Near-term Restoration Strategy

for the

Central Valley Project Improvement Act

Fish Resource Area

FY2021–FY2025

Final Version

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

Structured decision making 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 the process 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.

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

The mission of the U.S. Fish and Wildlife Service is working with others to conserve, protect, and enhance fish, wildlife, and plants and their habitats for the continuing benefit of the American people.

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Science Integration Team

Members are self-selected technical representatives from agencies and stakeholders who contribute to the structured decision making process to identify priority restoration actions and information needs to support the CVPIA anadromous fish doubling goals.

Modeling Support

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Executive Summary

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

Structured decision making 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. mykis*s, and green and white 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 structured decision making process to prioritize expenditures.

The Near-term Restoration Strategy is 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. Better understanding of *O. mykiss* and sturgeon is required to develop numerical models similar to those for salmon. Collectively, these priorities comprise a Strategy that builds toward 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 (FY2021–FY2025).

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.

Priority Restoration Actions

The actions that comprise the SIT-recommended restoration strategy for Chinook salmon are in Table ES-1, which includes brief descriptions of each action.

Table ES-1. SIT-recommended Restoration Actions for Chinook Salmon

These are the recommended restoration actions for Chinook salmon and the runs that would primarily benefit from the action. Numbering does not indicate priority level or sequencing.

Restoration Action	Runs primarily benefiting
Action 1: Juvenile habitat restoration in mainstem Sacramento River above the American River confluence. One project in the Sacramento River between the Feather and American Rivers with a BACI design and tier 3 monitoring.	All
Action 2: Reconnect ephemeral non-natal tributaries to the mainstem Sacramento River during a single project with a BACI design and tier 3 monitoring.	Winter
Action 3: Juvenile habitat restoration in Battle Creek in winter-run juvenile rearing locations.	Winter
Action 4: Juvenile habitat restoration in American River.	Fall
Action 5: Juvenile habitat restoration in the Stanislaus River downstream through the San Joaquin River at Vernalis.	Fall
Action 6: Juvenile habitat restoration in Clear Creek.	Spring, Fall
Action 7: Improve survival in Butte Creek in downstream areas.	Spring, Fall
Action 8: Juvenile habitat restoration in the lower Feather River below the confluence of the Yuba River.	Fall, Spring
Action 9: Maintain existing spawning habitats in Upper Sacramento, American, and Stanislaus Rivers; Clear and Butte Creeks.	All

Priority Information Needs

Although the DSMs represent the best snapshot of current understanding of 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. Further development of DSMs for *O. mykiss* and sturgeon also require additional information.

Chinook Salmon Information Needs

Results of the sensitivity analysis, SIT discussions during the prioritization, and the model grading were used to identify the most influential information needs of the Chinook DSMs. Improvements in understanding these parameters will require additional research and monitoring and will improve the DSMs and the resulting prioritizations of future restoration actions. Information needs for Chinook salmon are summarized in Table ES-2.

Table ES-2. Chinook Salmon Information Priorities.

Chinook salmon information priorities and the expected time needed to produce the information. Numbering does not indicate priority level or sequencing.

Chinook Salmon Information Needs	Duration
Info Need 1: Juvenile Chinook salmon survival: tributaries, mainstem, delta, ocean, and the effect of habitat on survival.	>5 years
Info Need 2: Juvenile Chinook salmon growth: tributaries, mainstem, delta, and the effect of habitat on growth.	2–3 years
Info Need 3: Juvenile Chinook salmon movement: site fidelity and effect of habitat type, the effect of temperature and flows on movement.	2–3 years
Info Need 4: Juvenile Chinook salmon territory size: site fidelity and effect of habitat type and other conditions.	2–3 years
Info Need 5: Southport Levee setback assess fish use, growth, and survival.	2–3 years
Info Need 6: 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.	2–3 years
Info Need 7: Habitat change through time.	3–5 years
Info Need 8: 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.	>5 years
Info Need 9: Adult escapement and prespawn mortality.	>5 years

O. mykiss and Sturgeon Information Needs

Currently the *O. mykiss* and sturgeon DSMs have significant data gaps that are necessary to address so that the SIT can use the DSMs to develop defensible restoration actions in future Strategies. The SIT, working with species-specific experts, identified the information needs outlined in Tables ES-3 and ES-4 that would improve the DSMs for consideration in future Strategies.

Table ES-3. O. mykiss Information Priorities.

The information needs for *O. mykiss* focus on identifying factors that facilitate anadromy of *O. mykiss* and the expected time needed to produce the information. Numbering does not indicate priority level or sequencing.

O. mykiss Information Needs	Duration
Info Need 1: Juvenile *O. mykiss* survival in tributaries, mainstem, delta, ocean with comparison of survival in tributaries with different environmental conditions.	>5 years

O. mykiss Information Needs	Duration
Info Need 2: Juvenile *O. mykiss* age and growth in tributaries and mainstem with comparison of growth in tributaries with different environmental conditions.	>5 years
Info Need 3: Genetic trends in *O. mykiss* populations through time.	>5 years
Info Need 4: Habitat modeling and estimates for larger sized (> 120 mm) *O. mykiss* habitats, including in ephemerally connected streams.	2–3 years
Info Need 5: *O. mykiss* redd counts.	>5 years
Info Need 6: Spatial distribution of anadromy prevalence.	2–3 years
Info Need 7: Juvenile *O. mykiss* production and escapement with emphasis on locations with existing long-term data.	>5 years

Table ES-4. Sturgeon Information Priorities.
The information needs for green and white sturgeon represent short and long-term priorities for improving the sturgeon DSMs and the expected time needed to produce the information. Numbering does not indicate priority level or sequencing.

Sturgeon Information Needs	Duration
Info Need 1: Early juvenile survival and growth of wild fish (larvae to age-1).	>5 years
Info Need 2: Adult and subadult survival and movement (system wide).	>5 years
Info Need 3: Spawner abundance monitoring.	>5 years
Info Need 4: Estimate juvenile rearing and adult spawning habitat availability (system wide).	2–3 years
Info Need 5: White sturgeon spawning distribution.	2–3 years

Process for Strategy Review and Revision

During the five-year implementation window for this Strategy, FY2021–FY2025, the Science Coordinator will develop annual Adaptive Management Updates (previously called Technical Memoranda) to describe 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, 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 Science Coordinator will inform the implementing agencies and all stakeholders as soon as practical.

Introduction

In 2008, the Bureau of Reclamation and the U.S. Fish and Wildlife Service, in response to a request by the Secretary of the Interior, received an independent review of the Central Valley Project 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, Reclamation and the Service adopted a Structured Decision Making process. Structured decision making 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. mykis*s, 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 structured decision making process to prioritize expenditures.

This Near-term Restoration Strategy is 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. The SIT determined that *O. mykiss* and sturgeon would benefit most from improving the state of knowledge for these taxa and therefore identified and prioritized information needs for the next five years. Collectively, these priorities comprise a Strategy that builds toward 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 (FY2021–FY2025).

Background

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

Structured Decision Making

Structured decision making 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, it is a concept that encompasses a very broad set of methods, not a prescription for a rigid approach for problem solving. Structured decision making provides clear roles for stakeholders and scientists when working on problems at the interface of science and policy. Key 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, integrating science and policy explicitly. At a very basic level, structured decision making is a formalized way of connecting decisions to objectives.

A structured decision making 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 U.S. Fish and Wildlife Service, 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 structured decision making and adaptive resource management process and example case studies. Undertaking the structured decision making process by the agencies established a foundation to support engaging and incorporating stakeholders and scientific understanding into the CVPIA decision making process.

The process continued with the formation of a CVPIA Science Integration Team (SIT) that is open to the public and includes 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 structured decision making process to refine objectives, expand and refine existing decision support models (DSM), and identify restoration priorities.

Science Coordinator

The CVPIA Science Coordinator is responsible for ensuring the production of the periodic Adaptive Management Updates (previously called 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 Adaptive Management Updates originate from the Science Coordinator but are meant to serve as an accurate representation of the entire structured decision making process. SIT members are provided multiple opportunities to review, suggest edits, and provide written addenda when or if they disagree with the findings.

Science Integration Team (SIT)

The SIT is a self-selected, collaborative team that uses the structured decision making process to make progress through scientific and technical discussions in support of adaptive resource management. 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 U.S. Fish and Wildlife Service and Bureau of Reclamation (collectively 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 adaptive resource management;
- Refining and revising DSMs with new and existing information;
- Recommending priorities for restoration, monitoring, and research; and
- Reporting back to their agencies or constituents regarding updates or need for additional information related to prioritization.

Prior Prioritization Efforts

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 candidate restoration strategies. 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

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 was 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 support documents are available for review at the SIT website.

To date, the structured decision making prioritization process has previously been documented through the preparation of two Technical Memos.

Uses for the 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 Structured Decision Making

During the implementation of the actions recommended in the current Strategy, the structured decision making process will continue to improve existing Chinook salmon DSMs, further develop DSMs for *O. mykiss* and green sturgeon, review improvements and changes to model inputs and subsequent outputs, and assess knowledge gains that result from monitoring or research projects.

These actions will occur over a regular schedule of bi-annual in-person SIT workshops as well as regularly scheduled teleconferences to review overall progress. Additionally, it is anticipated that numerous subgroups 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 SIT website.

Overview of SIT Prioritization Process

The SIT's structured decision making process uses quantitative modeling results (decision support models or DSMs) that are interpreted and supplemented by the expert judgement of the SIT members to prioritize restoration actions and information needs.

The process includes the following steps (Figure 1):

1. Define the decision context (or decision situation) relating to the management problem;
2. Identify stakeholder fundamental objectives and their quantifiable attributes;
3. Identify candidate management actions;
4. Develop decision support models (DSMs) that are used to predict the changes in quantifiable attributes that describe the state of fundamental objectives after implementing candidate actions; and
5. Conduct sensitivity analyses to identify the uncertainties that are most influential on candidate actions based on the DSMs;
6. Once the analysis is complete, finalize the prioritization.

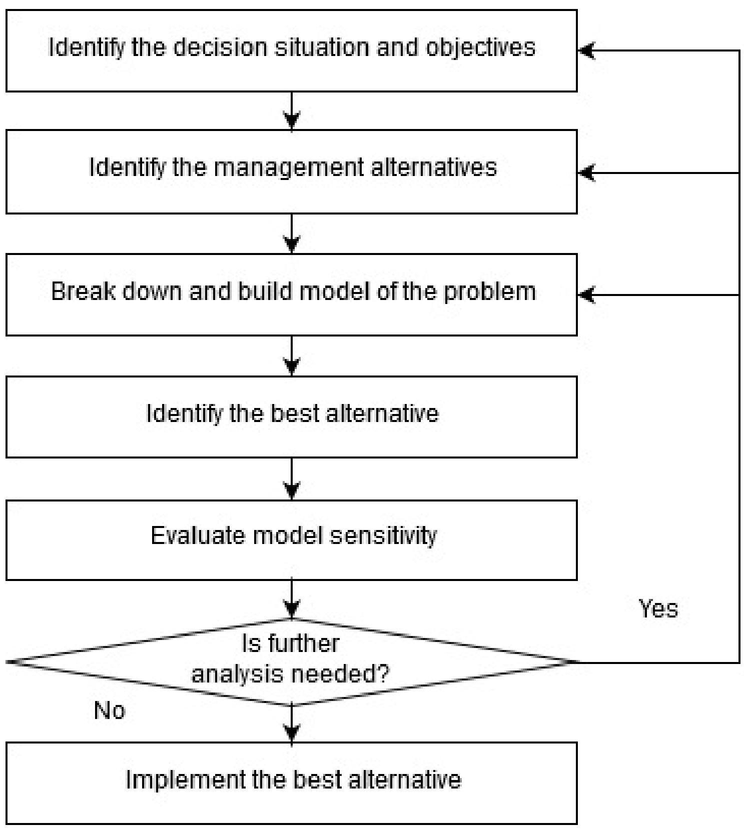

Figure 1. Steps in the Structured Decision Making Process.

The SIT uses a structured decision making process to determine priority restoration actions and information needs.

To begin, the SIT developed conceptual models of the life history of species of concern. These conceptual models focused attention on important factors affecting the life history of each species. Numerical models were then developed to represent the conceptual models based on measured inputs (where data was available). Unknown parameters (such as survival within a discrete river reach) were estimated through a calibration process.

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 salmon DSMs were used as a basis for evaluating 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 recommended restoration actions 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 five years focused on improving the state of knowledge for these taxa. Therefore, using information needs identified during previous prioritization efforts, the SIT worked with Project Work Team[1] members and other taxon-specific experts familiar with the Central Valley to identify and prioritize information needs for the next five years. The process used for each taxon is detailed below.

Chinook Salmon Prioritization Process

The structured decision making process resulted in the identification of Chinook salmon priorities for the Restoration Strategy.

Objectives

The context and the fundamental objectives remain unchanged from previous prioritization efforts. The SIT defined its fundamental objective for Chinook salmon as achievement of strong, self-sustaining populations. However, there were several modifications to Chinook salmon management attributes, the DSM model and inputs, and the process used to develop candidate restoration strategies. These changes were intended to increase transparency, simplify and streamline the process, and provide restoration, research, and monitoring priorities with greater specificity based on what was learned during previous prioritization efforts.

To begin 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

[1] Project Work Teams are self-selected teams of taxa-specific experts and managers from state and federal agencies, consulting firms, and academia.

because they resulted in too many combinations to evaluate. To streamline the effort, the SIT identified five objectives for the structured decision making process.

Three objectives were valley-wide:

1. total juvenile biomass at Chipps Island,
2. natural adult production, and
3. spatial diversity.

Two objectives were tributary-only:

4. total juvenile biomass at Chipps Island from an individual tributary, and
5. natural adult production in an individual tributary.

The SIT was provided with DSM outputs for all five metrics but focused on valley-wide total juvenile biomass at Chipps Island and valley-wide natural adult production during the strategy 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.

Identifying Candidate Restoration Strategies

The next 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 candidate restoration strategies.

The first phase used the fall-run DSM and optimal policy plots (described below) to simulate seven 20-year-long DSM outputs designed to contrast restoration actions across various areas in the basin.

The second phase focused on specific candidate restoration strategies informed by model output from Phase 1 to develop the best set of restoration actions across winter-run, spring-run and fall-run Chinook salmon.

For both phases, outputs were compared to a No action / No restoration model run to develop measurements of relative effect.

The Phase 1 strategies included:

A. Implement five optimal actions a year that maximized natural adult production valley wide.
B. Implement five optimal actions a year that maximized natural adult production valley wide, but only work in non-hatchery streams.
C. Implement five optimal actions a year that maximized natural adult production valley wide, but only work in hatchery streams.

D. Implement five 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.
E. Implement five optimal actions that resulted in the smallest increase in natural adult production valley wide.
F. Implement five 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 No action / No restoration 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 facilitated a more focused discussion during the consideration of winter- and spring-run DSMs. One notable result from this exercise was the comparison between Strategy A and D. Model output for Strategy D provided an indication that geographic diversity can also improve model output.

Additional information regarding specific actions in specific watersheds is available online.

Table 1. Model Output for Phase 1 Strategies.

Estimates for valley-wide Juvenile Biomass at Chipps and Natural Spawners represent the percent change in those attributes compared to a No Action Strategy.

Strategy	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. Figure 2 shows the location of the tributaries.

Table 2. Chinook Salmon Diversity Groups and Tributaries

The Chinook salmon Diversity Groups represent spatial groupings of tributaries based upon definitions by NOAA Fisheries (see Appendix D for more information). The Northern Sierra Diversity Group was separated into two groups for modeling so that all the Diversity Groups contain four to six 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	Father River, Yuba River, Bear River, American River, Cosumnes River, Mokelumne River
Southern Sierra Nevada	Calaveras River, Merced River, Stanislaus River, Tuolumne River

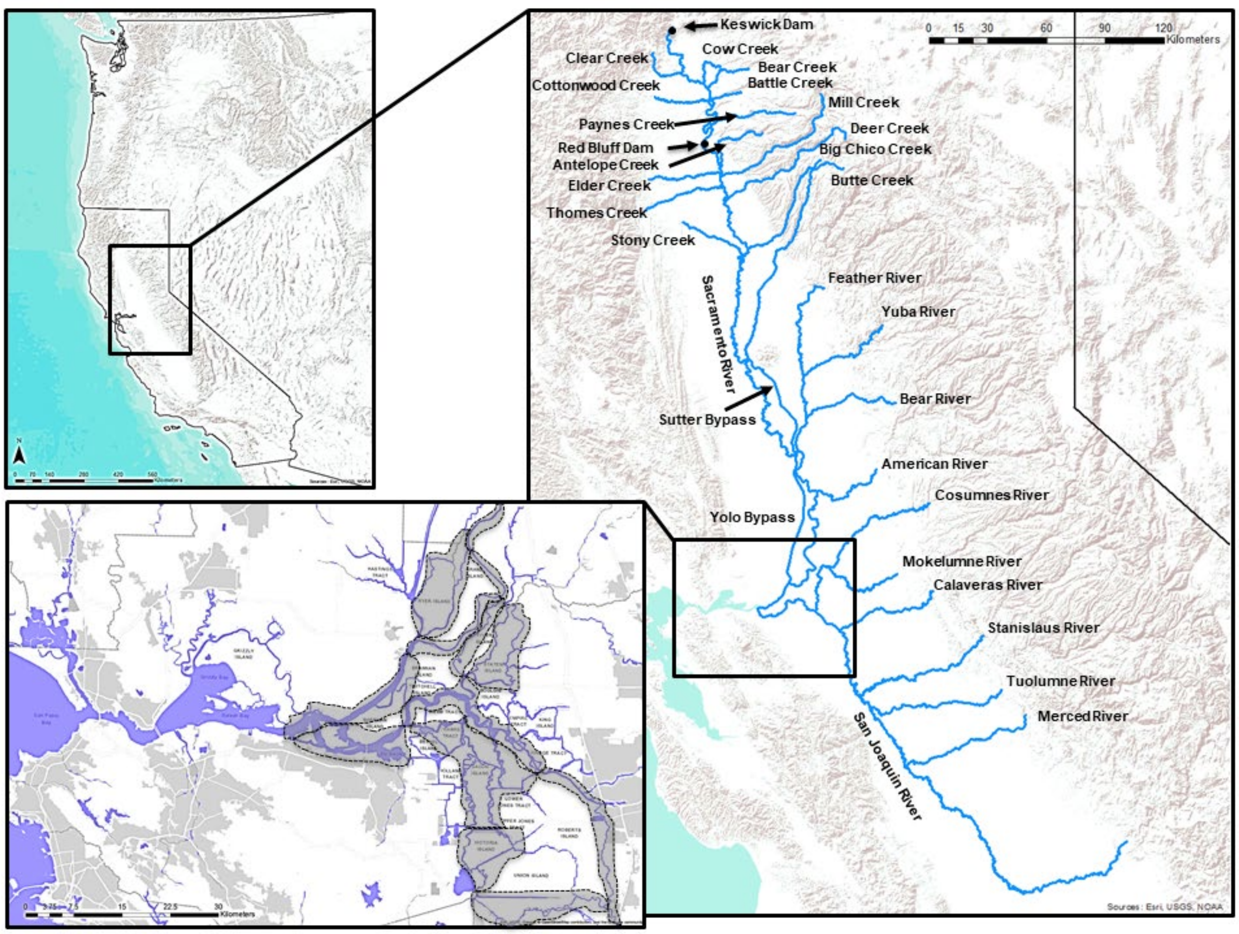

Figure 2. Locations of Tributaries

The map shows California's Central Valley and the location of the Sacramento River and its tributaries.

The SIT reviewed the results of the first phase and discussed patterns that emerged from the analysis and potential anomalies (i.e., unexpected benefits of restoration actions in certain tributaries). Using this information, the SIT developed a revised list of 14 candidate restoration strategies (Table 3) for further consideration. Two additional strategies were also developed specifically pertaining to winter-run Chinook salmon:

1. Improving habitat in Battle Creek, and
2. Improving connectivity between the mainstem Sacramento and ephemeral non-natal tributaries.

