SCIENCE WORK PLAN

Shasta RPA Adjustment

Contents

Version Preface

This January 16, 2018 version of the Shasta RPA adjustment Science Work Plan is provided for review. Information will be presented about the Science Work Plan at the January 26 Shasta RPA Stakeholder workshop #4 and time will be provided for questions and discussion. While feedback on any section of the Work Plan is desired, Reclamation and NMFS are particularly interested in comments regarding (1) sufficiency of the Management Questions section, (2) the collaborative science approaches to planning, prioritization, and implementation described in the Implementation section, and (3) adequacy of the Stakeholder Involvement and Outreach section. Questions and input can be provided via email to Evan Sawyer, evan.sawyer@NOAA.gov. Please send comments no later than COB February 2, 2018.

Introduction and Objectives

Plan Description

This draft Science Work Plan (Plan) is part of the documentation pursuant to proposed amendment of Reasonable and Prudent Alternative (RPA) Action Suite I.2 (collectively, Shasta RPA) of the National Marine Fisheries Service's (NMFS) 2009 Biological Opinion (BiOp) on the Coordinated Long-Term Operation (LTO) of the Central Valley Project (CVP) and State Water Project (SWP). Within this Plan, NMFS and the Bureau of Reclamation (Reclamation) identify a series of management questions intended to direct scientific inquiry that is relevant to Shasta temperature management and CVP and SWP operations. Over the next five years, efforts will include the planning, research and monitoring, and review of the work intended to inform these management questions as part of a broader adaptive management approach to protect, restore, and maintain ESA-listed species and effectively manage Shasta and Trinity Division cold-water resources. Furthermore, the Plan is intended to complement the objectives and actions already identified and underway in Reclamation's Draft Workplan for Shasta and Trinity Division Seasonal Operational Water Temperature Modeling (Modeling Workplan), which focuses on the physical conditions and operational modeling for the Shasta and Trinity Division of the CVP. The draft Science Plan is also intended to complement ongoing studies being conducted and tracked through the Northern California Water Association's (NCWA) Sacramento Valley Salmon Recovery Program Project.

This draft Plan represents the synthesis of NMFS and Reclamation's priority science and management questions. Our intent is to share this plan with water district and non-governmental organization stakeholders and develop a final plan that captures the full breadth of scientific expertise, represents management views, and sets priorities within the larger context of the reinitiation of consultation (ROC) on the LTO of the CVP and SWP.

Background

In 2014 and 2015, Reclamation and NMFS used Action I.2.3.C to manage Shasta Division operations in response to drought conditions and associated impacts to ESA-listed species in the Sacramento and San Joaquin river basins and Bay-Delta. Research and monitoring implemented during the drought showed that condition and response of ESA-listed species was poorer than expected based on the actions taken as part of the BiOp's Action I.2.3.C and multiple Temporary Urgency Change Petitions. Based on new information related to multiple years of drought, recent data demonstrating extremely low listed-salmonid population levels for the endangered winter-run Chinook salmon, and new information

available and expected to become available as a result of ongoing work through collaborative science processes, Reclamation requested the use of the adaptive management provision of the Shasta RPA. In a separate letter, also on August 2, 2016, Reclamation requested reinitiation of consultation on the long-term operation of the CVP and SWP.

On January 19, 2017, NMFS provided Reclamation with a draft proposed amendment to the 2011 amended RPA related to Action Suite I.2 in the LTO BiOp. In that letter, NMFS cited work including drought operations of Shasta and Keswick reservoirs, drought conditions, and new science and temperature survival models, as rationale for amending RPA Action Suite I.2 prior to completing the reinitiated consultation. The draft amendment to the RPA would transition from using performance measures to instead using an objective-based management approach, allowing operations to be managed to criteria that are more biologically meaningful. The proposed criteria (e.g. temperature dependent mortality maximums and Shasta storage targets) are interim and will be reviewed and further assessed within a pilot study for up to three years.

In its responses to NMFS, dated January 25 and March 22, 2017, Reclamation reviewed the draft amendment and hydrologic indicators, and suggested that the 2017 temperature management season would be well-suited for conducting a study to evaluate if the CVP could be operated to meet a temperature target of 53.0°F daily average temperature at the California Data Exchange Center Clear Creek (CCR) temperature gage station as a surrogate for a target of 55.0°F seven-day average of the daily maximum temperatures at the most downstream winter-run Chinook salmon redd . Further, Reclamation recommended a thorough analysis of the pilot study that evaluates the impacts of the concepts of the draft amendment, including but not limited to the revised temperature management concepts, temperature-dependent mortality objectives, storage objectives, initial Keswick release schedules, and other changes to the RPA that have the potential to alter CVP operations.

