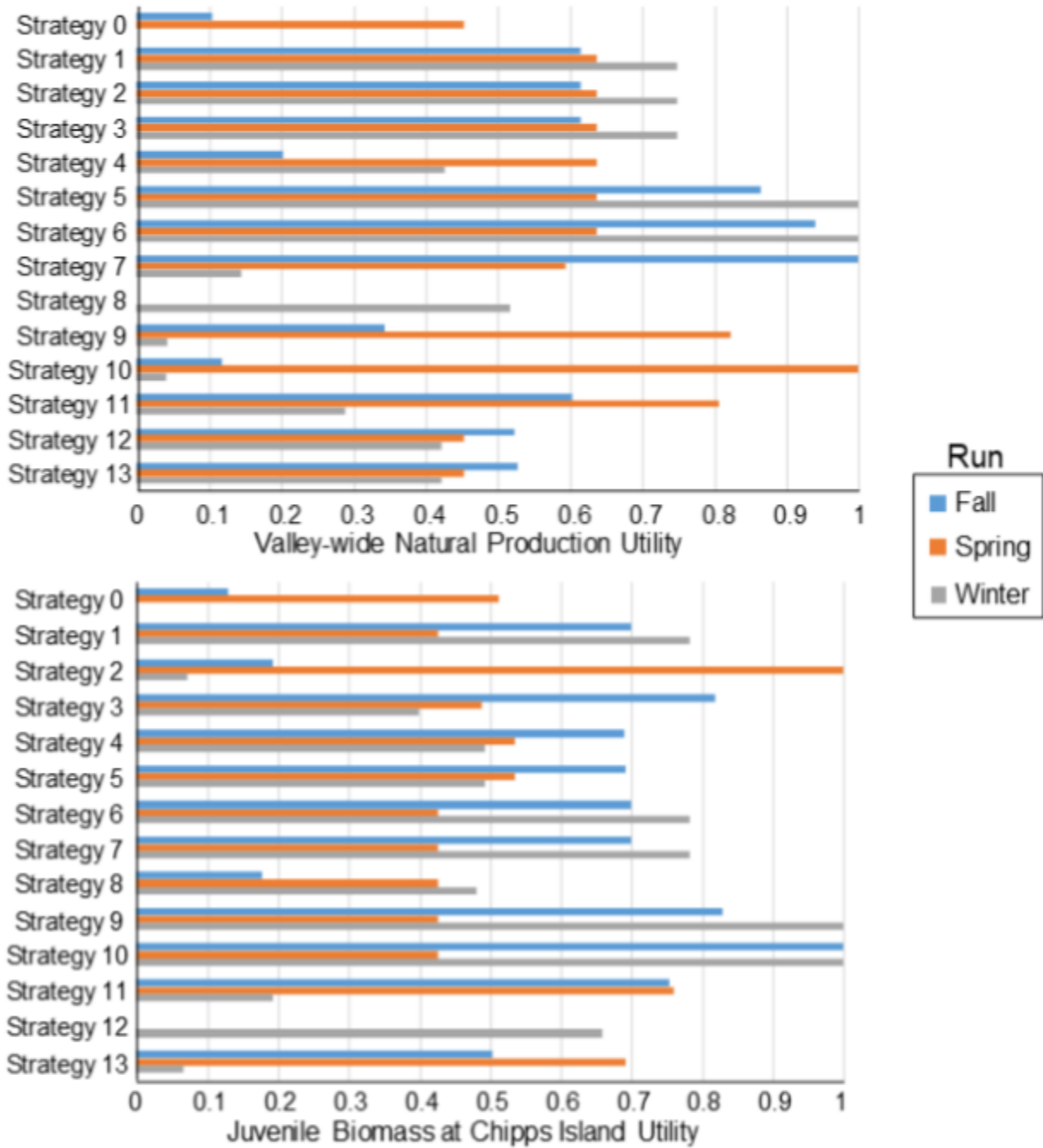


Figure 6. Natural production and juvenile biomass utilities.