These strategies would have required significant modifications to the DSM, however, and there was insufficient time to complete the modifications to the DSM and inputs. Therefore, these strategies remained qualitative strategies that could be informed by the quantitative output of DSMs when formulating the final Restoration Strategy.

Table 3. Phase 2 Candidate Restoration Strategies

The SIT developed the Phase 2 list of candidate restoration strategies based on the analysis and discussion of the DSM output from the Phase 1 strategies. This revised list of strategies was the basis for determining the final recommended restoration actions.

Strategy	Description of Action	Geographic Focus[2]
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

[2] Locations of tributaries are in Figure 2.

Strategy	Description of Action	Geographic Focus[2]
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 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[3] habitat restoration actions for winter-run Chinook salmon	Sacramento River (all reaches) **More emphasis:** Below Red Bluff
9	Optimize[3] 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
10	Optimize[3] 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[3] habitat restoration actions for fall-run Chinook salmon	**One action per diversity group per year:** Basalt and Porous Lava Northwestern California Northern Sierra 1

[3] See Figure 3 and associated discussion for description of optimization process.

Strategy	Description of Action	Geographic Focus[2]
		Northern Sierra 2 Southern Sierra Nevada **Once action per year:** Sacramento River Deer Creek Mill Creek Antelope Creek San Joaquin River
12	Optimize[3] habitat restoration actions for fall-run Chinook salmon	Upper Sacramento River Lower Sacramento River American River Stanislaus River Calaveras Rivers
13	Optimize[3] habitat restoration actions for fall-run Chinook salmon	Upper Sacramento River Lower Sacramento River American River Stanislaus River Mokelumne Rivers

Evaluating Candidate Restoration Strategies

The third step in the process was to evaluate the effectiveness of each candidate restoration strategy (Table 3) to improve measurable attributes and best achieve structured decision making objectives using the DSMs. Policy plots were used to evaluate strategies requiring optimization, while the other strategies focused restoration into the various geographic areas.

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).

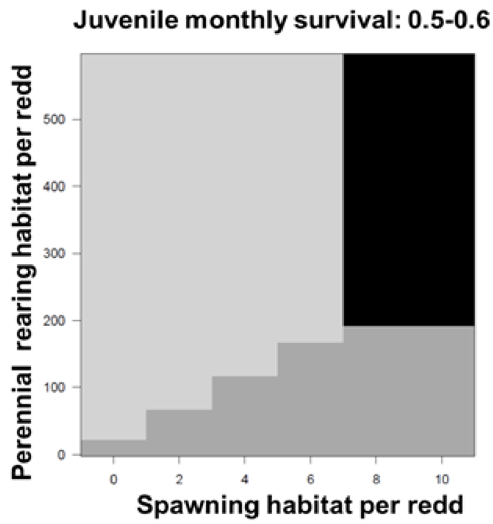

Figure 3. Example Policy Plot.

For the Phase 2 strategies that included the implementation of optimal restoration actions (strategies 8, 9, 10, 11, 12, and 13; 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 strategy, 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 strategy. 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. The five objectives (metrics) were output for each year.

Table 4. Units of Effort for Restoration Actions in Phase 2 Candidate Strategies.
The SIT used these standard units of effort in describing the candidate restoration 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 candidate 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 the SIT Tools webpage). 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 utility 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). Relative loss scores range from 0 (best strategy, least loss) to 1 (worst strategy, greatest loss).

Sensitivity Analysis to Identify Information Needs

The fifth step in the prioritization process was sensitivity analyses. Sensitivity analyses identify the components that have the greatest effect on model output, and more importantly, the components that have the greatest effect on what decision alternative is estimated to be the best (Conroy and Peterson 2013). Sensitivity analyses also help identify information needs that would improve future analyses.

One-way sensitivity analysis was used to identify the model components or inputs that had the greatest effect on valley-wide natural production. One component or input was varied at a time to evaluate the change in the estimated score.

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 are then plotted to examine how rankings of the strategies 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 ranking of the strategies changes twice (arrows) across the range of prespawn mortality, which means that the best strategy depends on the estimated prespawn mortality.

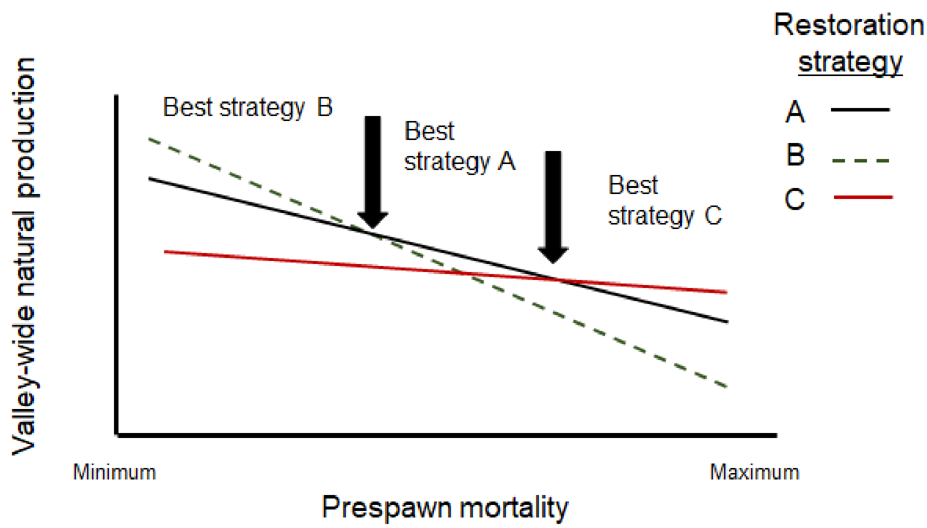

Figure 4. Example Sensitivity Analysis

This example compares three strategies. The best strategy has the highest natural production but the best strategy changes depending on the prespawn mortality estimate. The arrows indicate where the strategy ranking changes across the range of prespawn mortality. The degree of uncertainty regarding prespawn mortality would affect the value of increasing information and understanding of this estimate.

Identifying Priorities

The final step was agreeing on the restoration actions and information needs that constitute the Restoration Strategy for FY2021–25. The SIT recognized the importance of providing habitat to promote connectivity among the different locations throughout the Central Valley to benefit all three runs of Chinook salmon through increased production and spatial diversity.

The SIT reviewed the results of the simulated strategies during in-person meetings on November 20–21, 2019. After discussion of various strategies and the interactions of various actions, the SIT used the following criteria to decide on final set of recommended actions:

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.

Identifying DSM Improvements

Finally, Chinook salmon DSM inputs and model components were qualitatively assessed to develop a path for improving critical elements of the DSM. Model components were categorized by whether they had been improved since the last prioritization process, had room for further improvement, or had not been addressed since the previous iteration. Model components were graded for their degree of empirical support.

O. mykiss and Sturgeon Prioritization Process

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 Project Work Team 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 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.

Chinook Salmon DSM Results

Quantitative results from the DSMs (fall-, spring- and winter-run) 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.

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 there was a different best strategy 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 SIT discussed the large decrease in fall-run and winter-run natural production in years 10–16, which appears to correlate 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 3–4 years later, even though the drought may have ended.

Assessment of relative utilities in Figure 6 show the contrast between the candidate strategies with regard to the three species. Strategies 5 and 6 were 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 optimal actions 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), indicating that it was possible to negatively impact species through restoration actions.

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 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 candidate strategy was relatively minor and did not vary greatly among runs and strategies (Figure 7). The notable exception was for spring-run Chinook salmon under strategy 8, which was the optimal winter-run strategy. Winter-run Chinook salmon natural production relative loss was also greatest under strategies 0, 9, and 10. Relative loss in juvenile biomass revealed a different pattern with loss generally high for winter and spring-runs under strategies 0, 2, and 11–13 (Figure 7). The last of the candidate strategies (11–13) focused on implementing optimal fall-run actions in various configurations of tributaries.

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 Chinook salmon runs. Actions described in candidate strategies 8–13 were the focus for restoration actions, but discussions were not limited to the actions included in those strategies. During discussions, the concept of connectivity between habitats was identified as a valuable principle to organize and develop the final recommended restoration actions.

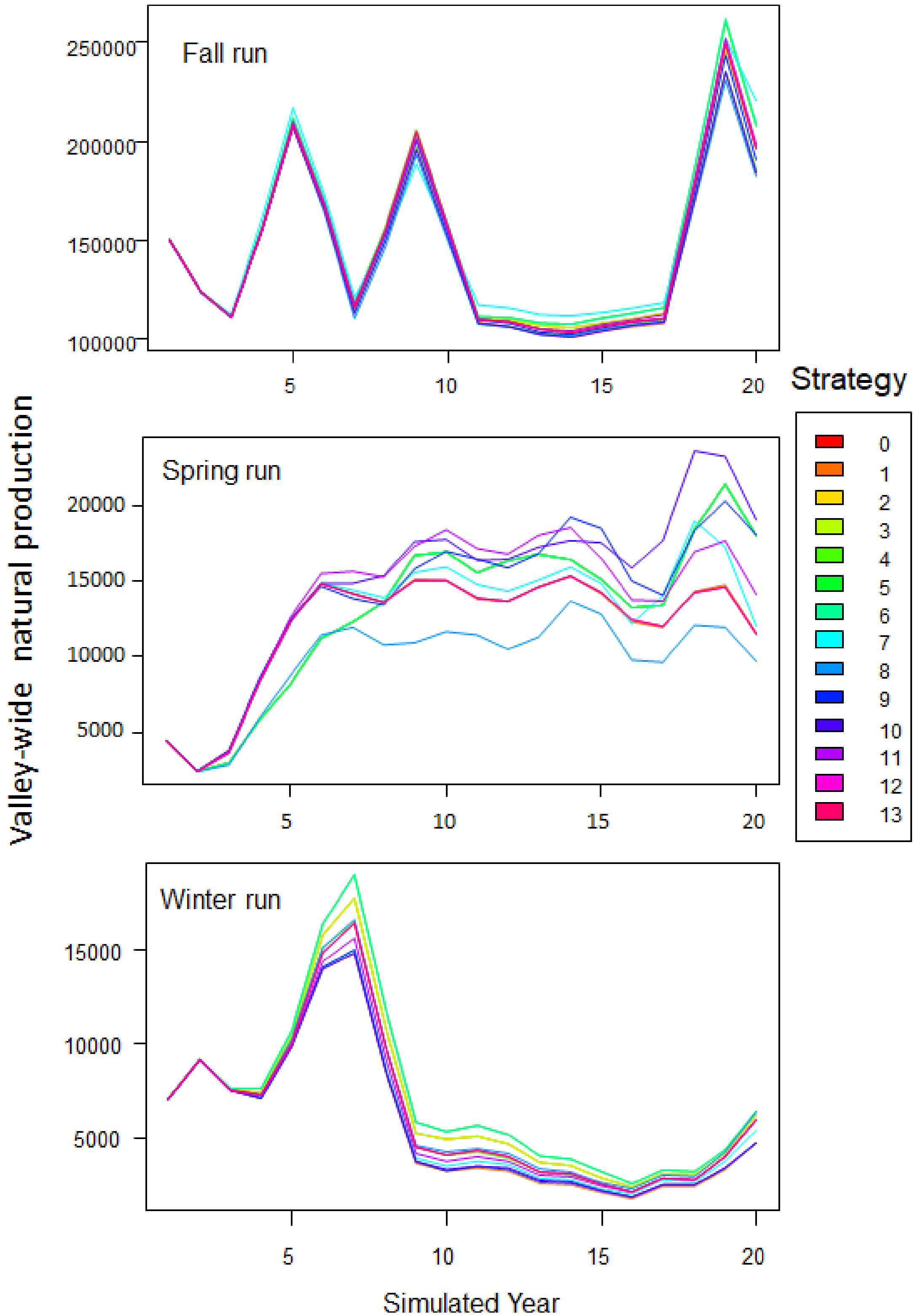

Figure 5. Modeled Chinook Salmon Natural Production.

The results indicated that for each salmon run, there was a unique candidate strategy that resulted in the best Valley-wide natural production across time.

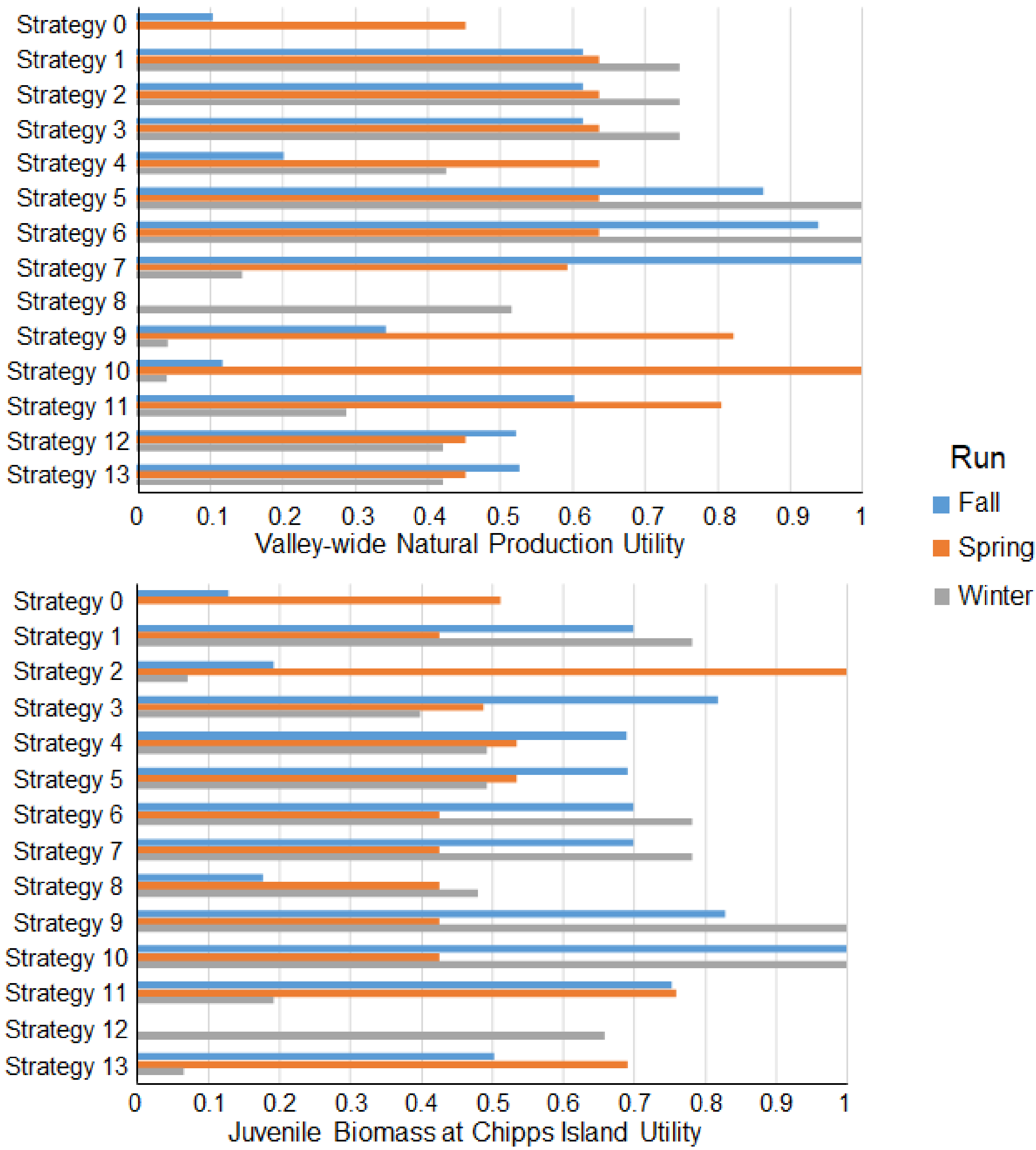

Figure 6. Natural Production and Juvenile Biomass Utility Scores.

Utility scores range from 0 for the worst strategy to 1 for the best strategy. This analysis assesses the positive effects of each strategy by run. The best strategies have the highest scores.

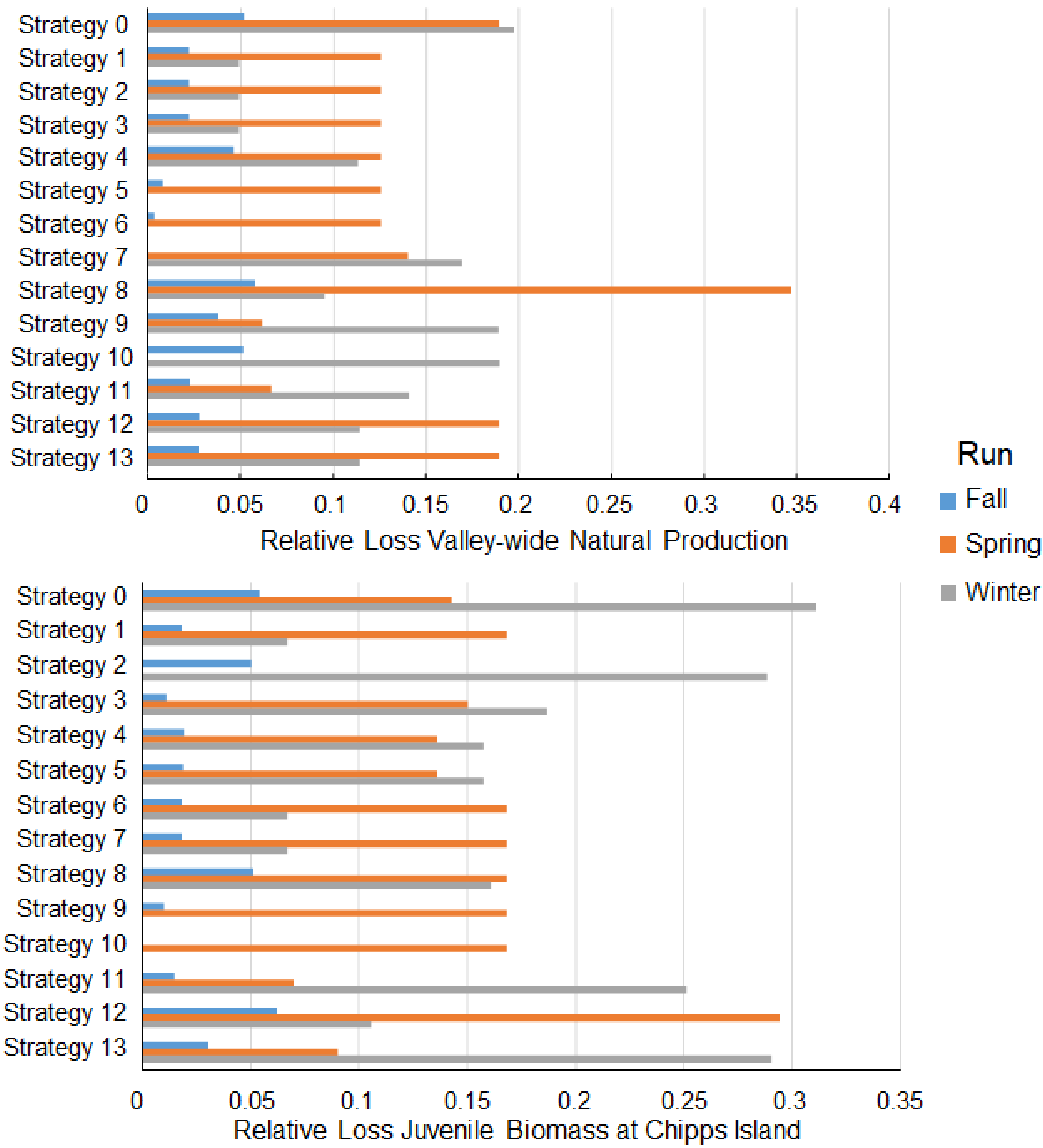

Figure 7. Relative Loss of Natural Production and Juvenile Biomass Utility Scores.
Relative loss scores represent the loss of implementing a candidate strategy relative to the best strategy. Scores range from 0 for the best strategy with least loss to 1 for the worst strategy with greatest loss. This analysis indicates the negative effects for each run based on the selection of an individual strategy. The best strategies have the lowest scores.