Part of the proposed amendment included the need to develop a Science Plan to address uncertainties and areas of science-based disagreement regarding Shasta operational requirements for ESA-listed salmonids. That acknowledgement, of scientific uncertainty and disagreement, is also a restatement of the agreement between the then Assistant Administrator for Fisheries, Eileen Sobeck, and the Sacramento River Settlement Contractors (SRSC). During their meeting on July 13, 2016, Ms. Sobeck and the SRSC agreed to undertake a “shared and integrated work plan” to develop a new temperature model for Sacramento River operations, as well as a need for shared science and understanding. This document provides the Shasta RPA Amendment Draft Science Plan for near term activities to improve understanding of how physical conditions relate to achieving the biological objectives described within NMFS’ January 19, 2017, letter and the draft amendment. For temperature management on the Sacramento River related to Shasta Dam facilities, this Plan uses a conceptual model to focus on identifying relevant management questions, reviews the current status of compliance monitoring and special studies associated with the focal topics, and suggests a path forward to improve the information available for informing decisions.

Plan Objectives

The purpose of this Plan includes:

- Identifying near-term monitoring, biological modeling, and analysis and synthesis needs to improve fish and water management decision-making regarding the Shasta RPA.

- Reducing uncertainty regarding the conditions necessary to achieve desired fish and water management goals.
- Coordinating activities between agencies, stakeholders, and other interested parties.
- Developing priorities that will inform budgeting and development of scopes of work and other resource allocation decisions and allow decisions and studies to be tracked in an integrated framework.

Activities will help guide use of funding in Federal fiscal year 2018, if possible, and into fiscal year 2019 and beyond. Upon material progress of activities identified in this document, Reclamation and NMFS will coordinate revisiting and updating this document, if necessary.

Concurrent Effort

Reclamation is currently updating the modeling framework used to forecast water temperature conditions in the Sacramento River for seasonal operations planning. As identified in the Modeling Workplan, the objectives of the updated water temperature model are similar to the existing HEC-5Q water quality modeling tool, in that the revised model will:

- Identify initial cold water pool volumes.
- Based on the initial cold water pool volume, forecast the effects of potential operational strategies on water temperatures through the temperature control period (late spring into fall).
- Assist in the development of a cold water management plan, with incorporation of uncertainty in model representation and future conditions (e.g., inflow quantity and temperature, meteorology, etc.).

These capabilities, slated for refinement by the Modeling Workplan, complement the objectives of this Plan; both are intended to reduce the uncertainty of achieving conditions necessary to meet fish and water management goals in a given year.

DRAFT Project Plan

Framework

Conceptual models and frameworks provide a basis for understanding how decisions result in a desired outcome. Conceptual models and frameworks also describe the strategies for making decisions and navigating uncertainty. This section describes promising examples of frameworks and conceptual models for prioritizing management questions to be addressed in this Plan. Further, this Plan leverages a conceptual model (Appendix A) for relevant life stages and locations to identify remaining management questions found across multiple environmental drivers, habitat attributes, and responses. These life stages include:

- Holding Adult to Spawning Adult
- Upper River Egg to Fry Emergence
- Upper River Rearing Juvenile to Outmigrating Juvenile

The upstream protection of winter-run Chinook salmon requires a focus on the egg to fry stage. Specifically, it requires that Shasta Division operations provide water cold enough to support optimal

temperature-dependent survival at the most-downstream winter-run redd for the duration of the egg incubation period and through the last emergence from any winter-run redds. Studies from the past few years show that there will be sequences of consecutive years when the Shasta Division will not be able to restore or maintain listed species performance, but also many years that meet the optimal biological outcome. Restoring and maintaining the winter-run Chinook salmon population will require examining additional habitat attributes that may affect non-temperature related mortality to achieve the highest biological objectives. Depending on how climate influences Shasta Division operations, decisions regarding hatcheries, harvest, exports, and habitat can be better structured by reducing uncertainties surrounding ESA-listed species, Shasta Division operations, and temperature processes.