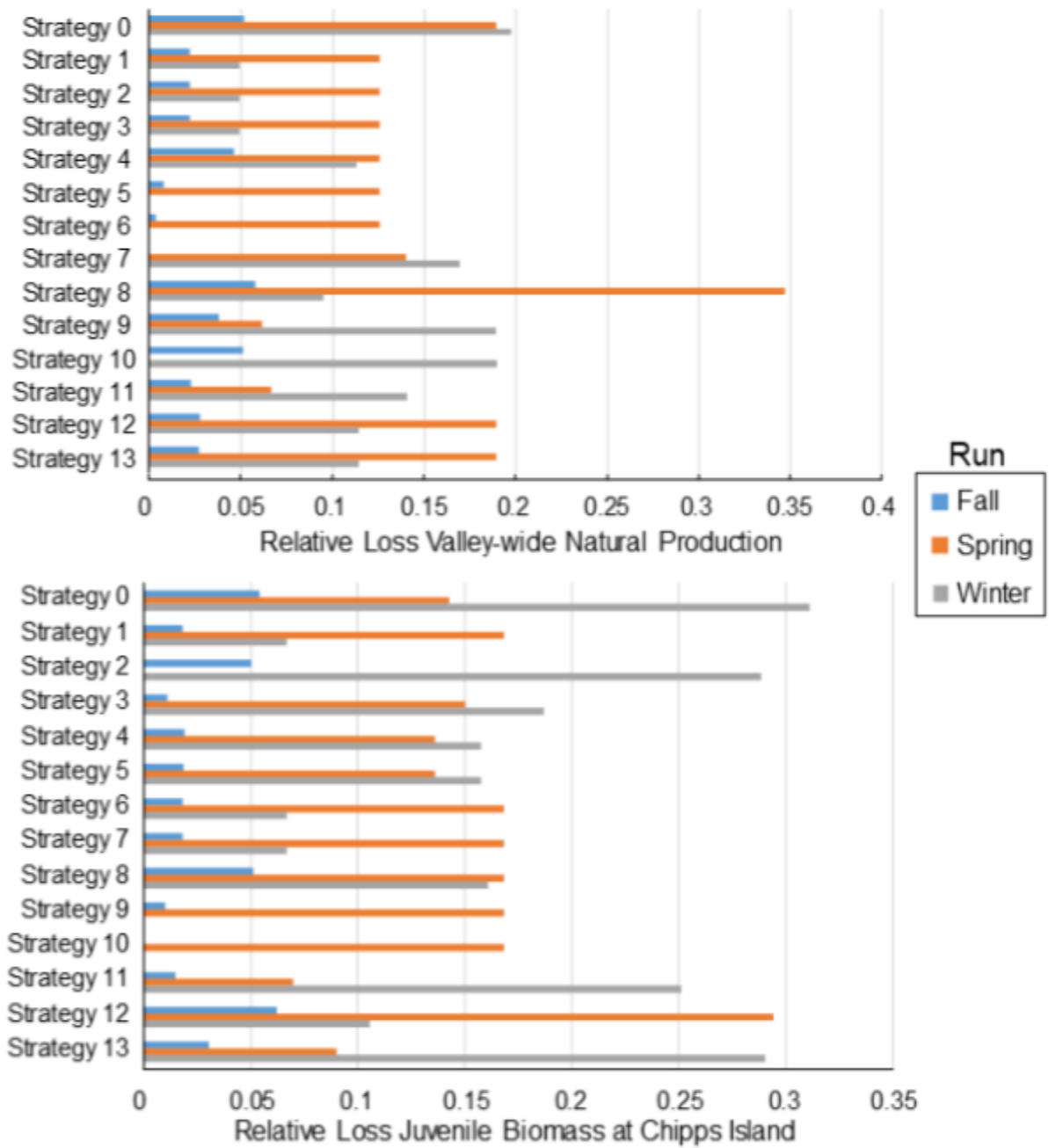


Figure 7. Relative loss of natural production and juvenile biomass utilities.

Table 5. Optimal actions selected during the simulation of strategies 8 - 13

Strategy	Location	Spawning Habitat	In-channel Habitat	Floodplain Habitat	Increase Survival
8	Upper Sacramento River		15		5
	Upper-mid Sacramento River		1	15	
	Lower-mid Sacramento River		18	9	
	Lower Sacramento River		19	8	
9	Upper-mid Sacramento River		1	14	
	Lower-mid Sacramento River		5		
	Lower Sacramento River			15	
	Antelope Creek				5
	Battle Creek		14		1
	Butte Creek		3		12
	Clear Creek	1	9		5
	Deer Creek				5
	Feather River		5		
	Mill Creek				5
10	Upper-mid Sacramento River			60	
	Antelope Creek				6
	Battle Creek		6		
	Butte Creek		7		
	Clear Creek		7		
	Deer Creek				7

STRUCTURED DECISION MAKING - FINAL

	Mill Creek				7
11	Upper Sacramento River		16		
	Upper-mid Sacramento River			2	
	Lower-mid Sacramento River		9	4	
	American River	1	11		
	Antelope Creek				1
	Battle Creek		3		
	Butte Creek				13
	Calaveras river				3
	Clear Creek		8		
	Cosumnes River				3
	Cottonwood Creek				12
	Cow Creek				1
	Deer Creek				6
	Feather River		5		
	Merced River				9
	San Joaquin River		3	2	
Stanislaus River		8			
12	Upper Sacramento River		20		
	Lower Sacramento River			20	
	American River	1	19		
	Calaveras River				20
	Stanislaus River		20		
13	Upper Sacramento River		20		
	Lower Sacramento River			20	

STRUCTURED DECISION MAKING - FINAL

	American River	1	19		
	Mokelumne River		20		
	Stanislaus River		20		

In the actions that were selected for strategies 8-13, spawning habitat was the least selected optimal action and was only selected 4 times, whereas juvenile rearing habitat restoration was selected 490 times with 66% of those being perennially inundated rearing habitat. See Table 5 for a summary of actions identified in strategies 8-13. For the spring-run simulations, increasing survival in the upper Sacramento River tributaries was selected more than 50 times with most of those for Butte Creek.

A complete list of all the potential actions and locations in all the strategies for fall-run, spring-run, and winter-run Chinook salmon is available at <http://cvpia.scienceintegrationteam.com/#tools>.

Sensitivity analysis

The sensitivity analysis indicated that the most influential model inputs included the current estimates of existing habitat across all runs and initial abundance for winter-run Chinook salmon (see Table 6). Sensitivity analysis of the model parameters indicated that the model was most sensitive to multiple juvenile survival parameters at all points in their life history (i.e., rearing, migrating) and at all locations included in the DSM (i.e., tributaries, mainstem, delta, and ocean; see Table 7). The second most influential parameters included juvenile growth and body size parameters, followed by reproduction parameters and adult survival along the migratory corridor and on the spawning grounds (Table 7). Improved understanding of these parameters would reduce sensitivity and increase confidence in model output.

Table 6. Changes to top 3 scenarios during input sensitivity analysis.

Model input	Fall	Spring	Winter	All
In-channel habitat	0	1	2	3
Initial abundance	0	0	2	2
Floodplain habitat	1	0	1	2
Spawning habitat	1	1	0	2

Note: Model inputs are grouped by type and sorted for most influential to least.

Table 7. Changes to top 3 scenarios during parameter sensitivity analysis.