Candidate Restoration Actions

To understand what was driving the DSM results from candidate strategies 8–13, the SIT examined the 590 simulated restoration actions selected by the models to be optimal across the strategies (Table 5). Across all the actions, juvenile rearing habitat restoration (represented by both in-channel and floodplain habitat restoration) was the most frequently selected action. Juvenile rearing habitat restoration was selected 490 times with 66% of those being in-channel rearing habitat. In contrast, spawning habitat restoration was the least selected optimal action and was only selected four times.

For the spring-run strategies, increasing survival in the Sacramento River tributaries was selected more than 50 times and the most frequently selected tributary was Butte Creek.

Overall, half of the selected actions were in the Sacramento River. In other words, the most successful model outputs relied primarily on actions to restore juvenile rearing habitat, with a particular focus on the Sacramento River.

Table 5 summarizes the number of times candidate actions were identified in the optimized strategies. A complete list of all the potential actions and locations in all the candidate strategies for fall-run, spring-run, and winter-run Chinook salmon is available on the SIT Tools webpage.

Table 5. Number of Times Candidate Actions were Identified in Optimized Strategies 8–13 by Location.

A total of 590 candidate restoration actions were identified for optimized strategies 8–13. Restoring spawning habitat was the least selected action (4 times) while restoring juvenile rearing habitat was the most selected action (490 times with 291 in-channel actions and 169 floodplain actions). Locations in the Sacramento River accounted for half of the selected actions.

Location	Spawning Habitat	In-channel Habitat	Floodplain Habitat	Increase Survival	TOTAL
Upper Sacramento River		72	74	5	151
Upper-mid Sacramento River		1	17		18
Lower-mid Sacramento River		32	13		45
Lower Sacramento River		19	63		82
American River	3	49			52
Stanislaus River		48			48
Butte Creek		10		25	35
Clear Creek	1	24		5	30
Battle Creek		23		1	24
Calaveras River				23	23
Deer Creek				18	18

Location	Spawning Habitat	In-channel Habitat	Floodplain Habitat	Increase Survival	TOTAL
Antelope Creek				12	12
Mill Creek				12	12
Cottonwood Creek				12	12
Feather River		10			10
Merced River				9	9
San Joaquin River		3	2		5
Cosumnes River				3	3
Cow Creek				1	1
TOTAL	**4**	**291**	**169**	**126**	**590**

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.

The sensitivity analysis results were a key element of the SIT determination of priority information needs.

Table 6. Changes to Top 3 Strategies during Input Sensitivity Analysis.

Sensitivity analysis results 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. Numbers in the table represent the number of times the top 3 strategies changed in the model for each salmon run based upon changes to the corresponding model input. Note: Parameters are grouped by type and sorted for most influential to least.

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**

Table 7. Changes to Top 3 Strategies during Parameter Sensitivity Analysis.

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 and at all locations included in the DSM. 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. Numbers in the table represent the number of times the top 3 strategies changed in the model for each salmon run based upon changes to the corresponding model parameter.

Parameter (grouped by type)	Fall	Spring	Winter	All
Juvenile survival parameters				**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 parameters				**18**
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
Reproduction parameters				**12**
Fecundity	1	1	3	5
Sex ratio	1	1	3	5
Redd size	1	1		2
Adult survival parameters				**8**
Prespawn survival: Intercept	1	1	2	4
En route survival: Adult harvest rate	1		1	2

Parameter (grouped by type)	Fall	Spring	Winter	All
En route survival: Intercept	1		1	2
Egg-to-fry survival parameters				**3**
Egg to fry survival: Proportion of natural origin adults			2	2
Egg to fry survival: Egg viability	1			1
Routing parameters				**2**
Adult straying: Natural origin adult	1			1
Delta routing: Entrained into Georgiana	1			1

Interpretation of Results into a Strategy

The SIT met during workshops held November 20–21, 2019, to discuss candidate 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 (2008), 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). While reviewing the effectiveness of various strategies, the SIT identified increased connectivity throughout the Sacramento and San Joaquin River Basins as a beneficial approach, particularly where actions in a mainstem river could benefit downstream migrants from tributaries.

Spatial diversity is also an important factor that can promote stability and persistence in animal populations (Lindley et al. 2007; Carlson and Satterwaite 2011). During review of various potential strategies, the SIT recognized population-level benefits from some candidate strategies that emphasized spatial diversity of anadromous populations in the Sacramento and San Joaquin River Basins.

Recommended Restoration Actions

The actions that comprise the SIT-recommended restoration actions for Chinook salmon are in Table 8 and a description of each with the rationale is detailed below. These serve as recommendations for restoration emphasis to the implementing agencies.

Table 8. SIT-recommended Restoration Actions for Chinook Salmon.

These are the recommended restoration actions for Chinook salmon included in the Strategy and whether they are anticipated to benefit connectivity, diversity groups, or natural productivity; whether the priority was evaluated by the DSMs; and the Chinook salmon runs that would primarily benefit from the action. Numbering does not indicate priority level or sequencing.

Restoration Action[4]	Connectivity	Diversity group(s)[5]	Natural productivity	DSM evaluated	Runs primarily benefiting
Action 1: Juvenile habitat restoration in mainstem Sacramento River above the American River confluence. One project in the Sacramento River between the Feather and American Rivers with a BACI design and tier 3 monitoring.[6]	Yes	Basalt and Porous Lava, Northwestern California, Northern Sierra 1 & 2	Yes	Yes	All
Action 2: Reconnect ephemeral non-natal tributaries to the mainstem Sacramento River during a single project with a BACI design and tier 3 monitoring.	Yes	Basalt and Porous Lava	Yes	No	Winter
Action 3: Juvenile habitat restoration in Battle Creek in winter-run juvenile rearing locations.		Basalt and Porous Lava		No	Winter
Action 4: Juvenile habitat restoration in American River.	Yes	Northern Sierra 2	Yes	Yes	Fall
Action 5: Juvenile habitat restoration in the Stanislaus River downstream through the San Joaquin River at Vernalis.	Yes	Southern Sierra Nevada	Yes	Yes	Fall
Action 6: Juvenile habitat restoration in Clear Creek.		Northwestern California	Yes	Yes	Spring, Fall

[4] All juvenile habitat restoration is assumed to consist of mixtures of perennial and seasonally inundated habitats.

[5] See Appendix D for more information on Diversity Groups.

[6] Tier 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.

Restoration Action[4]	Connectivity	Diversity group(s)[5]	Natural productivity	DSM evaluated	Runs primarily benefiting
Action 7: Improve survival in Butte Creek in downstream areas.		Northern Sierra 1		Yes	Spring, Fall
Action 8: Juvenile habitat restoration in the lower Feather River below the confluence of the Yuba River.	Yes	Northern Sierra 2		Yes	Fall, Spring[7]
Action 9: Maintain existing spawning habitats in Upper Sacramento, American, and Stanislaus Rivers; Clear and Butte Creeks.		All		Yes	All

Action 1: Juvenile habitat restoration in 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 Delta and would potentially serve as refugia from predators.

The SIT discussed which sections of the Sacramento River should be the focus of restoration efforts. Juvenile habitat restoration in the upper Sacramento River (above Red Bluff) was selected most often in the optimal fall-run strategies, 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

[7] There was some disagreement among the SIT about the actions related to spring-run in the Feather and Yuba.

of juvenile survival (Table 9). 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 placed 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 monitoring effort.

Action 2: Reconnect 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 would increase 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 fall 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 October).

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 one or more ephemeral tributaries 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 (Action 2).

Action 3: Juvenile habitat restoration in Battle Creek in winter-run juvenile rearing locations

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 natural populations of 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 populations 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.

Action 4: Juvenile habitat restoration in 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 provides rearing habitat for winter-run Chinook salmon (Phillis et al. 2018). The American River has the greatest potential increase in fall-run natural production within the Northern Sierra 2 diversity group. 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.

Action 5: Juvenile habitat restoration in the Stanislaus River downstream through the San Joaquin River at Vernalis

Juvenile habitat restoration in the Stanislaus River was consistently chosen in numerous fall-run optimization strategies, particularly those with requirements for spatial diversity. The two candidate mainstem juvenile habitat restoration strategies 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. The 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.

Action 6: Juvenile habitat restoration in 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 strategies, 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.

Action 7: Improve survival in Butte Creek in downstream areas

When evaluating the strategy 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 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.

Action 8: Juvenile habitat restoration in the lower 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 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.

Action 9: Maintain existing spawning habitat

During the strategy simulations, the best performing strategy for fall Chinook salmon contained the caveat that spawning habitat in several tributaries would 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.

SIT Monitoring Guidance for Ongoing and / or Proposed Restoration

The SIT Monitoring Guidance (Appendix C) outlines tiers of monitoring for ongoing or proposed restoration activities based on the degree of uncertainty reduction. Tier 1 represents the lowest, minimum expected monitoring effort while Tier 2 is moderate effort monitoring and Tier 3 is high effort monitoring. Tiers 2 and 3 would provide more information targeted at reducing key uncertainties. The guidance covers both physical and biological feature monitoring for the following restoration actions: spawning habitat restoration, juvenile rearing habitat restoration (perennially and periodically inundated), passage improvement (adult or juvenile), and screen/reduce water diversion.

Where applicable, the Strategy includes the recommended level of monitoring for particular restoration actions. This concept is discussed further under Implementation.

Priority Information Needs to Support the DSMs

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, further development of DSMs for *O. mykiss* and sturgeon will require additional information to calibrate DSMs for the species. Therefore, the SIT identified information needs for each taxon.

Information needs for Chinook salmon were based on DSM inputs and DSM parameters that were influential in the Chinook salmon strategies as well as the knowledge of SIT members. The *O. mykiss* and sturgeon information needs were based on the knowledge of the experts and Project Work Team members for their respective taxon and will be used to further develop *O. mykiss* and sturgeon DSMs.

The SIT expects that efforts 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.

Chinook Salmon Information Priorities

Table 9 summarizes the Chinook salmon information priorities and the justification for each follows, organized by research needs and monitoring needs.

Table 9. Chinook Salmon Information Priorities.

Chinook salmon information priorities include categorization as a monitoring or research need, and the expected time needed to produce the information. Numbering does not indicate priority level or sequencing.

Chinook Salmon Information Needs	Monitoring	Research	Duration
Info Need 1: Juvenile Chinook salmon survival: tributaries, mainstem, delta, ocean, and the effect of habitat on survival.	Yes	Yes	>5 years
Info Need 2: Juvenile Chinook salmon growth: tributaries, mainstem, delta, and the effect of habitat on growth.		Yes	2–3 years
Info Need 3: Juvenile Chinook salmon movement: site fidelity and effect of habitat type, the effect of temperature and flows on movement.		Yes	2–3 years
Info Need 4: Juvenile Chinook salmon territory size: site fidelity and effect of habitat type and other conditions.	Yes	Yes	2–3 years
Info Need 5: Southport Levee setback assess fish use, growth, and survival.		Yes	2–years
Info Need 6: 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
Info Need 7: Habitat change through time.	Yes		3–5 years
Info Need 8: 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
Info Need 9: Adult escapement and prespawn mortality.	Yes		>5 years

Chinook Salmon Research Needs

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 salmon DSMs. Increasing the certainty related to these inputs and parameters will require additional, targeted research in the Central Valley. Improvements in the understanding of these parameters would improve the DSMs and the resulting prioritizations of future restoration actions. The SIT identified the instances where the necessary information could be obtained either from targeted research or through the appropriate level of monitoring associated with restoration actions.

Juvenile survival

By far, juvenile survival in all locations (i.e., tributaries, mainstems, delta, and ocean) was the single most influential parameter driving variability of DSM output and results. Juvenile survival parameters 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 (Info Need 1; Table 9).

Research 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 longer than the five-year timeframe of the Strategy 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 Evolutionarily Significant Unit is Schroeder et al. (2016).

Juvenile growth

The next most influential parameter in the Chinook salmon DSM was 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—that will improve the growth estimates. However, the sensitivity of the DSM to growth and the lack of empirical estimates of the growth of wild juvenile Chinook salmon in the Central Valley dictate that it is a critical information gap that is needed by the SIT (Info Need 2; Table 9). Given the planned near-term improvements to the growth model, the information would be gained more efficiently through tier 2-3 monitoring associated with a restoration action.

Juvenile movement

While 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);
2. Based on fish size (i.e., the 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 (Info Need 3; Table 9).

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 ruleset 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 (Info Need 4; Table 9). As with growth, this information can be obtained through tier 2 and tier 3 monitoring associated with ongoing or future restoration actions.

Southport levee setback

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 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 (Info Need 5; Table 9).

Chinook Salmon Monitoring Needs

The SIT also identified monitoring efforts that would inform the Chinook salmon 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 the habitat modeling availability online). Habitats in many tributaries have 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 (see the model inputs online and 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 (Info Need 6; Table 9). A SIT subgroup was formed to identify which of these locations will require research to update the habitat estimates.

For the remaining locations, habitat availability estimates can be improved by incorporating information from projects through restoration monitoring.

Habitat change over time

Models of habitat change through time were identified as a high priority through the SIT proposal process (for more information on that process, 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 restoration monitoring (Info Need 7; 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 (Info Needs 8 and 9; Table 9). 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. For juvenile production monitoring, these priority locations include the American River, Red Bluff Diversion Dam, Stanislaus River, Mokelumne River, Clear Creek, and Feather River (Info Need 8; Table 9).

O. mykiss **Research and Monitoring Needs**

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 overall SIT information priority for *O. mykiss* in 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 and below.

Table 10. O. mykiss Information Priorities.

The information needs for *O. mykiss* focus on identifying factors that facilitate anadromy of *O. mykiss* and are categorized as a research or monitoring need along with the expected time needed to produce the information. Numbering does not indicate priority level or sequencing.

O. mykiss **Information Needs**	**Monitoring**	**Research**	**Duration**
Info Need 1: Juvenile *O. mykiss* survival in tributaries, mainstem, delta, ocean with comparison of survival in tributaries with different environmental conditions.		Yes	>5 years
Info Need 2: Juvenile *O. mykiss* age and growth in tributaries and mainstem with comparison of growth in tributaries with different environmental conditions.		Yes	>5 years
Info Need 3: Genetic trends in *O. mykiss* populations through time.	Yes		>5 years
Info Need 4: Habitat modeling and estimates for larger sized (> 120 mm) *O. mykiss* habitats, including in ephemerally connected streams.		Yes	2–3 years
Info Need 5: *O. mykiss* redd counts.	Yes		>5 years
Info Need 6: Spatial distribution of anadromy prevalence.		Yes	2–3 years
Info Need 7: Juvenile *O. mykiss* production and escapement with emphasis on locations with existing long-term data.	Yes		>5 years

<u>Demographic information</u>

Previous research reported that *O. mykiss* 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 (Info Needs 1 and 2; Table 10) but noted that it would require a longer than the five-year timeframe of the Strategy 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 or tributary pairs include Clear Creek and Deer or Mill Creeks.

Additionally, collection of genetic data would better inform understanding of genetic diversity in the species (Info Need 3; Table 10).

Habitat estimates

The habitat inputs for the in-progress *O. mykiss* DSM are incomplete for larger sized (> 120 mm) *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 (Info Need 4; 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. Habitat estimates would also improve through collection of *O. mykiss* redd counts to evaluate access to spawning habitat (Info Need 5; Table 10).

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 understanding the frequency of anadromy. In particular, another *O. mykiss* information priority is information on the prevalence of anadromy across the Central Valley (Info Need 6; Table 10). 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 (Info Need 7; Table 10). The existence of complete long-term data is rare for *O. mykiss*, so greater priority 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.

Sturgeon Research and Monitoring Needs

Members of the sturgeon Project Work Team met December 16, 2019 and discussed both near- and long-term information needs. 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 of study to properly link these estimates to environmental heterogeneity and environmental drivers of sturgeon populations.

The group discussed other topics they believe are important but not as urgent 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 priorities below are of greater importance.

Priorities discussed below apply to both green and white sturgeon unless specified.

Table 11. Sturgeon Information Priorities.

The information needs for green and white sturgeon represent short and long-term priorities for improving the sturgeon DSMs, along with a categorization as a research or monitoring need and the expected time needed to produce the information. Numbering does not indicate priority level or sequencing.

Sturgeon Information Needs	Monitoring	Research	Duration
Info Need 1: Early juvenile survival and growth of wild fish (larvae to age-1).		Yes	>5 years
Info Need 2: Adult and subadult survival and movement (system wide).		Yes	>5 years
Info Need 3: Spawner abundance monitoring.	Yes		>5 years
Info Need 4: Estimate juvenile rearing and adult spawning habitat availability (system wide).		Yes	2–3 years
Info Need 5: White sturgeon spawning distribution.		Yes	2–3 years

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 Project Work Team believes a long-term, targeted monitoring effort focused on estimating juvenile survival and growth of larvae to age-1 fish is needed (Info Need 1; Table 11). 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 (Info Need 2; Table 11). This information would be useful for 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 (Info Need 3; Table 11). 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 juvenile sturgeon 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 refine current habitat definitions and relate habitat to environmental factors (e.g., temperature, flow, etc.) in order to expand habitat estimates to multiple locations across the Central Valley (Info Need 4; Table 11).

The group discussed the fact there is more information available on where green sturgeon spawn than white sturgeon. Although they suspect that the majority of white sturgeon spawning occurs somewhere in the Middle Sacramento River, the 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 (Info Need 5; Table 11).

Strategy Implementation

Implementation of the Strategy will be critical to its success. The SIT uses information about project implementation to inform future prioritizations and strategies. Selection of projects and expenditures is the provenance of the implementing agencies outside of the structured decision making process, although it may be informed by structured decision making products. 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 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 Projects

This Strategy is 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 projects selected for implementation so that data and knowledge from those projects can be used for future prioritizations, improve the existing DSMs, and facilitate adaptive resource management. Where possible the SIT and / or SIT subgroups should provide guidance directly to projects for data management, monitoring methods, and research needs. Additionally, teams implementing projects could provide valuable insight for project costs, timelines, and local conditions that would improve the quality of SIT Adaptive Management Updates, Strategies, and DSMs.

Implementation Guidance

The implementing agencies, in consultation with 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. Better understanding of the practical nature of implementation would improve the ability to develop realistic strategies for future prioritizations.

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 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. To implement structured decision making, the agencies need to assess all 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 or others 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 tier—implementation monitoring—will include monitoring that all restoration-related projects have to complete. The next two tiers—effectiveness and validation monitoring—would provide more information targeted at reducing key uncertainties. A detailed description of the CVPIA project monitoring is presented in Appendix C.

Research

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

Current Projects from Prior Funding Cycles

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

Process for Strategy Review and Revision

During the five-year implementation window for this Strategy, FY2021–FY2025, the Science Coordinator will develop annual Adaptive Management Updates (previously called Technical Memoranda) to describe 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, 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 Science Coordinator will inform the implementing agencies and all stakeholders as soon as practical.

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Appendix A Model Documentation

Model Peer Review

The SIT decision support models have been peer reviewed and published. The article is available from Restoration Ecology (open access). Supplemental materials include parameter estimates and sources as well as model calibration results.

Citation

Peterson, J.T. and Duarte, A. (2020), Decision analysis for greater insights into the development and evaluation of Chinook salmon restoration strategies in California's Central Valley. Restor Ecol, 28: 1596-1609. https://doi.org/10.1111/rec.13244

Abstract

Considerable resources have been invested in ecological restoration projects across the globe to restore ecosystem integrity. Restoration strategies are often diverse and have been met with mixed success. In this article, we describe the Chinook salmon (*Oncorhynchus tshawytscha*) decision-support models developed by the Central Valley Project Improvement Act Science Integration Team as part of a larger structured decision-making effort aimed at maximizing natural adult production of Chinook salmon in California's Central Valley, the United States. We then describe the decision-analytic tools the stakeholder group used to solve the models and explore model results, including stochastic dynamic programming, forward simulation, proportional scoring, relative loss, expected value of perfect information, response profile analyses, and indifference curves. Using these tools, the stakeholder group was able to develop and evaluate restoration strategies for multiple Chinook salmon runs simultaneously, a first for the restoration program. We found that actions targeted at one run were detrimental to others, which was unexpected. Furthermore, information uncovered during this process was used to direct efforts towards targeted research/monitoring to reduce critical uncertainties in salmon demographic rates and make better restoration decisions moving forward. The decision sciences have established a wide range of analytical tools and approaches to simplify complex problems into key components, and we believe the concepts described in this article are of great interest and can be applied by many restoration practitioners that undoubtedly face similar difficulties when implementing restoration strategies for complex systems.