Environmental Watering

A framework that is being considered for managing environmental water in the Central Valley is the approach espoused in Victoria, Australia, and used in response to the Millennium Drought (1997- 2010). The Victorian Model is described in Mount (2016) and highlights environmental water as a portfolio that is accessed through differing objectives based on the planning scenario for water and fish. These scenarios vary for an ecosystem in response to fluctuations from critical drought to very wet, which may be prioritized, but not bound, by recovery objectives. This model could inform prioritization by considering which of the management questions are likely to gain the most information from the seasonal conditions observed in the Shasta Division (*i.e.*, dry, wet). For example, wetter conditions should provide an opportunity for rebuilding the winter-run Chinook salmon population by avoiding many of the impacts caused by the challenges of Shasta temperature and flow operations that manifest in drier years. Also, managers can consider whether these climatic and reservoir conditions require decisions to manage temperature, flows, and other stressors to protect, restore, or simply maintain the winter-run Chinook salmon population. For example, the viability of the winter-run Chinook salmon population is very low, which places the species at a higher risk of extinction, and requires greater protective efforts to improve survival and growth of the one remaining population.

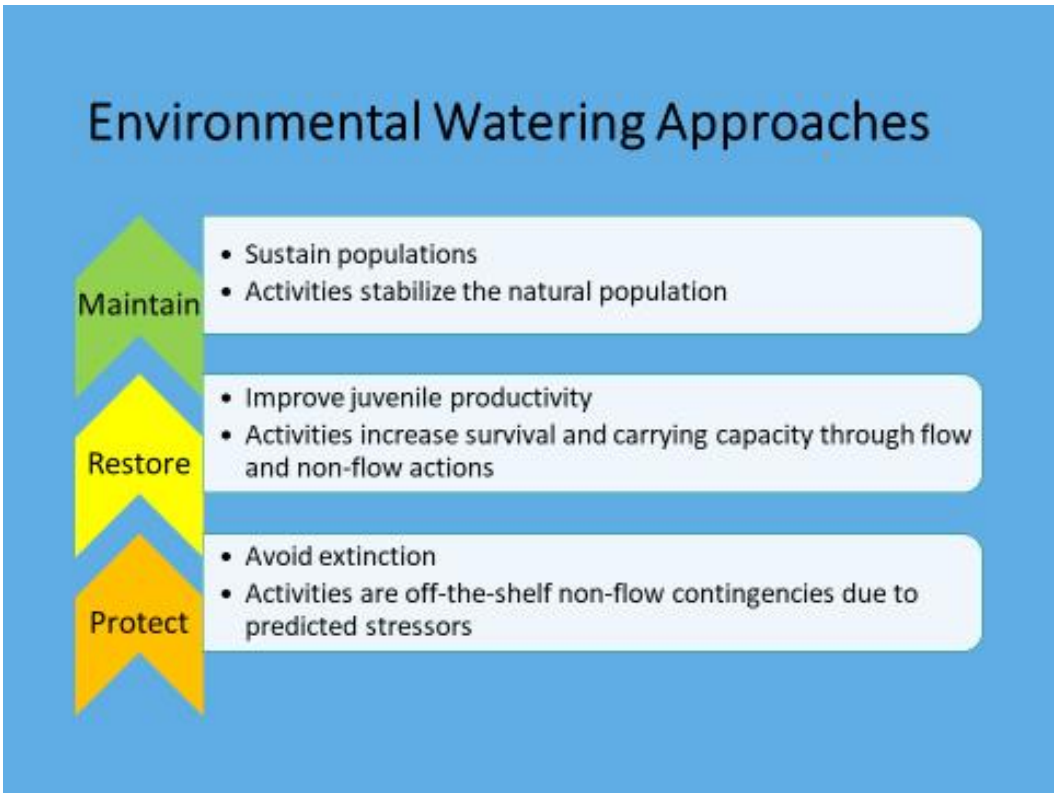

Figure 1: Example Environmental Watering Approach, with condition-based species objectives.

By implementing an objective-based management approach that uses a conceptual model for winter-run Chinook salmon, like the one described by Windell et al. (2017), tiered linkages provide a foundation for developing hypotheses regarding ESA-listed species and Shasta Division operations. The Windell et al. (2017) model identifies how management attributes on the landscape affect environmental drivers that create aquatic habitats. These aquatic habitats directly influence the response of fish (i.e., growth, survival, behavior), which managers are interested in ensuring for protection, restoration, and population maintenance objectives.