Parameter	Fall	Spring	Winter	All
Juvenile survival				24
Juvenile delta outmigrant survival: Delta flow model weight	1	2	2	5
Juvenile ocean entry survival: Intercept	1	1	3	5
Juvenile rearing survival: Body size			3	3
Juvenile rearing survival: Number of contact points x high predator		1	1	2
Juvenile ocean entry survival: Month since transition			2	2
Juvenile rearing survival: Stranding			2	2
Juvenile bypass rearing survival: Intercept	1			1
Juvenile delta rearing survival: Intercept	1			1
Juvenile delta rearing survival: Number of contact points x high predator	1			1
Juvenile rearing survival: Intercept	1			1
Juvenile delta outmigrant survival: Intercept			1	1
Juvenile growth and territory size				18

STRUCTURED DECISION MAKING - FINAL

Growth in seasonally inundated habitats	1	1	5	7
Growth in perennially inundated habitats	3	2	2	7
Juvenile territory size: Body size relationship	1	1	2	4
<u>Reproduction</u>				12
Fecundity	1	1	3	5
Sex ratio	1	1	3	5
Redd size	1	1		2
<u>Adult survival</u>				8
prespawn survival: Intercept	1	1	2	4
en route survival: adult harvest rate	1		1	2
en route survival: Intercept	1		1	2
<u>Egg-to-fry survival</u>				3
Egg to fry survival: Prop. nat. orig. adult			2	2
Egg to fry survival: Egg viability	1			1
<u>Routing</u>				2
adult straying: Natural origin adult	1			1
Delta routing : Entrained into Georgiana	1			1
<i>Note: Parameters are grouped by type and sorted for most influential to least.</i>				

Interpretation of results into a strategy

The SIT met during workshops held November 20-21, 2019 to discuss strategy simulation results and to develop a recommended Strategy. The SIT discussed the importance of the CVPIA doubling goals and the value of demonstrating progress toward those goals, consistent with the recommendations of the Listen to the River Report, which form the basis for the mission of the SIT.

While developing the Strategy, the early discussion focused on the importance of increasing connectivity between tributaries and the mainstem and suitable habitats in the mainstem Sacramento and San Joaquin Rivers. Habitat fragmentation in riverine landscapes is recognized as one of the major factors responsible for the loss in aquatic biodiversity and productivity (Ward et al. 2002; Pringle 2003; Jansson et al. 2007; Fullerton et al 2010; Seliger and Zeiringer 2018). Thus, a long-term goal of the SIT is to increase connectivity throughout the Sacramento and San Joaquin River Basins. The Strategy is one step towards this goal and takes into consideration the uncertainty associated with implementing some restoration actions.

Spatial diversity is also an important factor that can promote stability and persistence in animal populations (Lindley et al. 2007; Carlson and Satterwaite 2011). Consequently, another long-term goal if the SIT is to maintain and increase the spatial diversity of anadromous populations in the Sacramento and San Joaquin River Basins. This goal is also reflected in the Strategy. The actions that comprise the SIT Strategy for Chinook salmon are in Table 8 and a description of each with the rationale is detailed below.

Table 8. SIT-recommended Strategy

Action ^a	Connectivity	Diversity group(s) ^c	Natural productivity	Supported	Runs primarily benefiting
Juvenile habitat restoration in mainstem Sacramento River above the American River confluence. One project in the Sacramento River between the Feather and American Rivers associated BACI design and tier 3 monitoring ^b	Yes	Basalt and Porous Lava, Northwestern California, Northern Sierra 1 &2	Yes	Yes	All
Reconnect ephemeral non-natal tributaries to the mainstem Sacramento River during a single	Yes	Basalt and Porous Lava	Yes	Yes	Winter

STRUCTURED DECISION MAKING - FINAL

project with BACI design and tier 3 monitoring					
Juvenile habitat restoration in American River	Yes	Northern Sierra 2	Yes	Yes	Fall
Juvenile habitat restoration in the Stanislaus River downstream through the San Joaquin River at Vernalis	Yes	Southern Sierra Nevada	Yes	Yes	Fall
Juvenile habitat restoration in Clear Creek		Northwestern California	Yes	Yes	Spring, Fall
Improve survival in Butte Creek in downstream areas		Northern Sierra 1		Yes	Spring, Fall
Juvenile habitat restoration in Battle Creek in winter-run juvenile rearing locations		Basalt and Porous Lava		NA	Winter
Juvenile habitat restoration in the lower Feather River below the confluence of the Yuba River	Yes	Northern Sierra 2		Yes	Fall, (Spring)
Maintain existing spawning habitats in Upper Sacramento, American, and Stanislaus Rivers; Clear and Butte Creeks		All		Yes	All
<p>^aAll juvenile habitat restoration is assumed to consist of mixtures of perennial and seasonally inundated habitats</p> <p>^bTier 3 monitoring would not be necessary if monitoring/research were conducted at Southport Levee setback. See Appendix C for more information on CVPIA Monitoring Guidance</p> <p>^cSee Appendix D for more information on Diversity Groups</p>					

Areas of emphasis for restoration

Rationale for the restoration areas of emphasis are described below. These descriptions serve as recommendations for funding to the implementing agencies.

Mainstem Sacramento above American River confluence

Efforts to increase in-channel and floodplain juvenile rearing habitat restoration efforts in the mainstem Sacramento River were among the top actions for increasing valley wide natural production and juvenile biomass at Chipps Island across all runs. Restoring juvenile habitats in the mainstem Sacramento River would increase connectivity between natal tributaries and the dDelta and would potentially serve as refugia from predators.

The SIT discussed which sections of the Sacramento River should be focus of restoration efforts. The juvenile habitat restoration in the upper Sacramento River (above Red Bluff) was selected most often in the optimal fall-run scenarios, whereas the upper-mid (Red Bluff to Feather confluence) and lower (American confluence to Freeport) Sacramento River were most often selected for spring-run and all sections were approximately equally selected for winter-run. The SIT discussed the suitability of the lower-mid and lower Sacramento River. Previous tagging studies suggested that juvenile Chinook salmon mortality was very high through these sections presumably due to predation and high temperatures. It was pointed out that habitat restoration may provide refuge from predation in these sections. These sections also have the potential to serve as rearing habitat for most Sacramento River Basin juveniles and all runs from multiple upstream tributaries.