Model Grading

Part of the SIT process is to complete qualitative assessments of the DSM inputs and model parameters. These assessments are used to guide improvements of critical elements of the DSM. The following are the results of the SIT’s assessment of the model inputs (Table A1-1) and parameters (Table A1-2) for the DSM version used to decide on the priorities in the Near-term Restoration Strategy. This was conducted in November and December 2019. Future updates to the model grading will be documented in the annual Adaptive Management Updates.

Below are explanations of the different elements of the model grading summarized in Tables A1-1 and A1-2.

Relative Confidence

The *Relative Confidence* grades indicate the level of empirical support for the model input or parameter.

Low indicates little or no empirical support. The model component is based primarily on expert opinion or is based on limited empirical data available for less than 50% of watersheds.

Moderate indicates some empirical support. The model component is based on existing data or surrogate data (e.g., remote sensed or out of basin data), but data are incomplete.

High indicates strong empirical support. Data are available for large majority of watersheds, but improvement is possible.

Model Improvements

Improvements indicates whether the model component has been improved since the previous prioritization process ("Yes"), has not been addressed since the previous iteration ("No change"), or is a new component since the previous iteration ("New") and therefore has no basis for comparison.

Future Actions

Future actions indicates whether there is an existing or expected proposal for changes to a model component via a SIT proposal or a subgroup.

Relative Influence

Finally, each input and parameter was assessed based on its *relative influence* for the fall-, winter-, or spring-run Chinook salmon DSMs, receiving a score of either Low, Moderate, or High. In some instances, model parameters were not evaluated because the DSM only uses a single habitat use rule set.

Table A1-1 – SIT Grading of Model Inputs

Results of the SIT grading of model inputs, including confidence in the input, whether the input had improved since the previous iteration, whether there are planned changes to the model input, and the relative influence of the input on the DSMs for the different Chinook salmon runs.

Model input	Relative confidence	Improvement	Future action	Relative Influence for Fall Run DSM	Relative Influence for Winter Run DSM	Relative Influence for Spring Run DSM
Spawning habitat	Moderate	Yes	Subgroup select tributaries for updating/improving	High	Low	High
Juvenile perennially inundated rearing habitat	Moderate	Yes	Subgroup select tributaries for updating/improving; Get proposal for new habitat designation side channel	High	High	High
Juvenile ephemerally inundated rearing habitat	Moderate	Yes	Subgroup select tributaries for updating/improving; Possible ephemeral tributary additions	High	High	Moderate
Juvenile delta rearing habitat	Moderate	Yes	N/A	High	High	Moderate
Water temperature statistics	Moderate	Yes	N/A	Moderate	Moderate	Moderate
Streamflow statistics	High	No change	N/A	High	High	High
Total water diverted	Low	No change	N/A	Low	Low	High
Proportion water diverted	Low	No change	N/A	Low	High	Low
Number of unscreened diversions	Moderate	No change	N/A	Low	Low	Low
Number of days cross channel gates closed/open	High	No change	N/A	Low	Low	Low
Hatchery origin adults returning	Moderate	No change	N/A	Moderate	Moderate	Moderate
Predator prevalence	Low	No change	N/A	High	High	High
Contact point data	Low	No change	N/A	High	High	High

Table A1-2 – SIT Grading of Model Parameters

Results of the SIT grading of model parameters, including confidence in the parameter, whether the parameter had improved since the previous iteration, whether there are planned changes to the model input, and the relative influence of the parameter on the DSMs for the different Chinook salmon runs.

Parameter	Relative confidence	Improvement	Future action	Relative influence for Fall Run DSM	Relative influence for Winter Run DSM	Relative influence for Spring Run DSM
Adult en route survival	Moderate	No change	N/A	High	High	Low
Adult prespawn survival	Moderate	No change	N/A	Moderate	Moderate	Moderate
Adult straying dynamics	Low	No change	N/A	Moderate	Low	Low
Hatchery origin influence reproduction	Moderate	No change	N/A	Low	Moderate	Low
Reproduction parameters (sex ratio, fecundity, redd size)	High	New (redd size)	N/A	High	High	High
Egg to fry survival (viability)	Moderate	No change	N/A	Moderate	Moderate	Low
Juvenile behavioral dynamics in watershed (rearing)	Low	No change	N/A	not evaluated	not evaluated	not evaluated
Juvenile tributary survival (rearing)	Low	No change	N/A	High	High	High
Juvenile river growth (perennially and seasonally inundated rearing habitats)	Low	No change	N/A	High	High	High
Juvenile mainstem survival (rearing)	Low	No change	N/A	High	High	High
Juvenile movement (flow related)	Low	No change	N/A	Low	Low	Low
Juvenile routing north delta	Moderate	New	N/A	Moderate	Low	Low
Juvenile routing south delta	Moderate	New	N/A	Low	Low	Low
Juvenile survival north delta	Low	New	N/A	High	High	High
Juvenile survival south delta	Moderate	New	N/A	High	High	High
Behavioral dynamics in delta (rearing)	Low	No change	N/A	not evaluated	not evaluated	not evaluated
Juvenile delta growth (rearing)	Low	No change	N/A	High	High	High
Juvenile delta survival (rearing)	Low	No change	N/A	High	High	High
Ocean entry survival	Low	No change	N/A	High	High	High
Habitat change (degrade)	Low	New	Proposal in progress	Low	Low	Low

Appendix B Data Guidance

Below is the CVPIA Data Guidance version as of the publication of the Strategy. This is an evolving document and updated versions will be posted on the SIT website.

Data Guidance for CVPIA Funded and / or Authorized Work

Version: December 2020

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Introduction

In 1992 Congress passed H.R. 429, Public Law 102-575 which includes Title 34, the Central Valley Project Improvement Act (CVPIA). CVPIA mandated management changes for the Central Valley Project, particularly for the protection, restoration, and enhancement of fish and wildlife. Among the requirements of CVPIA are:

- special efforts to double anadromous fish populations by 2002,
- establishment of a restoration fund financed by water and power users for habitat restoration and enhancement, and
- a limit on new water contracts until fish and wildlife goals are achieved.

In 2006, the Office of Management and Budget (OMB) evaluated the progress of CVPIA. OMB had concerns that stemmed in part from the disparity between the “double by 2002” objective, and the status of Central Valley anadromous fish populations. OMB questioned the lack of measurable performance goals for program implementation, especially goals that could relate to factors within the control of the agencies in program implementation.

OMB recommended that the agencies undertake a comprehensive program review, including an independent science review. In response to the OMB critique, the Bureau of Reclamation (Reclamation) and the U.S. Fish and Wildlife Service (Service) organized an independent review (Listen to the River, 2008), seeking to address 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, Reclamation and the Service adopted a Structured Decision Making process. Structured decision making provides a formal, documented, open, and transparent process to develop quantifiable and measurable objectives and determine the best decision alternatives to achieve restoration using quantitative models. Decision support models represent how actions would improve natural production for all four runs of Chinook salmon, steelhead, and green and white sturgeon.

Development of the models is guided by an inter-agency, multi-stakeholder group of scientists and resource experts called the Science Integration Team (SIT). The models represent the 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 SIT models to inform and prioritize restoration fund expenditures. The Data Guidance described here will support continuous improvement of structured decision making within, between, and outside of the stakeholder agencies. Ultimately, these guidelines will result in better management of data used in the SIT models and generated by restoration fund expenditures, which is essential to achieving the CVPIA fish doubling goal.

Quality data is needed throughout CVPIA to drive continued improvement in project management and restoration practices. CVPIA uses data to:

1. Track project status and costs,
2. Calibrate and parameterize the Decision Support Models,
3. Improve understanding of limiting factors on fish populations, and
4. Quantify project success.

To achieve these goals, CVPIA requires quality data from researchers, fishery monitors, and restoration practitioners awarded funds for projects by CVPIA. To date, program guidance on data quality has not been sufficient to ensure quality data. This guidance describes the program's data needs and how practitioners should organize and document their data for submittal to CVPIA. Additionally, this guidance will characterize how CVPIA intends to utilize submitted data to support continuous improvement and innovation in fisheries restoration and species recovery.

Purpose

The purpose of this data guidance document is to increase, manage, and protect the value of data needed and generated by the CVPIA Science Integration Team, specifically through the structured decision making process. To implement structured decision making, the agencies need to assess all of the data available to build decision models and improve the basis and defensibility of decisions.

The data primarily supports the development of numerical population models that estimate effects of flows, habitat, and other parameters on winter-, spring-, and fall-run Chinook salmon populations, as well as *O. mykiss* and sturgeon populations. The numerical models are used to support prioritization of CVPIA restoration efforts and explain how that prioritization addresses the current state of knowledge about Central Valley salmonids. This guidance is consistent with several adjacent efforts such that sharing of source data across programs will support decision-making based on open, transparent data. The result should improve the shared understanding of resources.

Data Guidance for CVPIA Funded Projects emphasizes the creation and use of "tidy data" principles (Wickham 2014). The strategy, inspired by Hadley Wickham in his paper "Tidy Data" published in the Journal of Statistical Software (August 2014, Volume 59, Issue 10), creates datasets that are easy to manipulate, model, and visualize. Neatly structured data is essential to the CVPIA structured decision making process that relies on domain experts to focus on achieving the CVPIA fish doubling goal. The datasets will be hosted on public-facing websites so that reviewers and stakeholders can quickly access the data, output, visualizations, and source references.

This Data Guidance is intended to further the CVPIA Data Management Strategy. Data derived from CVPIA-authorized projects will be stored in a trusted repository that will safeguard the durability of the data. The trusted repository will include a consistent metadata standard and will be the registration authority for unique data generated by the program.

CVPIA Science Data Priorities

Data has been developed since the implementation of CVPIA, but without a central repository or data management standard, much of it has been unavailable to inform current and future efforts. This list of data priorities is based on current understanding of the system and the management needs of the CVPIA program. As the data management program evolves, the data priorities may change, consistent with the priorities determined by the SIT. This Data Guidance will serve to expedite that evolution.

The current direction of the SIT is to develop a series of five-year near-term restoration strategies. Strategies will be based on numerical population models and will outline the best recommendations to achieve the CVPIA doubling goals. Each five-year near-term restoration strategy will include restoration actions, monitoring needs, and research intended to support continuous improvement and adaptive management of the system. The SIT would continue developing and refining the near-term restoration strategies every five years until either the doubling goal is met, or it is determined by the Secretary of the Interior that the restoration actions are complete.

In developing the Data Guidance, SIT members identified information needs and categorized these needs according to three criteria:

1. Is the information used directly in the Decision Support Model (DSM)?
2. What is the needed frequency of collecting and compiling information?
3. Is the information needed for adaptive management?

The SIT considers these data essential to the DSM and adaptive management. The information and monitoring needed for the DSMs will include elements in the categories listed in the table below and included here:

1. DSM inputs
    a. modeled flow and diversions (CALSIM II)
    b. modeled and gaged temperature (HEC5Q, CDEC, districts)
    c. passage obstruction and predator contact points (PAD)
    d. survival and growth estimates
    e. territory size requirements
    f. habitat modeling
2. Annual fish monitoring data
    a. screw-trap capture and efficiency trial data
    b. coded wire tag data (hatchery allocation)
    c. trawl catch data
    d. creel census data

    e. adult escapement estimates
3. Research
    a. predator effects
    b. temperature estimation in tributaries
    c. habitat decay and evolution
    d. food availability
    e. entrainment rate

CVPIA Data for Program Management Priorities

In January 2006, the Assistant Secretary for Water and Science of the Department of the Interior (Assistant Secretary) in Washington D.C. directed the Commissioner of the Bureau of Reclamation and the Mid-Pacific Regional Director, to conduct a performance review of the CVPIA, with specific attention to the fish and wildlife provisions of the Act.

The primary purpose of that review was to determine when the relevant provisions of the Act would be sufficiently implemented to consider them “complete” for funding purposes. In response to the directive by the Assistant Secretary, Reclamation and the Service conducted the CVPIA Program Activity Review (CPAR). A specific concern and focus of many water and power contractors is Section 3407(d)(2), which describes a mechanism by which the Secretary of the Interior can reduce the Restoration Fund payments required of water and power contractors.

Collection of quality data about the status of expenditures and timing of projects is important for the regular assessment of 3407(d)(2) and allows for prudent management of the Restoration Fund. Specific information is required to support prompt reporting in both the Annual Work Plans and the Annual Financial Reports. Key data to collect will include:

1. Budget
2. Dates and milestones
3. Key personnel

This data will be used to inform annual reports to Congress as required in Section 3408(f) of CVPIA. Section 3408(f) is used to assess overall success of the program and the status of Restoration Fund collections.

Reporting of Quality Data

Who Reports

Practitioners awarded funds for projects by CVPIA should designate a ‘data steward’ on their project team. Data stewards manage the project data to ensure CVPIA data requirements are met, and data documentation is developed and maintained. Ideally, data stewards have a background in data management. This person is responsible for interacting with the CVPIA data managers to ensure that quality data is transferred in line with CVPIA standards.

Generally, the data steward performs the following tasks:

1. Prepare data management plan aligned with CVPIA data guidance,
2. Document how project data was generated, noting the methodology and equipment or software used,
3. Capture information about how the data has been altered or processed,
4. Track all file names and formats associated with the project,
5. Generate explanation of codes, abbreviations, or variables used in the data or in the file naming structure,
6. Manage data quality and backup datasets regularly,
7. Create metadata files,
8. Share data products with CVPIA data stewards, and
9. Schedule six-month data exchanges with designated CVPIA data manager.

The data steward should be actively engaged throughout the entire project life cycle. If not engaged early enough, important information is lost or more difficult to acquire. Committed data stewards are essential to CVPIA data products being well-described and fit for re-use.

Quality Data to be Reported

The purpose of this section is to guide practitioners while developing CVPIA projects. Projects will be scored in part on how well the proposed data management plan conforms to this guidance document and aligns with the priorities of the SIT, particularly as recorded in Near-term Restoration Strategies. If a project is awarded, during the contracting process a designated data steward must meet with the CVPIA data managers to ensure that data collected throughout the project conforms to standards. Data must meet the documentation requirements in these guidelines and be released in a machine-readable form during regular intervals until the end of the project. Upon project completion, the project data steward must conduct a close-out meeting with the CVPIA data managers to confirm proper submittal of all project data and necessary metadata information to ensure the continued value of the data beyond the project's lifespan.

Research and Monitoring

For research projects, researchers must state what hypothesis they are testing and how it addresses priority CVPIA areas of uncertainty. For monitoring projects, practitioners must state how their monitoring will address CVPIA priority data needs. Research and monitoring projects must specify types of data that will be collected, the project's location, and the interval at which data will be collected and published. The practitioners must provide a detailed description of the methodology for data generation, noting what type of equipment or software will be used.

Restoration

For projects that build structures or enhance spawning and/or rearing habitat, practitioners must supply estimates of existing suitable habitat and the additional suitable habitat generated by the project. During the project planning stage, the data steward should acquire existing habitat model estimates covering the project's extent. If the existing habitat data is insufficient (old, doesn't exist), then the project should include a plan to improve the quantification of the existing suitable habitat. Where feasible, habitat mapping generated with 2D hydraulic modeling and best available habitat suitability criteria should be produced.

Project proponents must describe the project type (e.g. spawning, perennial instream or seasonally inundated rearing habitats) and state whether the intervention is maintenance or new habitat. If the project is creating new habitat, provide an estimate of how many additional acres of habitat will be created and the expected suitability variability within the targeted range of flows. If the project is excavating to generate new habitat, discuss if there will be a loss of high flow habitat to gain suitable habitat at lower flows. For passage barrier removal, provide an estimate of how many additional acres of habitat are made accessible.

After construction, monitoring data must be collected and provided to confirm habitat is performing as designed. This could include, but is not limited to, topographic and/or bathymetric surveys to document as-built conditions, snorkel surveys to quantify habitat use, and habitat modeling if as-built conditions differ significantly from design with respect to suitable habitat creation.

Data for Program Management

All projects must provide information on project status to support reporting in the CVPIA Annual Work Plans and the Annual Financial Reports. Prompt and accurate reporting is necessary to facilitate those plans and to maintain public support for the program. Following selection of projects for funding, project management teams will establish timelines, budgets, and reporting schedules with the designated CVPIA data manager.

How to Report Quality Data to CVPIA

Data Repository

The long-term data management strategy for CVPIA is for all data to be hosted within a trusted data repository managed by the Bureau of Reclamation. Reclamation is currently developing RISE (Reclamation Information Sharing Environment), an effort to share a broad range of Reclamation's data in consistent, open, machine-readable formats via a centralized and sustainable public and internal data portal. CVPIA staff will coordinate with RISE developers to ensure that the data and metadata standards adopted are compatible with their standards. Until RISE is more mature, CVPIA data and metadata will be kept in cloud storage consistent with available RISE requirements. In the future, it is anticipated that web services and APIs will be developed to facilitate easy data access.

In the near-term, CVPIA data managers intend to use a data portal maintained by the Environmental Data Initiative (EDI) as a platform for curating data. EDI is a National Science Foundation funded project that actively promotes and enables curation and re-use of environmental data. EDI enables researchers to host their data according to FAIR data principles, an international stakeholder driven effort to improve data access and reuse. The EDI Data Portal contains environmental and ecological data packages contributed by a number of participating organizations, including USGS and USFWS.

EDI was developed to support high-level analysis and synthesis of complex ecosystem data across the science-policy-management continuum. Its intent is to advance ecosystem research. Through an open process, EDI seeks to improve:

1. the availability and quality of data from the varied contributing research sites,
2. the timeliness and quantity of derived data products, and
3. the knowledge gained from the synthesis of research data.

The EDI Data Portal uses a rolling-update approach to continuously release improved versions as they are ready for the community.

Restoration, Research, and Monitoring Data

Quality Assurance

Data should be reviewed periodically to discover inconsistencies and other anomalies in the data, as well as performing data cleansing activities (e.g. removing outliers, missing data interpolation) to improve the data quality. Increasing access and review of data will be a critical step in improving data quality.

Accepted Data Formats

Tabular datasets should be formatted in a machine readable format. Comma Separated Values (CSV) are flat datasets separated by delimiters and the standard format for publication. CSV files must be encoded in UTF-8. The first row must contain the headers for each column.

The following are not allowed within a machine readable file:

- Merged cells
- Multiple tables
- Notes/descriptions
- Non-data elements
- Blank row or columns within the data
- Aggregates (e.g., sum of values)

For more guidance on dataset formatting best practices, please refer to Hadley Wickham's paper Tidy Data.

In a tidy dataset:

1. Each variable forms a column
2. Each observation forms a row
3. Each type of observational unit forms a table

Vector geospatial datasets should be provided as Shapefiles and raster geospatial datasets as GeoTiffs.

If the data steward has collected data that cannot be provided in any of the above listed formats, please communicate directly with the CVPIA data managers to establish a mutually agreed upon appropriate data format.

Metadata Standards

Metadata standards endorsed by the Federal Geographic Data Committee (FGDC) are mandated for federal agencies by Executive Order 12906. CVPIA is using the Ecological Metadata Language (EML) schema, which maps to the federally approved metadata standard International Organization for Standardization (ISO) 19115-2 series of standards. EML is a robust and widely used set of protocols for extracting rich metadata from datasets with specifications particularly developed for the ecology discipline.

Metadata Creation Tools

The EML team provides an R package for automating the process of extraction; more details for this tool can be found here.