Stakeholder Involvement and Outreach

Objective:

Maintain transparency and interaction with stakeholders throughout the implementation process and through outreach activities.

Roles and Responsibilities:

- Reclamation and NMFS to convene Shasta RPA workshops soliciting stakeholder input on management questions and methods.
- Reclamation and NMFS to present at the Long-term Operations Biological Opinions review, where the independent science review panel will further identify research needed to address uncertainties in the proposed Shasta RPA amendment.

- Reclamation, NMFS, and/or Principal Investigators will present results in Collaborative Adaptive Science and Management Program (CSAMP) forums and Delta Science Program Independent Review Panels for input and recommendations on next steps.

Deliverables:

Meetings, calls, and other communications and project administrator activities. Collaboration with other agencies during scoping, monitoring, and research.

Management Questions

During the past five years, there have been years when the CVP and SWP have the capacity to maintain listed species performance, but also consecutive years when the CVP and SWP did not sufficiently protect listed species. Using the environmental watering approach, which acknowledges the difficulties of managing in uncertain conditions and the limitations of the current modeling capabilities, management questions are developed in a tiered approach for directing the necessary scientific studies to the most relevant issues for decision making and for adding, improving, or rejecting all or portions of conceptual models.

Forecasting (biological modeling and synthesis)

Objective:

Ascertain and establish the appropriate biological objectives for use in the environmental watering approach to water management.

Management Questions:

- What is a reasonable biological objective for temperature-dependent mortality to maintain (protect and restore) the winter-run Chinook population (percentage and year-to-year frequency)?
    - What levels of storage and releases are required from a prior year to achieve the biological objectives for a subsequent year?
    - What are the probabilities that different storage and releases from the prior year lead to successful attainment of biological objectives?
- What are the bounds of feasibility (Shasta storage, climate) driving cold-water volume and storage?
    - What are the effects of a changing climate?
- How do we prioritize biological needs in situations of limited cold water?
    - What are the population level risks from different balances on the downstream compliance location, water temperature targets, and risk of running out of cold water at the end of the season?
    - What practices for managing pre-spawning flows and temperatures minimize later risks to populations?
    - What is the relationship between pre-spawn flow, storage, temperatures, spawning location and density-dependent effects?
    - What are the trade-offs between temperature management and other flow-related survival?

- How do we develop effective tools that manage for recent conditions, and don't rely on past averages?

Species Viability and Variability (mechanistic studies of observation and experiments)

Objective:

Identify species and life-stage specific criteria on which to base biological objectives and metrics.

Management Questions:

- What are the appropriate egg-to-fry survival biological mechanisms to model?
- Have we appropriately characterized background mortality? Spatially, seasonally, and year to year?
- Can the endangered winter-run Chinook salmon species be managed to have temperature dependent mortality that would lead to recovery years, versus protection only years, per the Victorian model, and still allow for recovery?
    - What level of productivity is necessary to mitigate high temperature dependent mortality (i.e. critical years)?
    - What amount of optimal carrying capacity is necessary to support a viable population?
    - What can existing management tools, such as the NMFS Southwest Fisheries Science Center Central Valley Chinook Life Cycle Model, provide in understanding and crafting temperature-dependent survival targets?

Interactions between Stressors (community studies)

Objective:

Explore and refine the practicable management criteria and the (interaction with other) physical/environmental conditions that may influence the biological objectives.

Management Questions:

- What is the relative significance of temperature-dependent mortality compared to other sources of mortality?
    - Are the eggs or fish oxygen deprived?
    - How does substrate influence egg-to-fry survival? Does substrate size affect the sensitivity to temperatures?
- How can the following non-temperature dependent factors relieve (or increase) pressures on cold water management?
    - Disease
    - Predation
    - Spawning Habitat Quality
    - Rearing Habitat (Improve survival)
    - Migration Cues (Improve Survival)
    - What about multiple stressors interacting: temperature and pathogens; temperature and predation, temperature/food/energy

Structural Modification and Facilities (engineering studies)

Objective:

Consider the existing and potential facilities that could be used to achieve any biological objectives.

Management Questions:

- Are there any further structural modifications to reduce temperature dependent mortality?
- What additional reservoir cold-water pool conditions may see improved temperature performance through structural modifications or adjustments used during the recent drought (i.e. tarping the TCD, penstock operations)?
- What benefits to volume, and length and duration of gate operation of the TCD, can be achieved by these structural modifications?