However, there is currently no information on whether juvenile habitat improvements in these two sections would result in increased survival. The uncertainty regarding survival and habitat use through the sections makes restoration potentially risky. Therefore, near-term, the SIT recommends focused juvenile habitat restoration in the Sacramento River above the confluence with the American River and simultaneous research efforts focused on improving understanding of juvenile survival. The SIT assumed that the juvenile habitat restoration would consist of a mixture of both perennially and seasonally inundated habitats based on the opportunities available at the restoration areas. The intent is to enhance connectivity, benefit all Chinook salmon runs, benefit three diversity groups, and result in the greatest progress toward the doubling goal.

The SIT also recognized the high uncertainty of restoration actions in the lower-mid Sacramento River section (Feather River to the American River) and place high priority for a single restoration effort in that section if there is an opportunity to learn through a before-after, control-impact (BACI) design and tier 3 monitoring effort. However, the Southport Levee setback project in the lower Sacramento River has the potential to provide information on the use and survival of juvenile Chinook salmon in the near term without requiring the time needed to plan and implement a restoration project through a BACI design. In the absence of an adaptive

STRUCTURED DECISION MAKING - FINAL

management restoration project in the lower-mid Sacramento River, the SIT places a high priority in studying the use, growth, and survival of juvenile salmonids using the Southport Levee setback.

Non-natal rearing along mainstem Sacramento for winter-run Chinook salmon

The SIT agreed to consider two qualitative winter-run actions for the restoration strategy because the DSM could not be modified in time to evaluate the strategies quantitatively. The first strategy was increasing connectivity between the mainstem Sacramento River and ephemeral tributaries. Reconnecting ephemeral tributaries is consistent with the long-term SIT goal of increasing connectivity and recent studies have highlighted the importance of non-natal rearing habitat to winter-run Chinook salmon (Phillis et al. 2018). As detailed in the FY20 Tech Memo, these tributaries are often dry at the mouths and thus unavailable for juvenile winter-run Chinook Salmon during their rearing period in the upper river (late July into autumn months). Access to non-natal tributaries is periodically available during rain events or if water diversions on these tributaries are stopped for the off season (typically in Oct). In addition, SIT members indicated that these ephemeral tributaries serve as *O. mykiss* spawning habitats and reconnection would benefit multiple species. However, juvenile salmonids (non-winter-run Chinook salmon) can become stranded in these tributaries, so there are potential risks associated with the reconnections. Therefore, the SIT prioritizes one restoration effort that reconnects ephemeral tributary(ies) to the Sacramento River mainstem with an accompanying BACI design and tier 3 monitoring to quantify the benefits and risks of the reconnection restoration strategy.

Battle Creek

The second qualitative strategy for winter-run Chinook salmon was improving juvenile winter-run habitat in Battle Creek. The SIT discussed, at length, the ongoing efforts to establish winter-run in Battle Creek and the need for juvenile habitat improvement in winter-run sections of the river. Although this was not a strategy that was evaluated with the DSM, the SIT prioritized juvenile habitat restoration for winter-run in Battle Creek as part of the Strategy. The express intent is to facilitate an increase in spatial diversity of winter-run and increase natural production of winter-run Chinook salmon. This was also a high priority in the SIT FY20 Tech Memo. The SIT assumes that the juvenile habitat restoration would consist of a mixture of both in-channel and floodplain habitats based on the opportunities available at the restoration areas.

American River

Four of the five candidate strategies with the greatest predicted increase in natural production included substantial increases in juvenile habitat restoration in the American River. The American River also serves as rearing habitat for winter-run Chinook Salmon (Phillis et al. 2018) and is the member of the subdivided south Northern Sierra diversity group with the greatest potential to increase fall-run natural production based on the DSM. As above, the SIT assumes

that the juvenile habitat restoration would consist of a mixture of both in-channel and floodplain habitats based on the opportunities available at the restoration areas.

Stanislaus River

The SIT discussed the need for spatial diversity in keeping with their long-term goals and the lack of representation of Southern Sierra Nevada tributaries in the restoration strategy. Of those tributaries, juvenile habitat restoration in the Stanislaus River was consistently chosen in numerous fall-run optimization strategies. The two candidate mainstem juvenile habitat restoration strategy simulations indicated that efforts in the mainstem San Joaquin River would also be beneficial to fall-run natural production. The SIT also discussed the desire to increase connectivity in the San Joaquin River below the CVPIA tributaries. Thus, SIT prioritized juvenile rearing habitat restoration activities for the Stanislaus River and downstream to San Joaquin River at Vernalis. This would provide a benefit to Stanislaus River juvenile Chinook salmon and those from other tributaries in this diversity group. SIT assumed that the juvenile habitat restoration would consist of a mixture of both in-channel and floodplain habitats based on the opportunities available at the restoration areas.

Clear Creek

Clear Creek has consistently produced fall-run and spring-run Chinook salmon and the SIT recognizes that it has the potential to increase the natural production of both runs. The DSM results indicated that Clear Creek was included in the candidate strategies with the greatest increases in natural production and was frequently chosen for juvenile habitat restoration during the optimal spring-run and fall-run strategies. Based on the strategy simulations, juvenile habitat restoration in Clear Creek has the greatest potential to increase productivity in the Northwestern California diversity group. The SIT also assumed that the juvenile habitat restoration would consist of a mixture of both in-channel and floodplain habitats based on the opportunities available at the restoration areas.

Butte Creek

When evaluating the simulation output, the SIT observed that increasing survival in Butte Creek was frequently selected in the optimal spring-run candidate strategies as benefiting spring-run Chinook salmon. Members of the SIT familiar with the Butte Creek indicated that there were problems in the lower portion of the creek that affect juvenile salmonid survival. To address these problems, the SIT prioritizes restoration actions that increase survival in lower Butte Creek. However, it is recognized that some degree of monitoring or research may be required to identify appropriate actions prior to implementation.