A CVPIA specific EML metadata creation tool is in development. Templates will be provided to project data stewards and assistance from CVPIA data managers will be available in creating metadata documents to ensure consistent and quality metadata for the program.

Data Backups and Versioning

Data backups and versioning will be maintained by EDI as part of their hosting services.

Digital Object Identifier

A digital object identifier (DOI) will be provided for each dataset to facilitate citation. A DOI is a string of numbers, letters and symbols used to permanently identify an article or document and link to it on the web.

Data for Program Management

The data steward will be responsible for submitting the following information via a series of web forms that will be made available at contracting.

1. Type of Project (Monitoring / Research / Restoration)
2. Budget
3. Document Control Number
4. Agreement Number
5. CVPIA Authority
6. Obligation amount by Fiscal Year
7. Expenditure rate by Fiscal Year
8. Roles and responsibilities
9. Dates and milestones (as applicable)
    a. Kickoff meeting
    b. Permit submittal

c. Environmental documentation timeline
d. Design timeline
e. ESA Consultation status
f. SHPO Consultation status
g. 6-month reporting dates
h. Project archiving dates
i. Press release announcing completion

10. Contingency plans

The submittals will be evaluated by CVPIA data managers and resubmittals are necessary until the data meets completeness criteria.

How to Submit Questions and Comments Regarding Data Submission

Data stewards can contact the CVPIA data manager with questions, comments, or concerns at sgill@flowwest.com.

Legal Citations

Data Management Under the Law

In addition to improving the results of CVPIA investments, improvements to data management is increasingly a required action under various legal and policy directives. For example, data management is required by various pieces of legislation and Executive Orders, such as:

- **Information Quality Act** (Section 515 of The Treasury & General Government Appropriations Act for FY 2001) allows the public to examine and challenge the data disseminated by the federal agencies and provides review procedures for those challenges.
- **Clinger-Cohen Act** (IT Management Reform Act) established the position of Chief Information Officer to oversee information quality and IT implementation. It mandates that agencies develop Enterprise-wide information architectures to improve business performance and data portability.
- **Privacy Act** establishes a Code of Fair Information Practice that governs the collection, maintenance, use, and dissemination of personally identifiable information about individuals that is maintained in systems of records by Federal agencies.
- **Government Performance & Results Act** is one of a series of laws designed to improve government project management. GPRA requires agencies to engage in project management tasks such as setting goals, measuring results, and reporting their progress. In order to comply with GPRA, agencies produce strategic plans, performance plans, and conduct gap analyses of projects.
- **Computer Matching & Personal Privacy Act** expands the Privacy Act guarantees to ensure that privacy violations do not occur when databases are combined or integrated.
- **Government Paperwork Elimination Act** requires that, when practicable, Federal agencies use electronic forms, electronic filing, and electronic signatures to conduct official business with the public.

- **Paperwork Reduction Act** provides the basis for managing information as a resource. It mandates that agencies take steps to improve their data quality and data sharing capabilities.
- **Freedom of Information Act** (FOIA) is a Federal law that allows for the full or partial disclosure of previously unreleased information and documents controlled by the United States government. FOIA defines agency records subject to disclosure, outlines mandatory disclosure procedures, and grants exemptions to the statute.
- **Executive Order 12906** (Geospatial Data) [PDF] directed the Federal Geographic Data Committee (FGDC) to establish a National Spatial Data Infrastructure (NSDI) to acquire, process, store, distribute, and improve utilization of geospatial data.
- **Open, Public, Electronic and Necessary (OPEN) Government Data Act** provides a sweeping, government-wide mandate for federal agencies to publish all their information as open data – using standardized, non-proprietary formats. The OPEN Government Data Act builds on President Obama's May 2013 Open Data Policy. It makes the key aspects of the Open Data Policy permanent.

Follow good data management practices. It's the law!

Appendix C Monitoring Guidelines

Below is the SIT Monitoring Guidelines version as of the publication of the Strategy. This is an evolving document and updated versions will be posted on the SIT website.

CVPIA Science Integration Team Monitoring Guidelines

Version: December 2020

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Project-related Monitoring

Rather than specify a one size fits all monitoring guidelines for CVPIA restoration projects, we propose tiers of monitoring for ongoing or proposed restoration activities based on the degree of uncertainty reduction. Ideally, a subgroup of the Science Integration Team (SIT) with technical expertise and the Science Coordinator would review proposed or ongoing CVPIA restoration activities and place them into categories based on the potential of each project to reduce key uncertainties. These categories would map into monitoring tiers each with increasing levels of detail, effort, and costs. Here we propose three tiers where the lowest tier, *implementation monitoring* (Tier 1), includes monitoring that all restoration-related projects would have to complete. The next two tiers *effectiveness monitoring* (Tier 2) and *validation monitoring* (Tier 3) would provide more information targeted at reducing key uncertainties and improving the decision support model. Below, we propose the following monitoring specifications for the three tiers for four potential restoration actions that have been identified by the SIT.

Specific definitions of spawning and rearing habitat used by the SIT and the up and downstream boundaries defining the anadromous portions of each tributary are documented through the SIT website under tools. All monitoring data documentation and formatting need to follow the SIT data guidance (Appendix B).

Spawning Habitat Restoration (Constructed)

Implementation Monitoring (Tier 1)

Physical feature monitoring

One pre-action and post-action surveys that quantify existing spawning habitat at project site that occurs within the range of flows typically experienced during spawning. The resulting data should include expected amount of habitat created (pre-action), date of measurement, discharge, and estimated spawning habitat available. Estimates must include a quantitative measure of precision such as a variance or standard error.

Information gained: establish whether project was successfully implemented, better estimates of habitat added per project and partial controllability[8], some information on stage-habitat relationships.

Biological monitoring

One pre-action and post-action surveys that quantify the number of spawning adults (or redds) using the project site on at least 3 occasions during peak spawning to estimate peak spawning counts (Gallagher et al. 2007). Survey crews should note any patterns of redd distribution through the site (e.g., most redds are found at the pool tail). The surface area of a random selection of redds should be measured on at least one occasion using standard methods (Gallagher et al. 2007). A minimum of 10 redds should be measured at the project site. If there

[8] Partial controllability reflects the fact that completed restoration will likely differ from initial plans.

are fewer than 10 redds, all redds should be measured. The resulting data should include date of measurement, discharge, and water temperature during spawning, redd counts and redd density in the restoration area, notes on the redd distribution pattern, and the surface area of the randomly selected redds. Estimates must include a quantitative measure of precision such as a variance or standard error.

Information gained: establish whether project was successfully implemented and fish spawned in the area, better information on redd size and redd distribution within a spawning area (improve the model).

Effectiveness Monitoring (Tier 2)

Physical feature monitoring

One year of pre-action and a minimum of 4 years post-action surveys that quantify existing spawning habitat at project site at range of flows typically experienced during spawning with the post-action monitoring extending for a minimum of 4 years. Monitoring also should include one post-high flow topography (DEM with resolution) and spawning habitat area estimate (include any new habitat created downstream). The resulting data should include date of measurement, discharge, and estimated spawning habitat available. Estimates must include a quantitative measure of precision such as a variance or standard error.

Information gained: establish whether project was successfully implemented, better estimates of habitat added per project and partial controllability, some information on stage-habitat relationships, and information on habitat persistence following restoration.

Biological monitoring

At least 2 years of pre-action and 3 years of post-action surveys that quantify the number of redds using the project site and the nearest known spawning locations up and downstream of the project area. Each year, these sites should be visited weekly during spawning to estimate peak spawning counts. Each fresh redd detected during a survey should be georeferenced, stored electronically, and the surface area measured using standard methods (Gallagher et al. 2007). The resulting data should include monitoring locations, GPS redd coordinates, date of measurement, discharge, and water temperature during spawning, redd counts and redd density, the proportion of the redds in a tributary that are in the project area, and the dimensions of measured redds. Estimates must include a quantitative measure of precision such as a variance or standard error.

Information gained: establish whether project was successfully implemented and fish spawned the area, better information on redd size and redd distribution with a spawning areas (improve the model), information on the effect of habitat improvement on the distribution of spawners across a range of return sizes (evaluate model assumptions).

Validation Monitoring (Tier 3)

Physical feature monitoring

One year of pre-action and a minimum of 4 years of post-action surveys that quantify existing spawning habitat at all known or suspected spawning sites (including the project site) in the tributary[1] over a range of flows experienced during spawning with the post-action monitoring extending for a minimum of 4 years. In addition, the topography of the reach containing the project site should be measured annually and the substrate size composition and embeddedness at each riffle in the reach should be measured annually. The resulting data should include georeferenced known or suspected spawning site locations, date of measurement, discharge, and annual reach scale topography, substrate composition and embeddedness measurement, estimated spawning habitat available. Estimates must include a quantitative measure of precision such as a variance or standard error.

Information gained: establish whether project was successfully implemented, better estimates of habitat added per project and partial controllability, information on habitat availability throughout the tributary and stage-habitat relationships (model input improvement), information on habitat persistence following restoration and at non restoration sites (model improvement) and information that may be used to develop models for gravel augmentation actions.

Biological monitoring

At least 2 years of pre-action and 3 years of post-action surveys that quantify the number of redds using the project site and the nearest known spawning locations up and downstream of the project area. Each year, these sites should be visited weekly during the spawning to estimate peak spawning counts. Each fresh redd detected during a survey should be georeferenced, stored electronically, and the surface area measured using standard methods (Gallagher et al. 2007). At each location, a random selection of redds should be selected and monitored till fry emergence and the number of emerging fry estimated (e.g., McMichael et al. 2005). Water temperatures should be monitored at each spawning site from the initiation of spawning surveys till fry emergence. The resulting data should include monitoring locations, GPS redd coordinates, dates of measurement, discharge, and water temperature during spawning, redd counts and redd density, the proportion of the redds in a tributary that are in the project area, and the dimensions of measured redds, the number of fry emerging, dates of emergence, and discharge and water temperature during the monitoring period. Estimates must include a quantitative measure of precision such as a variance or standard error.

Information gained: establish whether project was successfully implemented and fish spawned the area, better information on redd size and redd distribution with a spawning areas (improve the model), information on the effect of habitat improvement on the distribution of spawners across a range of return sizes (evaluate model assumptions about habitat use), information on egg to fry survival (improve the egg-to-fry estimates in the model).

Juvenile Rearing Habitat Restoration (Perennially and Periodically Inundated)

Implementation Monitoring (Tier 1)

Physical feature monitoring

One pre-action and one post-action survey that quantify existing juvenile rearing habitat based on physical features at the project site that occurs within the range of flows typically experienced during juvenile rearing period (run-specific). The resulting data should include expected amount of habitat created (pre-action), expected frequency and duration of inundation for periodically inundated habitats, dates of measurement, discharge during measurement, and estimated rearing habitat available. Estimates must include a quantitative measure of precision such as a variance or standard error.

Information gained: establish whether project was successfully implemented, better estimates of habitat added per project and partial controllability, some information on stage-habitat relationships.

Biological monitoring

One pre-action and one post-action survey that quantify the number of juvenile fish using the project site on several occasions during the juvenile rearing. The site should be visited on at least 3 occasions during the juvenile rearing period to estimate juvenile fish abundance. The surveys should be conducted using the appropriate American Fisheries Society (AFS) standardized methods (Bonar et al. 2009) and the proper statistical design and estimator to allow the unbiased estimation of the number of juvenile salmonids using each site. Examples of estimators include distance sampling, double observer sampling, capture-mark-recapture, mark-resight, and occupancy estimation. The resulting data should include dates of measurement, discharge during surveys, and water temperature, turbidity, specific conductance, sample unit size, and juvenile abundance (occupancy) estimates (Williams et al 2002, Powell and Gale 2015). Estimates must include a quantitative measure of precision such as a variance or standard error.

Information gained: establish whether project was successfully implemented and juvenile fish used the area, better information habitat use and habitat capacity (improve the model).

Effectiveness Monitoring (Tier 2)

Physical feature monitoring

One year of pre-action and a minimum of 4 years of post-action surveys that quantify existing rearing habitat at project site based on physical features and within the range of flows typically experienced during juvenile rearing. The resulting data should include date of measurement, discharge, and estimated rearing habitat available. Estimates must include a quantitative measure of precision such as a variance or standard error.

Information gained: establish whether project was successfully implemented, better estimates of habitat added per project and partial controllability, some information on stage-habitat relationships, information on habitat persistence/evolution following restoration.

Biological monitoring

At least 2 years of pre-action and 3 years of post-action surveys that quantify juvenile fish abundance at the project site and the nearest juvenile habitats up and downstream of the project location. If no suitable juvenile habitats are available near the project site, comparable control sites should be established within 1 km up and downstream of the project site. Each year, these sites should be visited on at least 3 occasions during the juvenile rearing period to estimate juvenile fish abundance. The surveys should be conducted using the appropriate AFS standardized methods (Bonar et al. 2009) and the proper statistical design and estimator to allow the unbiased estimation of the number of juvenile salmonids using each site. The resulting data should include dates of measurement, habitat measurement (depth, current velocity, substrate, and cover) at each site, site GPS coordinates, discharge during surveys, and water temperature, turbidity, specific conductance, sample unit size (ha), and juvenile abundance (occupancy) estimates. Estimates must include a quantitative measure of precision such as a variance or standard error.

Information gained: establish whether project was successfully implemented and juvenile fish used the area, better information habitat use and habitat capacity (improve the model), information on the effect of habitat improvement on the distribution of juvenile across a range of juvenile abundances (evaluate model assumptions).

Validation Monitoring (Tier 3)

Physical feature monitoring

One year of pre-action and a minimum of 4 years of post-action surveys that quantify existing juvenile rearing habitat based on physical features at the project site and within the tributary for a distance of 0.5km up and downstream of the project site and within the range of flows typically experienced during juvenile rearing. The resulting data should include georeferenced habitat measurements, date of measurements, discharge during measurements, and estimated juvenile habitat available. Estimates must include a quantitative measure of precision such as a variance or standard error.

Information gained: establish whether project was successfully implemented, better estimates of habitat added per project and partial controllability, information on juvenile habitat availability throughout the tributary and stage-habitat relationships (model input improvement), information on habitat persistence/evolution following restoration and at non restoration sites (model improvement).

Biological monitoring

At least 2 years of pre-action and 3 years of post-action surveys that quantify the abundance, survival, and growth of juveniles at the project site and the nearest juvenile habitats up and downstream of the project location. Each year, these sites should be visited on at least 3 occasions during the juvenile rearing period to estimate juvenile fish abundance and more frequently to estimate the survival and growth of tagged wild juvenile fish. The surveys should be conducted using the appropriate AFS standardized methods (Bonar et al. 2009) and the proper statistical design and estimator to allow the unbiased estimation of the number of juvenile salmonids using each site, survival and growth. Example of proper estimators include (multistrata) Cormack-Jolly-Seber (survival, growth, movement), open and closed Robust Design (survival, abundance, emigration/immigration), and (multistrata) recapture-resight-recovery models (survival, growth, movement). Williams et al 2002, Powell and Gale 2015). Water temperatures should be monitored at survey site from fry emergence until the end of the rearing period. The resulting data should include georeferenced monitoring locations, dates of measurement, habitat measurements (depth, current velocity, substrate, and cover) at each site, site GPS coordinates, discharge during surveys, and water temperature, turbidity, specific conductance, sample unit size (ha), and juvenile survival, growth, and abundance estimates, capture/detection histories and body size measurements for tagged fish and water temperature during the monitoring period. Estimates must include a quantitative measure of precision such as a variance or standard error.

Information gained: establish whether project was successfully implemented and juvenile fish used the area, better information habitat use and habitat capacity (improve the model), information on the effect of habitat improvement on the distribution of juvenile across a range of juvenile abundances (evaluate model assumptions about habitat use), information influence of habitat on juvenile survival and growth (improve the estimates in the model)

Passage Improvement (Adult or Juvenile)

Implementation Monitoring (Tier 1)

Physical feature monitoring

One pre-action and one post-action survey that documents the existence and removal/modification of the passage obstruction and estimates of spawning and/or rearing habitat availability under base flow conditions upstream of the obstruction. If flow related passage obstruction, monitoring should include at least 3 discharge measurements during the migration/movement period. The resulting data should include before and after measurements of passage structure (if applicable), estimates of habitat availability upstream of the obstruction under base flow, discharge during measurements, and dates of measurement. Estimates must include a quantitative measure of precision such as a variance or standard error.

Information gained: establish whether project was successfully implemented, better estimates of project success and partial controllability.

Biological monitoring

One pre-action and one post-action survey that quantifies the number of fish passing the obstruction. The site should be visited on at least 3 occasions during the movement/migration period to estimate the number of fish passing the obstruction. The resulting data should include dates of measurement, method for estimating fish passage, discharge during surveys, and estimates of the number of fish passing over a 24-h period. Estimates must include a quantitative measure of precision such as a variance or standard error.

Information gained: establish whether project was successfully implemented and fish passed the obstruction, better information on fish passage (improve the model).

Effectiveness Monitoring (Tier 2)

Physical feature monitoring

One year of pre-action and a minimum of 2 years of post-action surveys that documents the existence and removal/modification of the passage obstruction and estimates of spawning and/or rearing habitat availability under base flow conditions upstream of the obstruction. If flow related passage obstruction, monitoring should include at least 3 discharge measurements during the migration/movement period. The resulting data should include before and after measurements of passage structure (if applicable), estimates of habitat availability upstream of the obstruction under base flow, discharge at obstruction, discharge during habitat surveys, and dates of surveys. Estimates must include a quantitative measure of precision such as a variance or standard error.

Information gained: establish whether project was successfully implemented, better estimates of project success and partial controllability, estimates of habitat availability and stage-habitat relationships (model input improvement)

Biological monitoring

One year of pre-action and a minimum of 2 years of post-action surveys that quantify the number of fish passing the obstruction and documents the use of habitats upstream of the passage barrier. The restoration site should be visited on at least 3 occasions during the movement/migration period to estimate the number of fish passing the obstruction. Spawning ground surveys should be conducted to quantify the number of spawning adults (or redds) using the areas above the obstruction. Each year, potential spawning locations should be visited on several occasions during the spawning season to estimate peak spawning counts. Juvenile fish sampling should be conducted in a random selection of a minimum of 10 juvenile habitats using the appropriate AFS standardized methods (Bonar et al. 2009) and the proper statistical design and estimator to allow the unbiased estimation of the number of juvenile salmonids using each site. The resulting data should include dates of measurement, method for estimating fish passage, discharge during surveys, and estimates of the number of fish passing over a 24-h period, habitat measurement, (depth, current velocity, substrate, and cover) at each site, peak redd counts, site GPS coordinates, discharge during surveys, and water temperature, turbidity, specific conductance, sample unit size (ha), and juvenile abundance (occupancy) estimates.

Estimates must include a quantitative measure of precision such as a variance or standard error.

Information gained: establish whether project was successfully implemented and fish passed the obstruction, better information on fish passage (improve the model), better information on redd size and redd distribution with a spawning areas (improve the model), information on the effect of habitat improvement on the distribution of spawners across a range of return sizes (evaluate model assumptions), better information habitat use and habitat capacity (improve the model), information on the effect of habitat improvement on the distribution of juvenile across a range of juvenile abundances (evaluate model assumptions)

Validation Monitoring (Tier 3)

Physical feature monitoring

One year of pre-action and a minimum of 3 years of post-action surveys that documents the existence and removal/modification of the passage obstruction and estimates spawning and rearing habitat availability under a range of stream discharges upstream of the obstruction. If flow related passage obstruction, monitoring should include at least 3 discharge measurements during the migration/movement period. The resulting data should include before and after measurements of passage structure (if applicable), estimates of habitat availability upstream of the obstruction at a range of flows that typically occur during spawning and rearing periods, discharge at the obstruction, discharge during habitat surveys, and dates of surveys. Estimates must include a quantitative measure of precision such as a variance or standard error.