Implementation

The implementation of this Plan is expected to occur over the course of a number of years. On an annual or biennial basis, a sub set of the Management Questions will be selected by agency directors for priority research. This selection will be based on the near-term need (e.g., assess the Shasta RPA amendment), but are also expected to reduce uncertainty and provide further insight on long-term management (e.g., provide for the reinitiation of consultation). The three most practical approaches to soliciting research proposals, garnering stakeholder involvement, and achieving management-relevant research are outlined in figure 2.

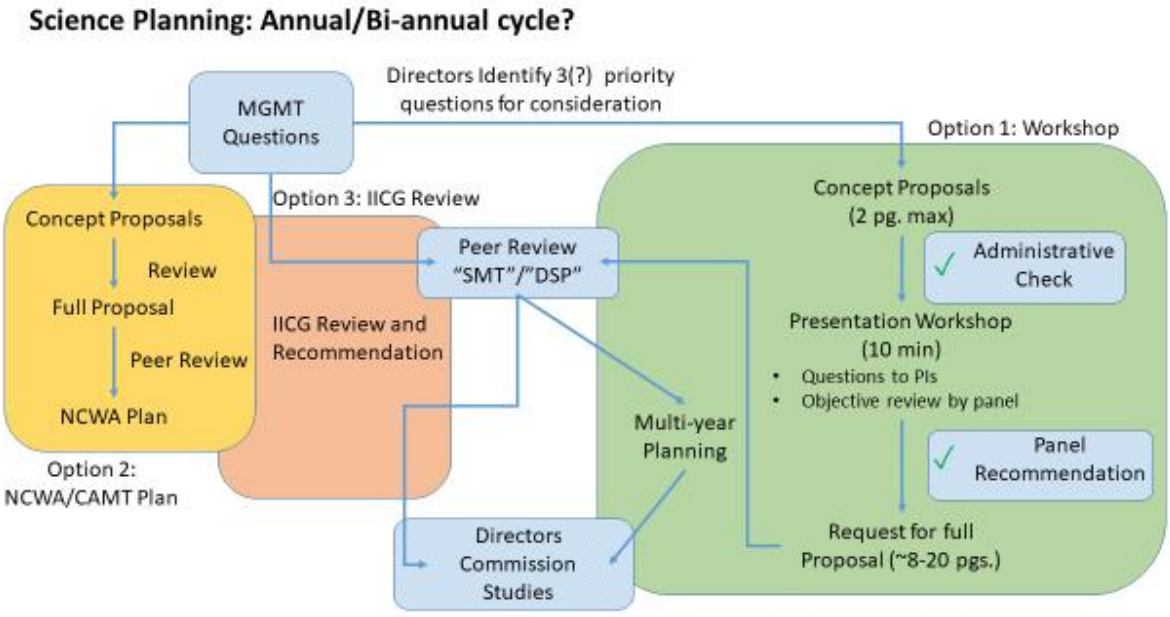

Figure 2: Possible science planning, review and initiation.

Option 1: Hold a workshop to present and review concept proposals of research intended to address the selected Management Questions. Solicited concept proposals would undergo an administrative check to ensure that there is a reasonable assurance that the proposed research activity would address and provide greater understanding of a Management Question. The workshop would consist of short presentations during which the objective review panel would ask questions of the Principal Investigators. The Review Panel would then a request a subset of the concept proposals be developed as full research proposals. The full research proposals would then be reviewed by and independent body

such as, or akin to, the Delta Science Program, which would provide a recommendation for funding consideration by the Agency Directors.

Option 2: A process similar to that which is used by CAMT or NCWA, where interested stakeholders have an opportunity to offer concept proposals via the mechanisms of the collaborative body (i.e., CAMT). These concept proposals could be further developed to full proposals that are considered for funding if the collaborative body recommends that action and it aligns or is incorporated into an annual work plan. Through this process, initial concept proposals are vetted by an internal review that recommends specific research proposals for further development and consideration.