Feather River below confluence with the Yuba River

The final Chinook salmon restoration priority adopted by the SIT is the creation of juvenile rearing habitat in the lower Feather River, below the confluence with the Yuba River. The DSM

STRUCTURED DECISION MAKING - FINAL

simulations indicated that juvenile habitat restoration in the Feather River would be beneficial toward increasing natural production of fall-run Chinook salmon. The SIT requested the lower portion of the river to benefit juveniles from the Bear and Yuba Rivers and increase habitat connectivity with the Sacramento River.

Ongoing maintenance of spawning habitat

During the strategy simulations, the best performing strategy for fall Chinook Salmon contained the caveat that spawning habitat in several tributaries be maintained during the simulation period. In keeping with the desire of the SIT to show progress (i.e., not go backward), the SIT prioritized the maintenance of spawning habitat in Upper Sacramento, American, and Stanislaus Rivers; as well as Clear and Butte Creeks.

Information needs of the SIT

The SIT recognized that although the DSMs represent the best snapshot of current understanding for chinook salmon in the Central Valley, there is substantial uncertainty regarding the influence of inputs and parameters that could have a large effect on DSM outputs and subsequent prioritizations. Additionally, development of DSMs for *O. mykiss* and sturgeon will require development of additional information.

The SIT identified information needs for each taxa. Information needs for chinook salmon focused on DSM inputs and DSM components that were influential in the Chinook salmon simulations as well as the knowledge of SIT members. The *O. mykiss* and Sturgeon information needs were based on the knowledge of the experts and PWT members for their respective taxon. The SIT expects that efforts selected to address these needs will coordinate with the SIT on the design of their monitoring and research activities to ensure that information developed will be consistent with the needs of the SIT. This coordination would occur during future SIT calls and in-person meetings similar to the predator contact point investigation.

Chinook salmon research

Results of the sensitivity analysis, SIT discussions during the prioritization, and the model grading were used to identify the most influential model parameters for the chinook DSMs. Increasing the certainty related to these inputs and parameters will require additional, targeted research in the Central Valley.

Juvenile survival

By far, juvenile survival in all locations (i.e., tributaries, mainstems, delta, and ocean) was the single most influential factor driving variability of DSM output and results. Juvenile survival components were based on published studies, expert knowledge of SIT members, and model intercepts estimated during calibration. In the DSM, only juvenile out-migrant and ocean entry survival are based on empirical data (i.e., marked hatchery fish). Although these are the best

estimates available, previous studies have reported substantial differences in juvenile survival and behavior between hatchery and wild fish (Hill et al. 2006; Beamish et al. 2012; Berejikian 1995; Fritts et al. 2007; Kostow 2004; Pinter et al. 2018; Salvanes 2017; Wessel et al. 2006). Thus, a critical information need is empirical estimates of wild juvenile Chinook salmon survival in all rearing areas and the ocean. Identification of factors affecting wild juvenile survival will be important for identifying management actions that could improve survival (Table 9).

Investigations should focus on the effects of habitat, temperature, stream flow, and prevalence of medium to large body sized piscivores. Improved understanding of these effects could then be incorporated into the SIT conceptual models and subsequently into the DSMs. Obtaining reliable estimates will require a period longer than the Strategy (i.e., five years) because adult fish may not return until after 2025. Survival may be estimated through existing restoration actions subject to tier 3 monitoring with BACI design. However, this may prove inefficient and may require more time to implement. More expeditious, coordinated research directly studying wild juvenile Chinook salmon survival and other demographic parameters (e.g., growth, movement, *see below*) would likely provide more comprehensive estimates and understanding within the five-year timeframe of this Strategy. Greater efficiency could be obtained if the research efforts were coordinated with similar ongoing or proposed studies (*see O. mykiss, below*). An example of an ideal long-term juvenile salmonid tagging project on a listed ESU is Schroeder et al. (2016).

Juvenile growth

The next most influential parameter in the Chinook salmon DSM is juvenile growth. Currently, growth is modeled as constant (mean and SD) in time and between tributaries but varying between in-channel and floodplain habitats. The values were obtained from published sources. A subgroup of the SIT is currently working on incorporating two factors known to affect growth, temperature and food, which will improve the growth estimates. However, the sensitivity of the DSM to growth and lack of empirical estimates of the growth of wild juvenile Chinook salmon in the CV dictate that it is a critical information gap that is needed by the SIT. Therefore, it is a high priority information need (Table 9). Given the planned near-term improvements to the growth model, the information would be gained more efficiently through a tier 2-3 monitoring associated with a restoration charter.

Juvenile movement

In the course of discussing the Chinook salmon DSM and sensitivity analysis, the SIT was concerned with the movement rulesets used in the DSM. In particular, the current DSM does not model fish movement out of suitable habitats when temperatures get too warm. Rather, the habitat holds fish and fish subsequently die if temperatures get too warm. In addition, the current DSM models assume that habitat use is:

1. Relatively static (i.e., once a fish finds suitable habitat, it stays until it gets large enough to smolt);

STRUCTURED DECISION MAKING - FINAL

2. Based on fish size (i.e., largest fish fill available habitat first until all habitat is filled then the remaining fish leave); and,
3. Floodplain habitats are filled before in-channel habitats.

Additional information about salmon movement would improve conceptual models and could result in revised DSMs.

Territory size

Sensitivity analysis also indicates that territory size is an influential parameter because it determines habitat capacity. Because the DSM uses a single habitat use and movement rule set for rearing fishes, sensitivity analysis could not be used to determine the relative influence of the rules. Variance in territory size likely results in substantial changes to DSM output. Thus, information on the movement of wild juvenile Chinook salmon and the effects of habitat and temperature on movement is a high priority SIT information need. As with growth, this information can be obtained through tier 2 and tier 3 monitoring associated with ongoing or future restoration charters (Table 9)

Southport levee setback

As discussed earlier, the Southport Levee setback project in the lower Sacramento River has the potential to provide information on habitat use and survival of juvenile Chinook salmon in the near term without requiring the time needed to implement a restoration project learn through a BACI design. In the absence of an adaptive management restoration project in the lower-mid Sacramento River, the SIT places a high priority in studying the use, growth, and survival of juvenile salmonids using the Southport Levee setback.