Information gained: establish whether project was successfully implemented, better estimates of project success and partial controllability, estimates of habitat availability and stage-habitat relationships (model input improvement)

Biological monitoring

One year of pre-action and a minimum of 3 years of post-action surveys that estimates the probability of passage and survival above and below the barrier. To estimate passage and survival, each year at least 20 adults (downstream of obstruction) and/or 50 juvenile fish (upstream) should be tagged with passive integrated transponder (PIT) or similar tags using the appropriate method. Adults should be tagged as soon as they arrive to the tributary. Juveniles should be tagged in natal habitats as soon as they are of sufficient size to handle the tag burden. Dual tag reader arrays should be installed above and below the previous obstruction and continuously monitored for the duration of the monitoring period. Spawning ground surveys should be conducted to locate tagged adults. Survival and movement should be estimated using the proper estimator such as multistrata Cormack-Jolly-Seber and multistrata recapture-resight-recovery models (Williams et al 2002, Powell and Gale 2015). Water temperatures should be monitored at the project site throughout the duration of the monitoring effort. The resulting data should include georeferenced fish capture and relocation (adult carcasses) locations, dates of sampling, site GPS coordinates, adult and juvenile survival and movement estimates, capture/detection histories for tagged fish, and water temperature during the monitoring period.

Estimates must include a quantitative measure of precision such as a variance or standard error.

Information gained: establish whether project was successfully implemented and fish passed the obstruction, better information on fish passage (improve the model), better information of adult en route survival and migratory patterns and juvenile survival and movement and timing (improve the model).

Screen/Reduce Water Diversion

Implementation Monitoring (Tier 1)

Physical feature monitoring

One pre-action and one post-action survey that documents the existence and addition/modification of screen. If action is reduction in amount of water diverted, measure stream discharge on at least 3 occasions above (0.5 km) and below (0.5 km) the diversion during the time period of the diversion reduction. Up and downstream discharge measurements should be conducted within the same 12h period. The resulting data should include before and after documentation of screening (if applicable), discharge (if applicable), and dates of measurement. Discharge estimates must include a quantitative measure of precision such as a variance or standard error.

Information gained: establish whether project was successfully implemented, better estimates of project success and partial controllability.

Biological monitoring

One pre-action and one post-action surveys that detect entrainment by the diversion if screening was the action. The survey should be sufficient to detect entrainment with a 90% probability both pre- and the post-screening during the juvenile fish rearing and migration period. If reduction in water diversion, no minimum monitoring is required. The resulting data should include dates of measurement, method for estimating probability of detecting entrainment event during surveys, and discharge during surveys. Estimates must include a quantitative measure of precision such as a variance or standard error.

Information gained: establish whether project was successfully implemented and fish entrainment was prevented, better information on entrainment (improve the model).

Effectiveness Monitoring (Tier 2)

Physical feature monitoring

One pre-action and one post-action survey that documents the existence and addition/ modification of screen if applicable. If action is reduction in amount of water diverted, measure stream discharge continuously above (0.5 km) and below (0.5 km) the diversion during the period of the diversion reduction. The resulting data should include before and after documentation of screening (if applicable), discharge (if applicable), and dates of measurement. Discharge estimates must include a quantitative measure of precision such as a variance or standard error.

Information gained: establish whether project was successfully implemented, better estimates of project success and partial controllability, estimates of increased water availability due to diversion reduction (model input improvement)

Biological monitoring

One year of pre-action and a minimum of 2 years of post-action surveys that quantifies the number of fish entrained over a 7-day period if screening action. The survey should be sufficient to estimate weekly entrainment rate with 90% precision during the juvenile fish rearing and migration period. If action is reduction in water diversion, no minimum monitoring is required. The resulting data should include dates of measurement, method for estimating entrainment rate, and discharge during surveys. Estimates must include a quantitative measure of precision such as a variance or standard error.

Information gained: establish whether a project was successfully implemented and fish entrainment was prevented, better information on entrainment (improve the model), quantitative estimates of entrainment from unscreened diversions (improve the model)

Validation Monitoring (Tier 3)

Physical feature monitoring

No validation monitoring for this action.

Biological monitoring

Two years of pre-action and a minimum of 3 years of post-action surveys that document survival in the reach spanning 0.5 km upstream and downstream of the diversion. To estimate survival, each year at least 100 juvenile fish should be tagged in areas > 0.5 km upstream of the diversion with passive integrated transponder (PIT) or similar tags using the appropriate method. Juveniles should be tagged in natal habitats as soon as they are of sufficient size to handle the tag burden. Dual tag reader arrays should be installed at the up and downstream boundaries of the 1km study reach and the diversion, and monitored for the duration of the monitoring period. Survival and movement should be estimated using the proper estimator such as multistrata Cormack-Jolly-Seber and multistrata recapture-resight-recovery models (Williams et al 2002, Powell and Gale 2015). Water temperatures should be monitored at the project site throughout the duration of the monitoring effort. The resulting data should include georeferenced fish capture locations, dates of sampling, site GPS coordinates, juvenile survival and movement estimates, capture/detection histories for tagged fish, and water temperature during the monitoring period. Estimates must include a quantitative measure of precision such as a variance or standard error.

Information gained: establish whether a project was successfully implemented and fish entrainment was prevented, better information on entrainment (improve the model), quantitative estimates of the changes in survival associated with screening or reduction in diversion (improve the model)

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Appendix D Central Valley Chinook Salmon and Steelhead Recovery Plan

The following is a summary of Central Valley Chinook and Steelhead Recovery Plan published by the National Marine Fisheries Service. It includes key information for Sacramento River winter-run Chinook salmon, Central Valley spring-run Chinook salmon, and Central Valley steelhead, including listing status, historical and current spawning distribution, key recovery actions, and an overview of the Diversity Groups.

The factsheet is also available for download at the NOAA website.

Summer 2014

Central Valley Chinook Salmon & Steelhead Recovery Plan

Background

Millions of wild salmon and steelhead once returned to spawn in the foothills and mountains of California's Central Valley. Streams fed by rainfall, snowmelt, and cold water springs encircled the valley, fostering a diversity and abundance of Chinook salmon and steelhead. However, the mid-1800s ushered in sweeping changes to the landscape that ultimately led to declines in the abundance, distribution, and diversity of these fish.

Gold mining, dam construction, water and hydropower management, and other land uses hindered fish populations from thriving in the Central Valley. By the 1990s, three of the valley's salmon and steelhead species were close to extinction and listed under the federal Endangered Species Act (ESA): Sacramento River winter-run Chinook salmon, Central Valley spring-run Chinook salmon, and Central Valley steelhead. Today, only a few of the historic populations remain, but a new ESA recovery plan provides a framework for recovering Central Valley's iconic fish.

Plan provides a path for salmon and steelhead recovery

In 2014, NOAA Fisheries adopted a plan to recover Sacramento River winter-run Chinook salmon, Central Valley spring-run Chinook salmon, and Central Valley steelhead.

A recovery plan is one of the most important tools in the recovery process. It provides a sound scientific foundation and guides decision-making for partners implementing the plan and its actions. This recovery plan sets goals and prioritizes actions for the Sacramento-San Joaquin Delta and its watersheds, laying out steps to achieve the species' recovery. It provides a framework for targeting conservation efforts and modifying actions based on new science and changing circumstances.

Recovery plans provide guidance and are voluntary; they do not have the force of law. As such, the success of recovery efforts ultimately depends on partnerships and cooperation to ensure the right actions are implemented to advance long-term species' recovery.

Spring-run Chinook salmon - photo courtesy Zeke Lunder

What will recovery look like under the Endangered Species Act?

Each of these species must be viable and able to survive variations in climate, ocean conditions, and productivity. They must also be able to withstand catastrophic changes, like droughts, floods and earthquakes.

NOAA FISHERIES WEST COAST REGION

Sacramento River winter-run Chinook salmon

- Listing Status: Endangered (listed as threatened in 1989, reclassified as endangered in 1994)
- Historical Spawning Distribution: Headwaters of the Sacramento River & Battle Creek
- Current Spawning Distribution: Sacramento River downstream of Shasta Dam

Central Valley spring-run Chinook salmon

- Listing Status: Threatened (listed in 1999)
- Historical Spawning Distribution: Headwaters of all major Central Valley rivers & numerous creeks
- Current Spawning Distribution: Several tributaries to the Sacramento River, confined below rim dams

Central Valley steelhead

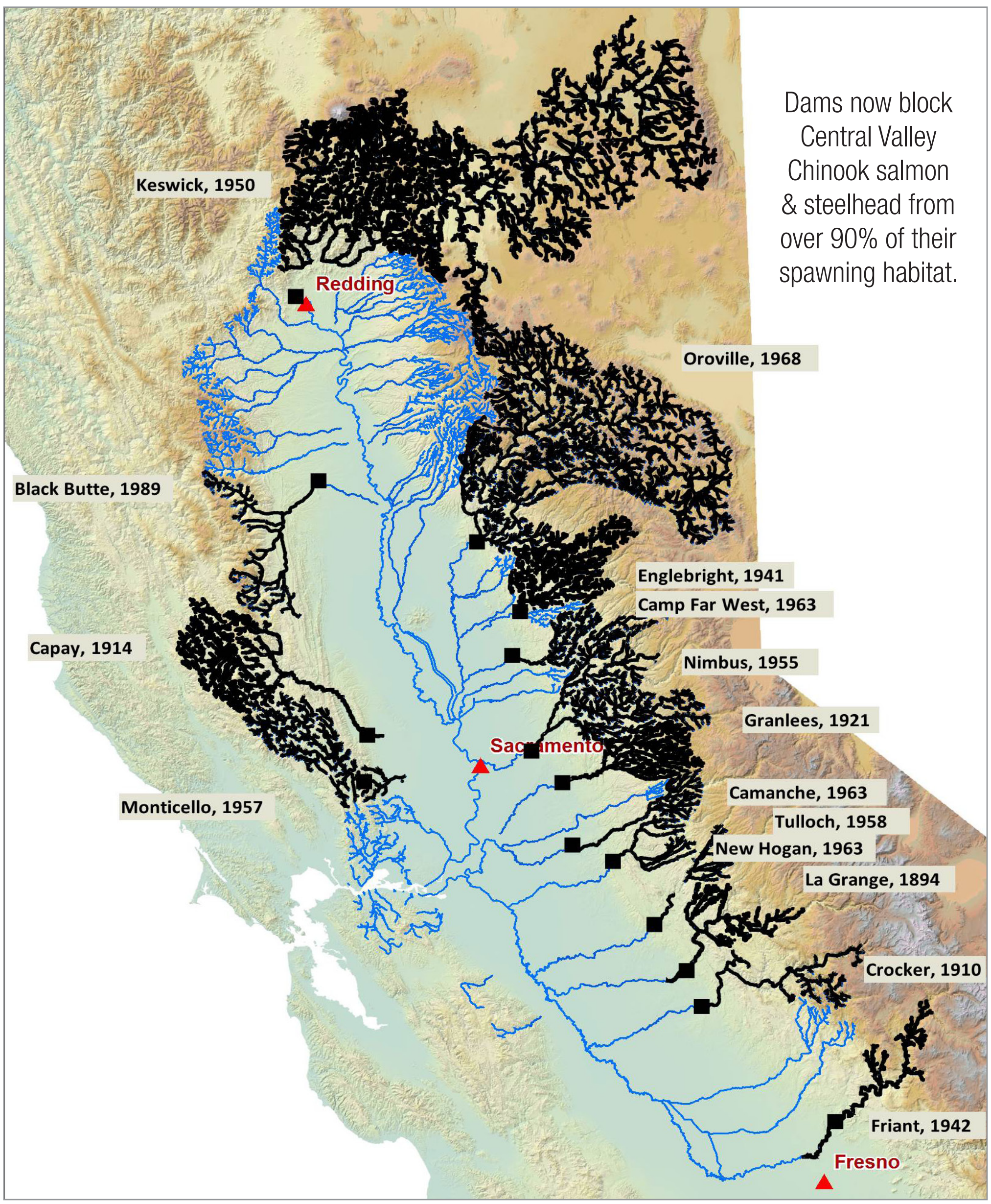
- Listing Status: Threatened (listed in 1998)
- Historical Spawning Distribution: Headwaters of all major Central Valley rivers & numerous creeks
- Current Distribution: Tributaries to the Sacramento & San Joaquin rivers, confined below rim dams

Central Valley Chinook Salmon & Steelhead Recovery Plan

Recovery actions target threats

Currently, dams block Chinook salmon and steelhead from over 90 percent of their historical spawning habitat in the valley. Reduced flows and warm temperatures below the dams further compound this problem. In addition, 98 percent of riparian and floodplain habitat in the lower river and Delta is no longer available to support healthy fish runs. But lost and degraded habitat is not the only challenge these fish face. Water withdrawals, commercial and recreational fisheries, the introduction of non-native fish, and legacy effects of hatcheries all contribute to declining populations.

The recovery plan targets actions to these very threats. The idea is to support the biological needs of fish by addressing the threats they face, whether it be warm water temperatures below dams or habitat loss. By addressing these threats collectively, the recovery plan provides a framework for restoring these populations.



Key recovery actions

- Reintroducing populations into key watersheds;
- Conducting landscape-scale restoration throughout the Delta;
- Incorporating ecosystem restoration into Central Valley flood control plans, including breaching and setting back levees;
- Restoring flows throughout the Sacramento and San Joaquin River basins and the Delta;
- Reducing biological impacts of exporting water through Jones and Banks pumping plants;
- Meeting water quality criteria established in the Central Valley Water Quality Control Plan for all potential pollutants;
- Annually reviewing impacts from commercial and recreational fisheries and modifying regulations as necessary to allow for species to recover;
- Implementing projects to minimize predation at artificial structures; and
- Implementing the recommendations of the California Hatchery Scientific Review Group.

The recovery plan is guided by the best available science. It includes a range of actions to restore winter- & spring-run Chinook salmon, steelhead, & their habitats. It sets priorities to guide investments & incorporates an adaptive management approach to make adjustments based on new information.

Central Valley Chinook Salmon & Steelhead Recovery Plan

Strategy for recovery

The recovery strategy focuses on protecting existing populations while reintroducing populations into their historical habitats. We prioritized fish populations and actions so that resources are strategically invested. This strategy, coupled with actions that address threats, will contribute to restored salmon and steelhead runs. Here's what the plan envisions for recovery:

Spring-run Chinook salmon

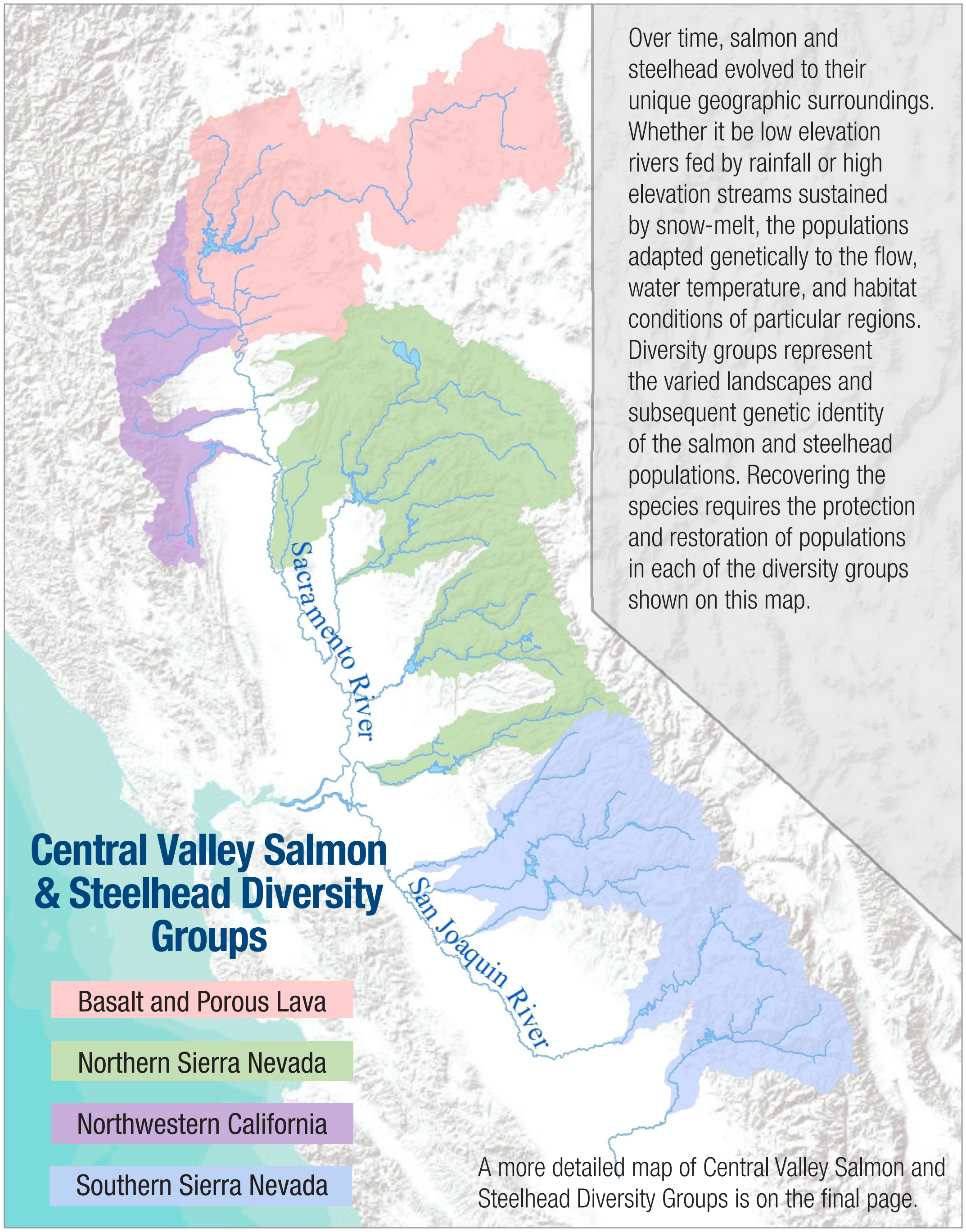
- One viable population in the Northwestern California Region
- Two viable populations in Basalt & Porous Lava Region
- Four viable populations in Northern Sierra Region
- Two viable populations in the Southern Sierra Region

Winter-run Chinook salmon

- Three viable populations in the Basalt & Porous Lava Region

Steelhead

- One viable populations in the Northwestern CA Region
- Two viable populations in Basalt & Porous Lava Region
- Four viable populations in Northern Sierra Region
- Two viable populations in the Southern Sierra Region



Over time, salmon and steelhead evolved to their unique geographic surroundings. Whether it be low elevation rivers fed by rainfall or high elevation streams sustained by snow-melt, the populations adapted genetically to the flow, water temperature, and habitat conditions of particular regions. Diversity groups represent the varied landscapes and subsequent genetic identity of the salmon and steelhead populations. Recovering the species requires the protection and restoration of populations in each of the diversity groups shown on this map.

A more detailed map of Central Valley Salmon and Steelhead Diversity Groups is on the final page.