Option 3: A process that would rely on the conceptual framework of the Adaptive Management Program (AMP)[1], that in turn describes the decision making process and governance of CVP and SWP water operations under the current Biological Opinions and California WaterFix. As per the AMP, the Interagency Implementation and Coordination Group (IICG) (co-led by Reclamation and DWR, and comprised of a representative of Reclamation, USFWS, and NMFS, as well as one designated representative each from DWR, CDFW, a participating SWP contractor, and a participating CVP contractor) shall be responsible for supporting those priority science needs identified by Collaborative Science Workgroups that the IICG determines are necessary to carry out the Adaptive Management Program. The IICG would then refer management-related research proposals, as appropriate, to the Delta Science Program for review by an independent science panel to provide a recommendation for funding consideration by the IICG. The IICG would then review funding commitments and any implementation issues relative to research priorities and recommendations from the Delta Science Program as part of the IICG's review and approval of the Annual Monitoring and Research Plan.

Monitoring

Core

Compliance monitoring in the Sacramento Division focuses on measuring biotic and abiotic data that may link operations of the CVP with these potential measurements. Juvenile and adult monitoring for winter-run, spring-run, fall/late fall-run Chinook salmon and steelhead is supported in CVP and non-CVP tributaries in the Sacramento Division. Improvements to the core monitoring framework are occurring as a recommendation of the SAIL advances (Johnson et al. 2017), and additional efforts will likely be associated with the Salmon Resiliency Strategy (California Natural Resources Agency, 2017) activities that are expanding habitat into historical habitats in the Sacramento Division. These additional efforts are likely to include new efforts to not just measure the abundance and distribution of salmonids, but also add to our understanding of the use (life history diversity, condition) of these areas, and inform further actions related to habitat restoration and habitat expansion. In 2017, approximately $6,000,000 were obligated for the compliance monitoring occurring in this division of the CVP.

[1]http://cms.capitoltechsolutions.com/ClientData/CaliforniaWaterFix/uploads/ProposedFinalAdaptiveManagementProgram_BA.pdf

Table 1. Core Monitoring Activity, Comment, and Life-Stage or Monitoring Use

Core Monitoring Activities	Comments	Life-Stage/Use
Sacramento River Basin Salmonid Monitoring	The escapement surveys for winter-run and spring-run Chinook in the Sacramento River, Clear Creek, Mill Creek, Deer Creek, and Battle Creek is a requirement in the 2009 water ops biological opinion with 2011 RPA amendment, Section 11.2.1.3 Monitoring and Reporting item 8.a. on page 12. The restoration effectiveness monitoring task is a CVPIA funded activity.	adult
Constant Fractional Marking/Tagging Program for Coleman and Nimbus Fish Hatcheries Chinook Salmon	The California Fish and Game Commission Salmon Policy requires hatchery releases of Chinook salmon to be externally marked and coded wire tagged at the CDFW standard. The current Department standard is 25% of all production releases in anadromous waters	juvenile
Coleman Hatchery Late Fall Chinook Tagging	2009 NMFS BiOp IV.4	juvenile
Sacramento River Salmonid Passage and Assessment of Salmonids	Terms and Conditions	data access
Red Bluff Diversion Dam Rotary Screw Trap Juvenile Monitoring Project	This project is required in Section 11.2.1.3.8.a of the CVP/SWP BiOp.	juvenile
Upper Sacramento River Winter Chinook Salmon Carcass Survey	This project is required in Section 11.2.1.3.8.a of the CVP/SWP BiOp.	adult
Adult Salmonid Escapement Monitoring in Battle Creek.	This project is required in Section 11.2.1.3.8.a of the CVP/SWP BiOp. The project is an element of the RPA Action I.2.6 Restore Battle Creek for Winter-Run, Spring-Run, and CCV Steelhead.	adult
Juvenile Spring Run and Steelhead Production Monitoring in Battle Creek.	This project is required in Section 11.2.1.3.8.a of the CVP/SWP BiOp. The project is an element of the RPA Action I.2.6 Restore Battle Creek for Winter-Run, Spring-Run, and CCV Steelhead.	juvenile