Chinook salmon monitoring

The SIT also identified monitoring efforts that would inform the conceptual models and DSMs.

Habitat estimates

The amount of habitat of all types currently available in the Sacramento River tributaries and mainstem is used to determine optimal state-dependent restoration actions, so habitat is a very influential parameter. Most of the habitat availability estimates are based on field studies.

However, most of the studies are > 10 years old (see for example:

<https://flowwest.shinyapps.io/habitat-modeling-availability/>). Habitats in many tributaries has likely changed during that time (e.g., Feather River after the Oroville Dam crisis). In addition, several habitat inputs had to be adjusted during the calibration to improve the fit of the DSM (Appendix A). The adjustments were necessary in a subset of tributaries (<https://flowwest.shinyapps.io/cvpia-model-inputs/>, select category Habitat). Therefore, the SIT places a high priority on improving contemporary habitat information in the mainstem Sacramento River upstream of the American River Confluence, American River, Stanislaus

River, San Joaquin River downstream of Stanislaus River to Vernalis, Clear Creek, Battle Creek, Feather River, and Yuba River. A SIT subgroup was formed to identify which of these locations will require directed study to update the habitat estimates. For the remaining locations, habitat availability estimates can be improved by incorporating information from projects through the restoration charter monitoring (Table 9)

Habitat change over time

Models of habitat change through time were identified as a high priority through the SIT proposal process. For more information, please refer to the SIT Guidance. These have yet to be incorporated into the DSMs. Instead, the DSMs used expert-based constants to model habitat change during the DSM simulation. The habitat change models created by the SIT subgroup will be incorporated into the DSM. However, the SIT places high priority on monitoring the change in habitat availability through time at restoration projects and adjacent areas through the restoration charter monitoring (Table 9).

Long-term monitoring

Long-term monitoring data on juvenile production, adult escapement, and prespawn mortality were used to calibrate the DSM and will likely be used to calibrate future DSMs and to evaluate the outcomes of this Strategy. Therefore, continued collection of this information is a high priority for the SIT. Locations with long-term monitoring that implement consistent monitoring (e.g., screw traps in the same locations) and provide higher quality estimates (e.g., through screw trap calibration) are highest priority for maintaining a high quality dataset and subsequent DSM (Table 9).

Table 9. Chinook salmon information priorities.

Information needs	Monitoring	Directed study	Duration	Implementation
Juvenile Chinook salmon survival: tributaries, mainstem, delta, ocean, and the effect of habitat on survival	Yes	Yes	>5 years	Restoration charter tier 3 Research charter
Juvenile Chinook salmon growth: tributaries, mainstem, delta, and the effect of habitat on growth		Yes	2-3 years	Restoration charter tier 2-3 SIT subgroup
Juvenile Chinook salmon movement: site fidelity and effect of habitat type, the effect of temperature and flows on movement		Yes	2-3 years	Restoration charter tier 3
Juvenile Chinook salmon territory size: site fidelity and effect of habitat type and other conditions	Yes	Yes	2-3 years	Restoration charter tier 3
Southport Levee setback assess fish use, growth, and survival		Yes	2-3 years	Research charter
Update habitat modeling and estimates for: Sacramento River upstream of American River, American River, Stanislaus River, San Joaquin River downstream of Stanislaus River to Vernalis, Clear Creek, Battle Creek, Feather River, Yuba River	Yes	Yes	2-3 years	Restoration charter, tiers 1-3 SIT subgroup
Habitat change through time	Yes		3-5 years	Restoration charter, tier 3 SIT subgroup
Juvenile Chinook salmon production emphasis on tributaries with existing long term data that are calibrated: American River, Red Bluff Diversion Dam, Stanislaus River, Mokelumne River, Clear Creek, Feather River	Yes		>5 years	Varies
Adult escapement and prespawn mortality	Yes		>5 years	PFSMC funding

***O. mykiss* research and monitoring**

In previous *O. mykiss* prioritization efforts, the most often identified information need was to identify factors that facilitate anadromy of *O. mykiss*. For three years (FY18-20), the SIT prioritized implementation of projects that sought to increase the frequency of *O. mykiss* anadromy. The general tenor of the previous prioritization meetings was that the Central Valley contained sufficient *O. mykiss* populations, but not enough fish were exhibiting anadromous life history. Thus, the SIT information priority for the Strategy is to identify factors that facilitate anadromy of *O. mykiss*. A smaller group of SIT members with other *O. mykiss* experts met to discuss research needed to identify those factors, which are summarized in Table 10.

Demographic information

Previous research reported that the anadromous life history is influenced by multiple, interacting factors including genetics, somatic growth, body condition, and survival during early life history, size and age at maturity, and environmental conditions, such as flow and temperature (Kendall et al. 2014 and references therein). Thus, the experts identified demographic information on juvenile *O. mykiss*, survival, age and growth, as high priority but noted that it would require a longer term than the Strategy (i.e., more than 5 years) to capture inter-annual variation. The experts noted that a demographic study may be more successful if conducted in paired tributaries with different environmental conditions to provide a greater contrast in how environmental conditions affect demographic rates and ultimately, anadromy. In the San Joaquin River Basin, examples of such pairs include the Stanislaus River and the Merced or Tuolumne Rivers. In the Sacramento River Basin, examples of tributary pairs include Clear Creek and Deer or Mill Creeks.