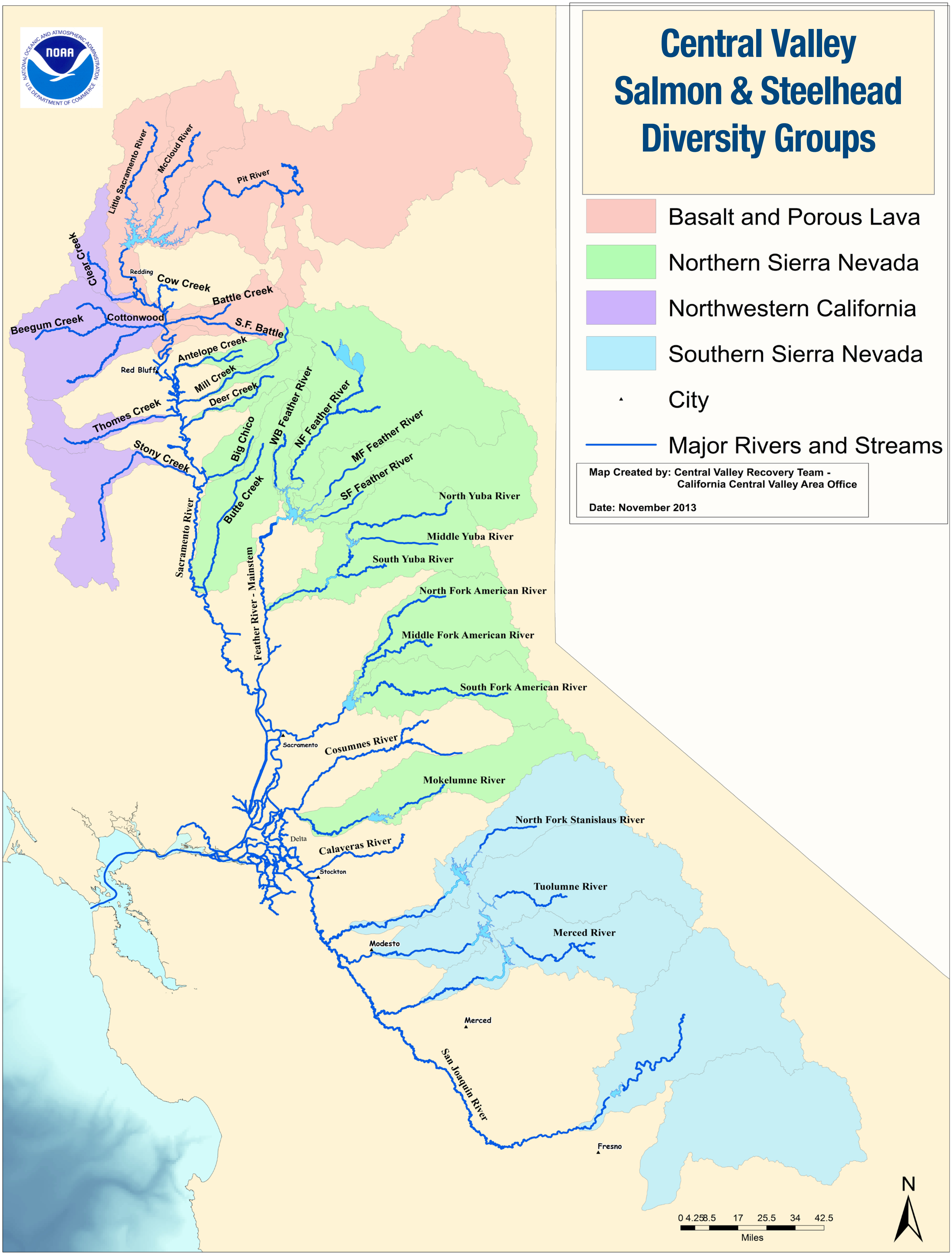
LEARN MORE…

To learn more about recovery efforts in California's Central Valley please visit:

On the web: westcoast.fisheries.noaa.gov/protected_species/salmon_steelhead/recovery_planning_and_implementation/california_central_valley/california_central_valley_salmon_recovery_domain.html

Central Valley Technical Recovery Team:

On the web: swfsc.noaa.gov/textblock.aspx?Division=FED&ParentMenuId=54&id=2260



Central Valley Salmon & Steelhead Diversity Groups
Basalt and Porous Lava
Northern Sierra Nevada
Northwestern California
Southern Sierra Nevada
City
Major Rivers and Streams
Map Created by: Central Valley Recovery Team - California Central Valley Area Office
Date: November 2013
Little Sacramento River
McCloud River
Pit River
Clear Creek
Redding
Cow Creek
Battle Creek
Beegum Creek
Cottonwood
S.F. Battle
Antelope Creek
Red Bluff
Mill Creek
Deer Creek
Thomes Creek
Stony Creek
Big Chico
Butte Creek
WB Feather River
NF Feather River
MF Feather River
SF Feather River
Sacramento River
Feather River - Mainstem
North Yuba River
Middle Yuba River
South Yuba River
North Fork American River
Middle Fork American River
South Fork American River
Sacramento
Cosumnes River
Mokelumne River
Delta
Calaveras River
Stockton
North Fork Stanislaus River
Tuolumne River
Merced River
Modesto
Merced
San Joaquin River
Fresno
N
0 4.25 8.5 17 25.5 34 42.5
Miles

Appendix E Glossary

Common terms used in CVPIA Structured Decision Making process

The following glossary terms are specific to the Structured Decision Making process and are borrowed from the full glossary from the USFWS National Conservation Training Center, which is available as an online resources for their SDM course. Where applicable, terms unique to the CVPIA process have been added to the original Glossary. In addition, some terms have been referenced from Conroy and Peterson (2013).

Adaptive (Resource) Management (ARM) – incorporation of the reduction of structural uncertainty as part of optimal resource management via sequential decision making (Conroy and Peterson 2013).

ARM, active adaptive optimization – seeking of an optimal sequence of decisions that anticipates future reduction of structural uncertainty (Conroy and Peterson 2013).

ARM, passive adaptive optimization – seeking of an optimal sequence of decisions that does not anticipate future reduction of structural uncertainty (Conroy and Peterson 2013).

Algorithm – a logical arithmetical or computational step by step procedure that, if correctly applied, ensures the solution of a problem.

Alternatives – Different management actions that are available. This element requires explicit articulation of the alternatives available to the decision maker. The range of permissible options is often constrained by legal or political considerations, but structured assessment may lead to creative new alternatives.

Anchoring – the tendency to be influenced by initial estimates – people will be drawn to the guesses made by others and will defer their judgments to people they believe have greater authority.

Assumption – something taken to be true without proof or demonstration.

Assessment – obtaining a range of outcomes (usually over an 80% range of uncertainty: “10-50-90” for a particular uncertainty from an informed expert acceptable to the decision maker or decision board).

Attribute (criteria) – a quantitative measure of performance associated with a particular criterion according to which an alternative is to be evaluation. Attributes fall into three categories: 1) natural; 2) constructed; and 3) proxy.

Calibration – the likelihood that the expert’s probabilities correspond with a set of repeated experimental results, the probability that the difference between the expert’s judgment and the observed values have arisen by chance.

Calibration of Models – adjusting model parameters, structures, and assumptions so that they fit available data and intuition, i.e., refinement of ideas.

Carrying Capacity – the maximum number of individuals that a given environment can support indefinitely, usually determined by the organism's resource requirements.

Coefficient of Variation – a measure of the relative variation of a distribution independent of the units of measurement; the standard deviation divided by the mean.

Cognitive Availability – the tendency to judge the probability of an event by the ease with which examples are recalled.

Conceptual Model/Diagram – verbal models, diagrams, logic trees, or sets of mathematical equations representing components in a system, including input and output, flows, cycles, system boundaries, causal links, and so on.

Conditional Probability – the probability of occurrence of an event given the occurrence of another conditioning event.

Confidence – the degree to which we are sure that an estimate lies within some distance of the truth.

Confidence Interval – in the long run, someone who computes 95% confidence intervals will find that the true values of parameters lie within the computed intervals 95% of the time.

Consequences – The results of different management actions, in terms that are relevant to the management objectives. Often, we predict the consequences of the alternative actions with some type of model. Depending on the information available or the quantification desired, consequences may be modeled with highly scientific computer applications or with professional judgment elicited carefully and transparently. Ideally, models are quantitative, but they need not be; the important thing is that they link actions to consequences.

Constraint – a limitation imposed by external conditions.

Context – the setting of the problem at hand.

Cost-benefit Analysis – examination, usually in economic terms, of the advantages and disadvantages of a particular course of action.

Criterion – a particular perspective according to which decision alternatives may be compared, usually representing a particular interest, concern, or point of view.

Decision – a choice between two or more acts, each of which will produce one of several outcomes, a conscious, irrevocable allocation of resources with the purpose of achieving a desired outcome, a judgment on an issue under consideration; the act of making up one's mind or reaching a conclusion, a verdict reached or a judgment announced.

Decision Analysis – is a methodology and set of probabilistic frameworks for facilitating high quality, logical discussions; illuminating difficult decisions, and leading to clear and compelling action by the decision maker.

Decision Analysis Cycle – a systematic approach for solving problems; structuring a problem to capture the essentials, evaluation to gain insight, and agreement with the world to make something happen.

Decision Hierarchy – a method to organize decisions into those that are policy or constraints, those which are the focus of the analysis, and others which are required for implementation.

Decision Maker – person or team with the responsibility and authority to allocate resources and implement the decision.

Decision Making (descriptive) – how people actually do make decisions.

Decision Making (prescriptive) – a rational framework for how people should make decisions, and techniques to aid them doing so.

Decision Node – a point in a decision tree where a decision must be made.

Decision Support Model – A numerical representation of a conceptual model (typically a life-cycle model or similar) that allows for interrogation of various scenarios, calibrations, assumptions, inputs, and outputs.

Delphi (method, technique) – a form of behavioral aggregation that consists of questionnaires, elicitation, aggregation of results, review of combined results by experts and iteration of feedback until consensus is achieved.

Density Dependence – this is when survival or fecundity is a function of the difference between the total number of adults and the carrying capacity of the environment, creating a feedback between population size, and the rate at which the population grows.

Deterministic Model – a model in which there is not representation of variability.

Deterministic Sensitivity – if a parameter is changed by a small amount in the region of the best estimate, it is the magnitude of change we see in model output, relative to the amount of change in the parameter.

Empirical – derived from or relating to experiment and observation rather than theory.

Environmental Variation – variation in climate, landscapes, and other unpredictable influences that lead to uncertainty about the effects of management.

Estimation – the aggregation of field data into measures of resource attributes. Examples include means, variances, and correlation coefficients computed with sample data. Multiple estimators are always available for any resource attribute, and the choice of which particular estimator to use is based on statistical features such as bias and precision.

Evidence – direct experimental observation of cause and effect, probability, or frequency.

Expected Utility – the magnitude of an anticipated gain, discounted by the chance that the outcome will be achieved.

Expert – someone who has knowledge, skill, experience, training, or education about an issue at an appropriate level of detail and who is capable of communicating their knowledge. See also substantive expertise and normative expertise.

Fecundity (with reference to PVAs) – the number of offspring born per adult, and alive at the time of the next census.

Fundamental Objective. One of the ultimate goals of the decision. An objective that we care about for its own sake, or which is an end in itself. See also Means Objective.

Hypothesis – a suggested but unconfirmed assertion or explanation of observed patterns. Hypotheses can take many forms, for example, a hypothesized magnitude of a resource attribute or a mathematical relationship between attributes. Hypotheses are tested by comparison against field data.

Implementing Agencies – U.S. Fish and Wildlife Service and Bureau of Reclamation.

Likelihood – the extent to which a proposition or model explains available data (the relation between hypothesis and evidence).

Management Action – an action affecting a managed system, taken as a result of a management decision. In the context of natural resources, management actions typically influence the status of resources or the processes that control resource dynamics.

Management Alternative – a potential management action. In sequential management, a management action is selected at each point in time from an identified set of management alternatives. The set of management alternatives constrains and influences the choice of a management strategy.

Management Decision – a decision to take a management action. In adaptive management, decision making typically is driven by management objectives, with active stakeholder involvement. Adaptive decision making takes into account both the current status of resources and the level of understanding about them.

Management Strategy – a prescription of management actions pursuant to management objectives. In the context of adaptive management, a management strategy describes time-specific management actions to be taken, conditional on current resource status and the level of understanding about resource dynamics. Management strategies often are expressed in terms of resource thresholds, on either side of which a different action is to be taken.

Means Objective – An objective that is not sought for its own sake, but as a means of achieving a more fundamental objective.

Measurable Attribute – metric used to assess achievement of an objective.

Minimum Viable Population – the smallest isolated population having an acceptable chance of surviving for the foreseeable future.

Model – any representation, whether verbal, diagrammatic, or mathematical, of an object or phenomenon. Natural resource models typically characterize resource systems in terms of their status and change through time. Models imbed hypotheses about resource structures and functions, and they generate predictions about the effects of management actions, an explicit approximation of reality, typically expressed as a series of mathematical relationships.

Model Uncertainty – uncertainty arising from the fact that, often, many alternative assumptions and models could be constructed that are consistent with data and theory, but which would generate different predictions.

Monitoring – sampling and analysis to determine compliance with a standard or deviation from a target or prediction, or to measure the state and response of the system to management strategies.

Objectives – An explicit statement of a desired outcome, typically expressed in subject-verb-object sentence structure. Objectives (even those that are stated in scientific terms) are always a reflection of values, so setting objectives falls in the realm of policy and should be informed by legal and regulatory mandates as well as stakeholder viewpoints. A number of methods for stakeholder elicitation and conflict resolution are appropriate for clarifying objectives.

Outcome – the subsequent events that determine the ultimate desirability of pursuing a particular alternative.

Policy plots – graphical representations of state-dependent, globally optimal policies, which determine the optimal restoration actions for any condition that arises in a modeled simulation.

Probability – the statistical frequency (or relative frequency) with which an event is expected to occur, or the degree of belief warranted by evidence; see also belief, chance, confidence, credibility, cumulative probabilities, likelihood, plausibility, possibility, risk, posterior probabilities, prior probabilities, tendency),a number between zero and one (inclusively) representing the degree of belief a person attaches to the occurrence of an event.

Problem – a question or situation that presents doubt, perplexity, or difficulty; a question offered for consideration, discussion, or solution.

Problem Definition – The first step in a structured analysis of a decision, in which the nature and scope of the decision is clarified. It helps to ask some of the following questions: Who is the decision maker? What specific decision has to be made? What are the spatial scope of the decision? When does the decision have to be made? Will the decision be iterated over time?

Process Model – a mathematical representation of a conceptual model, such as a population model, an expert system, a logic tree, or any other quantitative model.

Project Work Team – a collection of subject matter experts who meet regularly to review the status of threatened and endangered species in the Central Valley.

Rapid Prototyping – an approach to structured decision making that involves quickly framing a simple prototype of the decision problem then stepping back to assess its basic structure and major components. Rapid prototyping is very useful for quickly validating objectives, evaluating model components, and setting parameters for sensitivity analysis with a minimum investment of time. The rapid prototype concept comes from engineering (quickly building a trial version of a new device or machine to see if it will work) and is useful for structured decision analysis and biological model building in natural resource management.

Restoration Fund – a condition established in CVPIA authorization that established a surcharge on water and power sales to Central Valley Project customers that is used to fund improvements to waterfowl and fishery resources in the Central Valley.

Scenario Analysis – an approach to creating alternatives for problem formulation, constructed and communicated with a storyline in which events unfold through time through a series of imagined causes and effects.

Scenarios – shared, agreed upon mental models, internally consistent descriptions of possible futures created in structured brainstorming exercises. The SIT defines a scenario as a single action proposed to achieve objectives, as compared to scenarios which focus on multiple actions.

Science Integration Team – a self-selected technical group made up of agency staff and stakeholders that maintains and refines the Decision Support Models and recommends 5-year science and management priorities for CVPIA fish programs.

Sensitivity Analysis – Measuring the impact of uncertainty on the preferred alternative or the expected performance, in order to understand the robustness of a proposed solution to the existing uncertainty. Often this is done to determine which uncertainties are critical, and perhaps allow resolution of that uncertainty prior to making the decision.

SMART (Simple Multi-attribute Ranking Technique) – One of several specific methods of analyzing tradeoffs when a decision contains multiple objectives.

***Stochastic Dynamic Programming* (SDP)** – is similar to dynamic programming but incorporates uncertainty due to stochastic events.

Stakeholder – individuals and organizations (e.g., managers, scientists, private citizens, nongovernmental organizations) with a vested interest in a shared experience. Interests can include an expectation of received benefit, a perceived threat, a prior investment of time and/or resources, or values shared with others associated with the enterprise. Active engagement of stakeholders promotes the successful implementation of adaptive management.

Stochastic Model – a model in which at least some of the parameters are drawn from statistical distributions, or in which there is some other explicit recognition of uncertainty.

Strategy – a plan of action or policy designed to achieve a major or overall aim. The SIT defines a strategy as multiple actions proposed to achieve objectives, as compared to scenarios which focus on single actions.

Structural Uncertainty – a lack of understanding about biological mechanisms that limits the effectiveness of management.

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.

Subjective Belief – personal judgment in the truth of a proposition.

Threshold – the limiting value of a resource attribute that triggers a change in management actions. Management strategies often include thresholds, such that one action is specified for resource values less than the threshold and a different action is specified for larger resource values.

Tradeoffs – In a multiple objective setting, gains in one objective that come at the cost of losses in another objective. In most complex decisions, it is not possible to perfectly achieve all objectives; the best we can do is choose intelligently between less-than-perfect alternatives. Numerous tools are available to help determine the relative importance or weights among conflicting objectives and to then compare alternatives across multiple attributes to find the 'best' compromise solutions.

Uncertainty – Because we rarely know precisely how management actions will affect natural systems, decisions are frequently made in the face of uncertainty. Uncertainty makes choosing among alternatives far more difficult. A good decision-making process will confront uncertainty explicitly and evaluate the likelihood of different outcomes and their possible consequences.

Utility – a measure of the total benefit or cost resulting from each of a set of alternative actions (decisions), a scale of preferences among outcomes.

Utility function – a continuous representation of utilities. Calculations depend on a probability associated with each state.

Utility-based Criteria – decisions based on the valuation of outcomes; for example, probabilistic benefit-cost, maximizing multi-attribute utility, or maximizing/minimizing chances of extreme outcomes.

Validation/verification (of model) – comparing independent field observations with predictions, i.e., testing ideas.

Variability – naturally occurring, unpredictable change, differences in parameters attributable to 'true' heterogeneity or diversity in a population.

Addenda

As described earlier in the document, the Near-term Restoration Strategy was developed through participation of the SIT. Members of the SIT were given a final opportunity to review the draft and submit a formal set of comments to be addended to the final version of the Strategy.

Two sets of comments were received—from the National Marine Fisheries Service (NMFS) and the Golden State Salmon Association (GSSA). Below is a brief response to each set of comments followed by their submitted comments in full.

Response to NMFS Comments

Thank you for the review of the Near-term Restoration Strategy and comments. Below are responses to specific comments in the submitted addendum. We look forward to continuing to work with the National Marine Fisheries Service on the CVPIA Science Integration Team.

NMFS Comment: We suggest the SIT discuss the implementing agencies embarking upon an independent science review of the Decision Support Models (DSM) and the NTRS in 2020, and decide whether or not such a review would be useful. Planning for this typically takes several months (at least with Delta Science Program as the facilitator) and the timing is appropriate given this iteration of the DSM and the generation of the NTRS. Science review was identified as a component of the Adaptive Resource Management Process in the CVPIA Fish Program Implementation Plan, "... *solicit an independent science review of the DSMs and 5-year plan, to occur after each revised 5-year plan is released (i.e., on a 5-year cycle)* (USFWS 2016)."

- ***Response***: This is not a comment on the Strategy; however, Reclamation and the Service are in the process of scheduling program reviews that may occur in 2024. The Science Coordinator will relay the suggestion of an independent science review to the implementing agencies for further consideration.

NMFS Comment: Related to independent science review, The Listen to the River Report made the following recommendation that, if implemented, would be valuable: "*Employ a standing independent scientific review panel to provide advice on major program questions, to review proposed expenditures, and to review the reported results of implementation activities. Examples include the CALFED Science Panel and the panels that are part of the Columbia River Basin Fish and Wildlife Program, the Independent Scientific Advisory Board (ISAB) and the Independent Scientific Review Panel (ISRP)*. We would like the SIT to consider and discuss this recommendation.

- ***Response***: As noted above, program reviews are under consideration by the implementing agencies.

NMFS Comment: We recommend the SIT discuss the extent to which the DSMs incorporate climate change projections, and assess whether further work is needed to ensure the CVPIA Fish Program is pursuing restoration activities that will allow species to adapt and respond to a changing environment. We are surprised to see that the Strategy does not mention climate change and its projected impacts on Central Valley salmonid habitat. From review of the 2009 Delivery Reliability Report, we assume that the model uses a climate characterization for conditions at 2029, which is the future climate scenario modeled in that report. We recommend that the SIT consider a longer-term projection of climate conditions to better characterize the potential for actions to provide suitable habitat that persists despite changing climate conditions. We would like to help the SIT lead the way in planning and prioritizing actions that will allow Central Valley salmonids to persist despite warming temperatures and changing hydrology patterns.