Adult Steelhead and Late-fall Chinook Escapement Monitoring in Clear Creek	This project is used to develop adult population estimates required in Sections 11.2.1.3.7 and 11.2.1.3.8.a of the CVP/SWP BiOp. The project provides spawning gravel evaluations required in Action I.1.3 Spawning Gravel Augmentation	adult
Juvenile Spring-Run and Steelhead Production Monitoring in Clear Creek	This project is used to develop juvenile population estimates required in Sections 11.2.1.3.7 and 11.2.1.3.8.a of the CVP/SWP BiOp	juvenile
Adult Spring Chinook Escapement Monitoring in Clear Creek.	This project is used to develop adult escapement estimates required in Sections 11.2.1.3.7 and 11.2.1.3.8.a of the CVP/SWP BiOp. This monitoring data guides the pulse flows provided in Action I.1.1. Spring Attraction Flows. The project provides spawning gravel evaluations required in Action I.1.3 Spawning Gravel Augmentation. The project provides water temperature data and spring Chinook locations to evaluate Action I.1.5 Thermal Stress Reduction.	adult
Operation of Segregation Weir in Clear Creek	This project is used to develop adult escapement and juvenile production estimates required in Sections 11.2.1.3.7 and 11.2.1.3.8.a of the CVP/SWP BiOp. The project is described in the Biological Assessment for the BiOp as a part of the CVP	adult
DFW Yolo Bypass stranding and fish passage monitoring	This project is used to evaluate risks associated with RPA Action I.6.1	adults

Special Studies

This section describes recent and ongoing special science studies related to the Shasta Division, ESA-listed species, and temperature. These efforts focus on management questions, performance measures, and management tools in these areas of interest between agencies, stakeholders, and interested parties. These efforts have primarily included observational and modeling studies, but future efforts may also require laboratory investigation depending on the management question and desired performance measure. This information is useful for determining if recent and ongoing efforts may address management questions identified above.

Table 2. Special Studies Activity, Management Question Category, Type and Status

Science Activities	Category	Type	Status
Sacramento River temperature modeling review	Shasta Division, temperature	modeling	Currently reviewing 2 draft Technical Memos
Implementing the individual based model, inSalmo, in the Upper Sacramento River	temperature, ESA listed fish	modeling	Project Completion Date: April 2018
Tracking Migration and Survival in Juvenile Winter-Run Chinook Salmon in the Sacramento River and Delta over Drought Years	ESA listed fish	observational	Project Completion Date: April 2018
Sacramento River Temperature Management Decision Support Tools	Shasta Division, temperature, fish	observational and modeling	CVTEMP site established
Genetic Signatures of Drought Conditions and Disease in Central Valley Salmonids	temperature, fish	observational	Project Completion Date: December 2017
Sacramento River Salmonid Passage Model for Data Assessment in Real Time	Shasta Division, temperature, fish	observational and modeling	SacPAS site established
Sacramento River Basin Salmonid Monitoring	ESA listed fish	observational	Enhanced habitat monitoring occurring
Red Bluff Diversion Dam Rotary Screw Trap Juvenile Monitoring Project	ESA listed fish	observational	USFWS sampling effort occurring
Linking Drought and Southern DPS Green Sturgeon Recruitment	ESA listed fish	laboratory and model	Project Completion Date: April 2018
Workplan for Shasta and Trinity Division Seasonal Operational Water Temperature Modeling	Shasta Division, temperature, engineering	model	Technical Team meeting continuing in Fall 2017

Task Management and Timeline

Implementation of Tasks

Task:	Option 1: Workshop	Option 2: NCWA/CAMT	Option 3: IICG Review
MGMT Question Prioritization (January)	✓	✓	✓
Concept Proposals (January, February)	✓	✓	
Administrative Review (March)	✓		
Workshop (March)	✓		
Full Proposal (End of May)	✓	✓	✓
DSP Review (June, July)	✓	✓	✓
Funding Recommendation (September)	✓	✓	✓
$$ Level/Source	5 Agencies (?)	USBR, Federal Contractors	USBR, Settlement Contractors

Long-term Timeline/Phasing of the Plan

Task	Timeline
Final version of Science Plan	November 2017 - January 2018
Study prioritization and planning	January - June 2018-2020
Study funding and implementation	October 2018 - September 2021
Study Status Reporting	Biennial WY 2019-2021
Monitoring Status Reporting	Open data approach
Biological Review Panel (Independent review of final findings and monitoring)	September 2019, 2021, 2023

Literature Cited

California Natural Resources Agency. 2017. Sacramento Valley Salmon Resiliency Strategy. http://resources.ca.gov/docs/Salmon-Resiliency-Strategy.pdf.