Habitat estimates

The habitat inputs for the *O. mykiss* DSM are incomplete for larger sized *O. mykiss* and many of the juvenile habitat estimates are based on juvenile Chinook salmon habitat. Habitat will likely be influential in *O. mykiss* DSM simulations based on the Chinook salmon results. Therefore, habitat estimates, particularly larger *O. mykiss* habitat availability, are a high priority information need for the Strategy (Table 10). Greater efficiency in obtaining the estimates may be obtained if efforts were combined or collaborated with other habitat estimation efforts in the Central Valley.

Evaluate contrasting tributaries

The experts discussed the lack of comprehensive information on the degree of *O. mykiss* anadromy across the Central Valley. Such information could be used to evaluate relationships between anadromy and environmental factors and provide insights into factors that may be manipulated (e.g., flow) to facilitate anadromy. In addition, the information could be used to track progress toward the SIT *O. mykiss* objectives, frequency of anadromy. Therefore, another *O. mykiss* information priority is information on the prevalence of anadromy across the Central

STRUCTURED DECISION MAKING - FINAL

Valley. As discussed above, the experts suggested that projects may be more successful if evaluations are conducted in locations with contrasting environmental conditions including ephemeral tributaries in the Sacramento River Basin, which are hypothesized to be significant producers of the anadromous life history.

Long-term monitoring

Long-term data on *O. mykiss* smolt production and adult escapement will likely be used to calibrate future DSMs and to evaluate the outcomes of future restoration strategies. Therefore, *O. mykiss* smolt production and escapement information is a high priority for the Strategy. The existence of complete long-term data is rare for *O. mykiss*, so greater propriety should be given to locations with long- or medium-term data (i.e., more than 5 years) collected with consistent monitoring designs and estimators to facilitate calibration.

Table 10. O. mykiss information priorities.

Information needs	Monitoring	Directed study	Duration	Implementation
Juvenile <i>O. mykiss</i> survival in tributaries, mainstem, delta, ocean with contrasting survival in tributaries with different environmental conditions, see text for explanation		Yes	>5 years	Research charter
Juvenile <i>O. mykiss</i> age and growth in tributaries and mainstem with contrasting growth in tributaries with different environmental conditions, see text for explanation		Yes	>5 years	Research charter
Habitat modeling and estimates for larger sized (> 120 mm) <i>O. mykiss</i> habitats, including in ephemerally connected streams		Yes	2-3 years	Research charter
Spatial distribution of anadromy prevalence, see text for explanation		Yes	2-3 years	Research charter
Genetic trends in <i>O. mykiss</i> populations through time	Yes		>5 years	Research charter
Juvenile <i>O. mykiss</i> production with emphasis on locations with existing long-term data [DA1]	Yes		>5 years	

O. mykiss redd counts	Yes		>5 years	
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Sturgeon research and monitoring

Members of the sturgeon PWT met December 16, 2019 and discussed both near- and long-term information needs priorities. Near-term information needs are priorities the group believed would provide useful information and data for improving the existing Sturgeon DSMs within five years. Long-term information needs are priorities the group believed could provide useful information for improving the existing sturgeon DSMs in five years, but acknowledged that these priorities will require more than five years study properly link these estimates to environmental heterogeneity and environmental drivers of sturgeon populations. Note that the group discussed other topics they believe are important but not as urgent of an issue as the agreed upon priorities. For example, the group discussed the need for basic information on life history variation (including genetic, phenotypic, or other traits), and the influence of predation and poaching on sturgeon. The group believes reducing these uncertainties would benefit sturgeon conservation, but that the below priorities are of greater importance. Priorities discussed below apply to both green and white sturgeon unless specified.

Long-term needs

The group discussed how patterns of recruitment for sturgeon are intermittent, and spike approximately every ten years associated with wet years. This is concerning because cohorts from these spike events are critical to maintain sturgeon populations. Thus, the PWT believes a long-term, targeted monitoring effort focused on estimating juvenile survival and growth of larvae to age-1 fish is needed. The group discussed the importance of estimating these parameters for wild fish (rather than fish in laboratories or mesocosms) and the need to have this monitoring effort in multiple locations to capture spatial variability in recruitment. They also noted that data collected as part of ongoing studies (in the Sacramento River at Red Bluff Diversion Dam) and previous studies (in the San Joaquin River) could be useful in these efforts.

The group discussed the importance of understanding how adult Sturgeon survive and move through the system in relation to environmental factors. This information would be useful for integrating with the DSMs and will directly inform conservation efforts for Sturgeon.

The group discussed the importance of developing long-term monitoring efforts focused on tracking spawner abundance. This information will be useful for DSM calibration and provides information on the status and trends of sturgeon.

Short-term needs

The group discussed ongoing projects that are focused on the types of habitat juveniles are using while rearing and types of habitats adults are using while spawning. These projects are currently location specific. However, the group believes a priority would be to use these data to

STRUCTURED DECISION MAKING - FINAL

refine current habitat definitions, and relate habitat to environmental factors (i.e., temperature, flow, etc.) in order to expand habitat estimates to multiple locations across the Central Valley.

The group discussed the fact there is more information concerning where green sturgeon spawn than white sturgeon. Although they suspect that the majority of white sturgeon spawning occurs somewhere in the Middle Sacramento River, exact reaches where spawning occurs is poorly understood. Some spawning locations have been documented in the San Joaquin River, but due to poor habitat and high temperatures, it is likely that San Joaquin River spawning is unsuccessful in most years. They discussed the importance of developing a better understanding of where white sturgeon spawn for both the DSM and white sturgeon conservation in general.

Table 11. Sturgeon information priorities.