- ***Response***: Climate change was a topic discussed during several SIT meetings. A specific proposal from SIT membership that includes the rationale and proposed future condition could be considered by the SIT as modifications to the model inputs.

NMFS Comment: The Listen to the River Report encouraged the CVPIA Fish Program to take a broader interpretation of its authorities in order to achieve the doubling goal. Fish passage to historical habitat falls into that realm and, given the weight of the Listen to the River Report that is placed in other sections of the document and the increased knowledge on the projected impacts of climate change, the action/topic should be considered by the CVPIA Fish Program and SIT. The Listen to the River Report states, "*Three of the limiting factors most responsible for the severe decline of natural salmon and steelhead production in the valley have not been addressed by the CVPIA program: 1) the construction of storage dams that block access to much of the historical habitat for anadromous fish, 2)extensive alteration of the channel of the mainstem Sacramento River, and 3) the substantial export of water out of the system, especially in the Delta. Without addressing these three systemic factors, significant increases in natural production of salmon and steelhead may be achievable only in certain watersheds and is not likely to translate into meeting the "doubling" goal at the scale of the entire basin*." We agree with the Listen to the River Report and recommend the CVPIA Fish Program consider expanding its authorities where needed to address limiting factors, including fish passage to historical habitat.

- ***Response***: Strategies and scenarios to achieve the doubling goals are developed as part of the evaluation of potential actions by the SIT. Storage dams and extensive re-operation in the Delta were not identified as actions to take though substantial increases in rearing habitat was identified as an action. There will be opportunities during the implementation of the Near-term Restoration Strategy to develop additional potential actions for future restoration. It is important to note that the natural production goals in CVPIA quantify the "fish produced to adulthood *without direct human intervention* [emphasis added] in the spawning, rearing, or migration processes."

NMFS Comment: We would like to ensure that the spring-run Chinook salmon DSM includes consideration of spring-run Chinook salmon in the Yuba and the San Joaquin rivers, and we look forward to helping with such proposals for the SIT to consider.

- ***Response***: Participation in further development of the DSMs is greatly appreciated and proposals for changes to the DSMs for the SIT to consider are welcome at any time.

Response to GSSA Comments

Thank you for the review of the Near-term Restoration Strategy and comments. Below are responses to specific comments in the submitted addendum. We look forward to continuing to work with the Golden State Salmon Association on the CVPIA Science Integration Team.

GSSA Comment: For reference, we are attaching a report card on the recent doubling achievements. It shows that in the last five years only 11 percent of the doubling has been achieved. This does not speak well for the program and suggests more changes are needed.

- ***Response***: In assessing progress toward the doubling goals, it is important to ensure we are comparing the right metrics. The summary you provided compiles GrandTab data from the California Department of Fish and Wildlife from 2015–2019. GrandTab provides escapement estimates for Chinook salmon runs but the data requires additional calculations to develop estimates of natural production. In addition, the CVPIA doubling goals are assessed over the entire period since CVPIA enactment (1992–present). The most up-to-date natural production estimates are available on the Service's CAMP website (see the Annual Reports). The SIT's decision support model indicated where and which actions would lead to increased natural production. The resulting suite of recommended restoration actions represent the best estimate of maximizing natural production of Chinook salmon based on the model output and expertise of SIT members.

GSSA Comment: The American River certainly has an opportunity for more abundance but the question remains how much can it improve if the temperatures continue to go lethal in the early fall as they have in the past?

- ***Response***: The issue of temperature in the American River has not previously been raised by SIT members. Further dialogue as well as relevant data or information on this issue is welcome. Assumptions regarding temperature used in the SIT evaluations are available here. If there are more relevant data sets available to inform the model, the SIT could review alternative data sets to replace existing inputs.

GSSA Comment: We have some concerns about the nine recommended restoration actions. We understand the logic behind the combined restoration and diversity objective but we are not clear these actions will make much improvement in the doubling need. Three of the projects are targeted to the winter and spring runs and one is targeted to the Stanislaus where recovery is very difficult. Doubling the listed species is very important but it will do very little for the overall doubling need. It seems to us, if any substantial progress is going to be made towards doubling, that more activity is needed on the fall run. We would like to see a structured decision analysis of the projects that these proposals will generate. It appears that most of those projects will be low in abundance yield as compared to some bigger possibilities. The side channel objectives are definitely big in yield for all the runs and we strongly support them. We have concerns on the others.

- ***Response***: Spatial diversity has been an objective of SIT since its inception. Therefore, the SIT wanted actions in all diversity groups that would lead to the greatest increases in natural production. The model indicated where and which actions would lead to increased natural production. The resulting suite of recommended restoration actions represent the best estimate of maximizing natural production of Chinook salmon based on the model output and expertise of SIT members.

GSSA Comment: In preparing its Restoration Strategy, it appears that the SIT has ignored several major opportunities where the science suggests that major abundance opportunities exist. We suggest that these be reviewed and where appropriate, be included in the plan. We have attached a copy of the twelve projects in the GSSA Recovery proposal for your review.

- ***Response***: Any SIT members can request the evaluation of proposed restoration strategies. The specific actions identified in the GSSA plan were not raised during the SIT process that led to the development of this Near-term Restoration Strategy. We welcome and encourage the GSSA to participate throughout the SIT process as their input would improve the process in future iterations.

GSSA Comment: GSSA science estimates that 8.9 million fall-run eggs and fry are lost annually when the Bureau of Reclamation drops the Keswick flows in October following the emergence of the winter-run fry. When the flow drops, the edges of the river are dewatered and the remaining fall-run eggs and stranded fry perish. Application of the SDM model to the saved fry indicates that 13,000 additional ocean adults will be saved by improving this action. We suggest that the benefit of stopping these losses should be recognized in the Restoration Strategy and implemented as a priority.

- ***Response***: This issue was included in the SIT evaluation through the creation of spawning habitat to increase capacity.

GSSA Comment: GSSA recently completed a study correlating Sacramento River flows into the Delta in January through March to the survival of adults in the ocean two years later. Those three months are when most of the winter, fall and spring juveniles are migrating. In the data, there were ten years when the flows were very low ranging from 10,000 acre feet to 40,000. Most of the ocean survivals in those cases were low between 200,000 adults and 350,000. Below about 300,000 the runs are not sustainable. However, when the flows were high as they were in 2010, 2011 and 2017, the average resulting ocean population was 650,000. GSSA proposes that a minimum of 50,000 acre feet into the Delta be established for the three month period. That would yield approximately 500,000 fall-run adults and also a significant number of winter and spring adults. We suggest that this science and its implications be included in the CVPIA Restoration Strategy.

- ***Response***: The Chinook salmon DSM does include a mechanism whereby increased streamflow leads to increased survival of juveniles through the delta and results in increased adult production in the future. There were no flow-related actions proposed by SIT members during the development of candidate restoration strategies for this Strategy, but there will be future opportunities for proposing additional restoration strategies.

GSSA Comment: Earlier, we mentioned that between year 2001 and 2019, an average of 50% of the fall- run adults in the upper basin entered Battle Creek. This causes severe superimposition problems in Battle Creek and major losses in the Coleman hatchery. In low water and drought years, up to 80,000 fall-run adults have entered Battle Creek and the hatchery. The hatchery needs about 12,000 for brood stock and is forced to kill the rest. This is a huge loss particularly in low water and drought years when ocean abundance is low and fishing is curtailed. GSSA proposes that a removable weir be considered in Battle Creek somewhere 5 to 15 miles upriver from the hatchery. The weir would then be operated like the one in Clear Creek. It would be open for the winter and spring runs when they are returning. It would then be closed in the fall and the fall and late-fall would be allowed to spawn below the weir. We suggest that the science that supports this and the project be added to the Restoration Strategy. GSSA estimates that 15 miles of new fall-run spawning area would produce 3.4 million additional fry. When SDM is applied to this figure, the fall-run ocean abundance would increase by 14,000 adults. The project would also provide help to the late-fall run which is currently near extinction. This project requires current instream barriers above and below Eagle Canyon Dam be removed to reopen this stretch of Battle Creek.

- ***Response***: If the approach described here would translate to increased spawning habitat, then the SIT evaluated this. If the approach would translate to reduced proportion of fish taken for hatchery practices and an increase in spawning habitat, this could easily be analyzed in the model but it has not been previously suggested by the SIT. We encourage you to develop and submit a SIT proposal for this change to the model.

NMFS Submitted Addendum

The following is the text of the addendum received from the National Marine Fisheries Service.

National Marine Fisheries Service
Addendum for
CVPIA Near-term Restoration Strategy
October 2020

The purposes of this addendum are to: (1) acknowledge the significance of the Near-Term Restoration Strategy (NTRS) and the great achievement that the Science Integration Team (SIT) has made in reaching this milestone; and (2) document science and process topics that NMFS would like to explore with the SIT moving forward.

The release of the NTRS is a significant milestone for the CVPIA Fish Program, demonstrating that the implementing agencies have addressed components of a key recommendation made in the Listen to the River Independent Science Review Report (Cummins et al. 2008). Specifically, the NTRS is a product of a new process that helpsaddress the recommendation for an improved science-based framework incorporating adaptive management.

Additionally, the new process used to develop the NTRS addresses a 2006 recommendation made by the Office of Management and Budget calling for the CVPIA Fish Program to "*Improve the transparency and accountability of the fish restoration programs to management, stakeholders, and the public*." Development of the NTRS was transparent, open to all, and focused on science to identify restoration priorities thatexplicitly link to CVPIA Fish Program doubling goals.

We look forward to working with the SIT and the Science Coordinator to help develop annual Adaptive Management Updates to further the successful identification of restoration priorities that will make the most gains to achieve the CVPIA doubling goals.We note the following topics for the SIT to consider to improve the NTRS and the CVPIA Fish Program.

- We suggest the SIT discuss the implementing agencies embarking upon an independent science review of the Decision Support Models (DSM) and the NTRS in 2020, and decide whether or not such a review would be useful. Planning for this typically takes several months (at least with Delta Science Program as the facilitator) and the timing is appropriate given this iteration of theDSM and the generation of the NTRS. Science review was identified as a component of the Adaptive Resource Management Process in the CVPIA Fish Program Implementation Plan, "...*solicit an independent science review of the DSMs and 5-year plan, to occur after each revised 5-year plan is released (i.e., on a 5-year cycle)* (USFWS 2016)."
- Related to independent science review, The Listen to the River Report made the following recommendation that, if implemented, would be valuable: "*Employ a standing independent scientific review panel to provide advice on major programquestions, to review proposed expenditures, and to review the reported results of implementation activities. Examples*

include the CALFED Science Panel and the panels that are part of the Columbia River Basin Fish and Wildlife Program, the Independent Scientific Advisory Board (ISAB) and the Independent Scientific Review Panel (ISRP). We would like the SIT to consider and discuss this recommendation.

- We recommend the SIT discuss the extent to which the DSMs incorporate climate change projections, and assess whether further work is needed to ensurethe CVPIA Fish Program is pursuing restoration activities that will allow species to adapt and respond to a changing environment. We are surprised to see that the Strategy does not mention climate change and its projected impacts on Central Valley salmonid habitat. From review of the 2009 Delivery Reliability Report, we assume that the model uses a climate characterization for conditions at 2029, which is the future climate scenario modeled in that report. We recommend that the SIT consider a longer-term projection of climate conditions to better characterize the potential for actions to provide suitable habitat that persists despite changing climate conditions. We would like to help the SIT lead the way in planning and prioritizing actions that will allow Central Valley salmonids to persist despite warming temperatures and changing hydrology patterns.
- The Listen to the River Report encouraged the CVPIA Fish Program to take a broader interpretation of its authorities in order to achieve the doubling goal. Fishpassage to historical habitat falls into that realm and, given the weight of the Listen to the River Report that is placed in other sections of the document and the increased knowledge on the projected impacts of climate change, the action/topic should be considered by the CVPIA Fish Program and SIT. The Listen to the River Report states, "*Three of the limiting factors most responsible for the severe decline of natural salmon and steelhead production in the valley have not been addressed by the CVPIA program: 1) the construction of storage dams that block access to much of the historical habitat for anadromous fish, 2) extensive alteration of the channel of the mainstem Sacramento River, and 3) thesubstantial export of water out of the system, especially in the Delta. Without addressing these three systemic factors, significant increases in natural production of salmon and steelhead may be achievable only in certain watersheds and is not likely to translate into meeting the "doubling" goal at the scale of the entire basin*." We agree with the Listen to the River Report and recommend the CVPIA Fish Program consider expanding its authorities whereneeded to address limiting factors, including fish passage to historical habitat.
- We would like to ensure that the spring-run Chinook salmon DSM includes consideration of spring-run Chinook salmon in the Yuba and the San Joaquin rivers, and we look forward to helping with such proposals for the SIT to consider.

GSSA Submitted Addendum

The following is the text of the addendum received from the Golden State Salmon Association.

October 1, 2020

To: Megan Cook

Cc: Rod Whittler, Heather Casillas, Mike Urkov

From: Dick Pool and John McManus, Golden State Salmon Association

Subject: Comments on the SIT Meeting of Sept. 16th and the Restoration Strategy

Megan,

Congratulations on your new role as science coordinator and thanks for organizing the recent briefing. As you requested, we will comment on the meeting and also on the Near-term Restoration Strategy.[9]

We have some concerns about the nine recommended restoration actions. We understand the logic behind the combined restoration and diversity objective but we are not clear these actions will make much improvement in the doubling need. Three of the projects are targeted to the winter and spring runs and one is targeted to the Stanislaus where recovery is very difficult. Doubling the listed species is very important but it will do very little for the overall doubling need. It seems to us, if any substantial progress is going to be made towards doubling, that more activity is needed on the fall run. We would like to see a structured decision analysis of the projects that these proposals will generate. It appears that most of those projects will be low in abundance yield as compared to some bigger possibilities. The side channel objectives are definitely big in yield for all the runs and we strongly support them. We have concerns on the others.

For reference, we are attaching a report card on the recent doubling achievements. It shows that in the last five years only 11 percent of the doubling has been achieved. This does not speak well for the program and suggests more changes are needed.

Clear Creek needs improvement but it does not appear to be a location where substantial increased abundance can be achieved. I the last five years, an average of only 5,560 fall-run and 36 spring-run returned to Clear Creek. This is reflective of the significant total drop of adults returning to the upper river. In the decade between 2000 and 2010, 1,220,678 wild fall-run adults returned to spawn above Red Bluff. In the most recent decade, 2009-2019 only 432,683 returned; a decrease of 65%. In the same period, the spring-run decreased 53%. This problem is serious and is compounded by what is taking place in Battle Creek. Between year 2001 and 2019, an average of 50% of all the fall-run returns above Red Bluff entered Battle Creek instead of continuing upstream. All of this suggests more high priority work should be done on the upper river rather than just focusing on Clear Creek and the listed runs.

[9] Note: a comment was removed that did not pertain to the Strategy.

The American River certainly has an opportunity for more abundance but the question remains how much can it improve if the temperatures continue to go lethal in the early fall as they have in the past?

In preparing its Restoration Strategy, it appears that the SIT has ignored several major opportunities where the science suggests that major abundance opportunities exist. We suggest that these be reviewed and where appropriate, be included in the plan.

We have attached a copy of the twelve projects in the GSSA Recovery proposal for your review.[10] Following are some examples from that plan.

- The science of the Feather River shows that the 15 miles below the Thermalito outlet is unsatisfactory for spawning or rearing because of the high temperatures coming from the Thermalito. The FERC relicense of the Oroville Dam required DWR to extend cold water from the dam to the15 miles below the Thermalito. DWR has started that project design but it needs more priority. This is a high benefit project for the fall and spring runs. There is almost no new spawning area available in the Central Valley and this is available. We suggest it belongs in the Restoration Strategy. GSSA estimates the project will create 9.9 million additional fall-run juveniles and the application of the SDM model indicates the additional ocean survival will be 58,000 adults. The spring run increases have not yet been estimated but the improvement will be proportional.
- GSSA science estimates that 8.9 million fall-run eggs and fry are lost annually when the Bureau of Reclamation drops the Keswick flows in October following the emergence of the winter-run fry. When the flow drops, the edges of the river are dewatered and the remaining fall-run eggs and stranded fry perish. Application of the SDM model to the saved fry indicates that 13,000 additional ocean adults will be saved by improving this action. We suggest that the benefit of stopping these losses should be recognized in the Restoration Strategy and implemented as a priority.
- The Santa Cruz Science Center Sacramento River salmon survival studies show that up to 80% of the Sacramento juvenile salmon entering the South Delta through the Cross Channel Gates and Georgians Slough do not survive. Disorientation, high temperatures, lack of suitable habitat and predation all take a heavy toll. This 80% indirect loss represents the highest juvenile loss in the entire Central Valley system. It destroys approximately 10 million juveniles annually. Endless Delta studies have found no solutions to the problem. Some efforts have been made to keep the juveniles in the Sacramento River. One proposal was to install a screen upriver of the Cross Channel gates and then open a bypass canal from the screen to the existing canal below the gates. Georgina Slough would then be blocked and the Cross Channel Gates would be closed in periods of heavy out migration. GSSA is proposing that this option be opened again, considered and included in the Restoration Strategy. Up to ten million fall-run juveniles could be saved and applying SDM would show an additional ocean survival of 74,000 adults. The additional winter and spring runs were not analyzed but they would be proportional.

[10] This report is available on the GSSA website.

- GSSA recently completed a study correlating Sacramento River flows into the Delta in January through March to the survival of adults in the ocean two years later. Those three months are when most of the winter, fall and spring juveniles are migrating. In the data, there were ten years when the flows were very low ranging from 10,000 acre feet to 40,000. Most of the ocean survivals in those cases were low between 200,000 adults and 350,000. Below about 300,000 the runs are not sustainable. However, when the flows were high as they were in 2010, 2011 and 2017, the average resulting ocean population was 650,000. GSSA proposes that a minimum of 50,000 acre feet into the Delta be established for the three month period. That would yield approximately 500,000 fall-run adults and also a significant number of winter and spring adults. We suggest that this science and its implications be included in the CVPIA Restoration Strategy.
- Earlier, we mentioned that between year 2001 and 2019, an average of 50% of the fall-run adults in the upper basin entered Battle Creek. This causes severe superimposition problems in Battle Creek and major losses in the Coleman hatchery. In low water and drought years, up to 80,000 fall-run adults have entered Battle Creek and the hatchery. The hatchery needs about 12,000 for brood stock and is forced to kill the rest. This is a huge loss particularly in low water and drought years when ocean abundance is low and fishing is curtailed. GSSA proposes that a removable weir be considered in Battle Creek somewhere 5 to 15 miles upriver from the hatchery. The weir would then be operated like the one in Clear Creek. It would be open for the winter and spring runs when they are returning. It would then be closed in the fall and the fall and late-fall would be allowed to spawn below the weir. We suggest that the science that supports this and the project be added to the Restoration Strategy. GSSA estimates that 15 miles of new fall-run spawning area would produce 3.4 million additional fry. When SDM is applied to this figure, the fall-run ocean abundance would increase by 14,000 adults. The project would also provide help to the late-fall run which is currently near extinction. This project requires current instream barriers above and below Eagle Canyon Dam be removed to reopen this stretch of Battle Creek.

We believe the science and opportunities in these sample proposals and other examples could substantially improve the CVPIA doubling progress. We urge a broader examination of the science and potential doubling opportunities and we hope to see good on the ground projects in the final plan.[11]

For your info, CSAMP has initiated a project to focus on Central Valley salmon recovery. It will tabulate currently proposed or underway projects and then work to provide management guidance on which ones are the best for improving recovery. We would like to talk with the CVPIA about linking efforts on this and also potentially to have access to the DSM model for assistance in rankings.

We look forward to further discussions.

[11] Note: a comment was removed that did not pertain to the Strategy.