Information needs	Monitoring	Directed study	Duration	Implementation
Early juvenile survival and growth of wild fish (larvae to age 1)		Yes	>5 years	Research charter
Adult and subadult survival and movement (system wide), see text for explanation		Yes	>5 years	Research charter
Estimate juvenile rearing and adult spawning habitat availability (system wide)		Yes	2-3 years	Research charter
White Sturgeon spawning distribution, see text for explanation		Yes	2-3 years	Research charter
Spawner abundance monitoring	Yes		>5 years	Research charter

Implementation

Implementation of the Strategy will be critical to its success. In the past, implementation has been conducted separately from prioritization, resulting in loss of data and feedback for future prioritization and lack of knowledge transfer between implementation projects. This section outlines implementation guidance to:

1. improve efficiencies of CVPIA efforts,
2. monitor performance,
3. establish interaction between SIT prioritization efforts with research and monitoring efforts
4. provide stewardship for data generated by the CVPIA, and
5. facilitate transfer of knowledge

Implementation guidance is intended to improve and support Adaptive Resource Management (ARM) within the CVPIA program. Implementation of the Strategy requires increased standardization of implementation, including consistent project development, design, data collection and dissemination, monitoring, and research. If successful, implementation guidance should improve the knowledge base, improve future restoration efforts, and improve program efficiency.

Identification and selection of charters

This Strategy is a consultative document intended to inform expenditures from the Restoration Fund, but is not binding on the implementing agencies. However it is important that the SIT be made aware of charters selected for implementation so that data and knowledge from those charters can be used for future prioritizations, improve the existing DSMs, and facilitate ARM. Where possible the SIT and / or SIT subgroups should provide guidance directly to charters for data management, monitoring methods, and research needs. Additionally, teams implementing charters could provide valuable insight for project costs, timelines, and local conditions that would improve the quality of SIT Tech Memos, Strategies, and DSMs.

Implementation Guidance

The SIT should develop and maintain a repository of project information from prior-funded restoration, monitoring, and research projects. This repository would serve as a resource for developing future projects. Types of information collected are described below.

Project development

Information related to project development would include environmental documentation and permitting, feasibility reports, and conceptual models. This information would be valuable to establish lead times from project concept to project initiation. Where possible, some of this information could be developed into templates to expedite environmental reviews and

STRUCTURED DECISION MAKING - FINAL

permitting. Some information may also be valuable to share best practices for project development, including stakeholder involvement, landowner relations, and project identification.

Project design

Examples of project design, including technical aspects such as hydraulic modeling, design specifications, design drawings and as-builts, research design, and monitoring specifications should be collected to develop a repository of design approaches. Maintaining an open approach to project design and best practices should expedite development of new efforts.

Data

The purpose of data guidance is to increase, manage, and protect the value of data needed and generated by the SIT and CVPIA-funded efforts. In order to implement SDM, the agencies needed to assess all of the data available to build decision models and improve the basis and defensibility of decisions. Detailed guidance on best data practices and data requirements for CVPIA-funded projects are outlined in Appendix B.

Monitoring

CVPIA restoration projects will be categorized into categories of monitoring for ongoing or proposed restoration activities based on the degree of uncertainty reduction. Each action will be evaluated by the Science Coordinator and a designated subgroup of the SIT with relevant technical expertise. CVPIA restoration activities will be placed into categories based on the potential of each project to reduce key uncertainties. Categories would map into three distinct monitoring tiers each with increasing levels of detail, effort, and costs. The lowest, minimum expected effort, will include monitoring that all restoration-related projects have to complete. The next two categories -- moderate effort and high effort -- would provide more information targeted at reducing key uncertainties. A detailed description of the CVPIA project monitoring program is presented in Appendix C.

Research

This Strategy has outlined several areas of information needs to reduce uncertainty, improve DSMs, and support ARM. It is expected that subgroups of the SIT with appropriate expertise will help guide research charters through coordination and consultation with appropriate principal researchers to reduce areas of uncertainty. Research efforts will be reviewed on a case-by-case basis.

Current restoration projects from prior funding cycles

Where possible, currently funded restoration projects should be reviewed for applicability to the updated prioritization presented in this Strategy. If appropriate, existing charters should be amended to accommodate additional restoration in the targeted areas.

Current monitoring efforts from prior funding cycles

Where possible, currently funded monitoring projects should be reviewed for applicability to the updated prioritization presented in this Strategy. If appropriate, existing charters should be amended to accommodate additional restoration in the targeted areas.

Current research efforts from prior funding cycles

Where possible, currently funded research projects should be reviewed for applicability to the updated prioritization presented in this Strategy. If appropriate, existing charters should be amended to accommodate additional restoration in the targeted areas.

Process for review and revision

During the five-year implementation window for this Strategy, FY2021-FY2025, the SIT will develop annual Tech Memos to update progress on implementation of the Strategy. During that time, it is likely that information will be developed that will revise DSM inputs, parameters, or conceptual models. A regular function of the SIT during implementation of the Strategy will be to review the current prioritizations and assess whether they remain applicable. It is possible that large-scale changes in the understanding of habitat estimates, survival rates, or system operations, or other topics could necessitate an update to the prioritization and a revision to this Strategy. If revisions to the Strategy appear likely, the SIT will inform the implementing agencies and all stakeholders as soon as practicable.

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STRUCTURED DECISION MAKING - FINAL

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Appendix A Model Documentation

<https://drive.google.com/file/d/1ZuwSsLLAdNx-qOT0glJu0GaHZUMQP0nb/view?usp=sharing>

STRUCTURED DECISION MAKING - FINAL

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Appendix B Data Guidance

[To be included following SIT review and policy guidance.](#)

STRUCTURED DECISION MAKING - FINAL

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Appendix C Proposed CVPIA project related monitoring

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STRUCTURED DECISION MAKING - FINAL

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Appendix D Central Valley Chinook Salmon & *O. mykiss* Recovery Plan

https://archive.fisheries.noaa.gov/wcr/publications/recovery_planning/salmon_steelhead/domains/california_central_valley/cv_chin_stlhd_r_plan_fs_071614.pdf

Appendix E Glossary

https://training.fws.gov/courses/ALC/ALC3183/resources/handouts/14_glossary.pdf

From: USFWS National Conservation Training Center