Johnson, R. C., S. Windell, P. L. Brandes, J. L. Conrad, J. Ferguson, P. A. Goertler, B. N. Harvey, J. Heublein, J. A. Israel, and D. W. Kratville. 2017. Science Advancements Key to Increasing Management Value of Life Stage Monitoring Networks for Endangered Sacramento River Winter-Run Chinook Salmon in California. San Francisco Estuary and Watershed Science 15(3).

Mount, J., B. Gray, C. Chappelle, J. Doolan, T. Grantham, N. Seavy. 2016. Managing Water for the Environment During Drought: Lessons from Victoria, Australia. Public Policy Institute of California, San Francisco, CA.

Windell, S., P. L. Brandes, J. L. Conrad, J. W. Ferguson, P. A. Goertler, B. N. Harvey, J. Heublein, J. A. Israel, D. W. Kratville, and J. E. Kirsch. 2017. Scientific Framework for Assessing Factors Influencing Endangered Sacramento River Winter-Run Chinook Salmon (Oncorhynchus Tshawytscha) across the Life Cycle. Us Department of Commerce. NOAA Technical Memorandum NMFS-SWFSC 586:49.

Appendix A – Conceptual Model

From Windell et al 2017

Figure X.

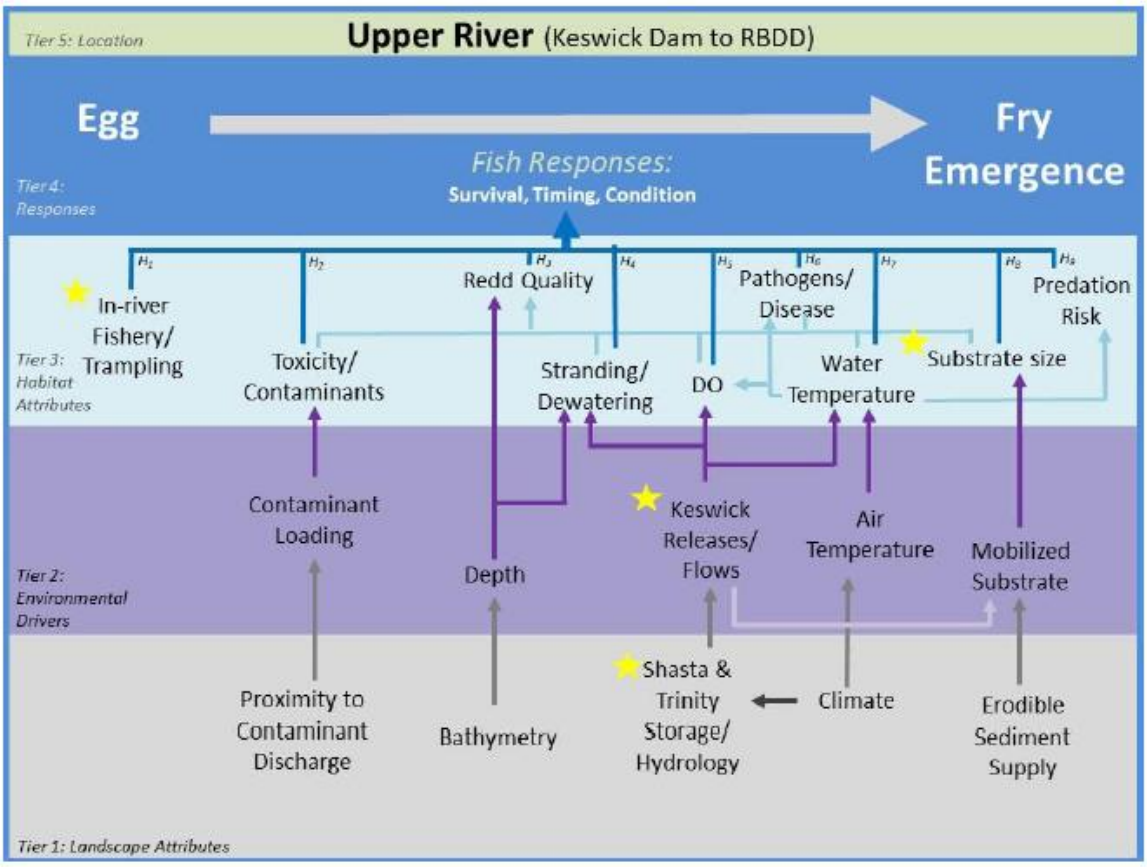

Figure 3. Conceptual model of drivers affecting the transition of SRWRC from egg to fry emergence in the Upper Sacramento River. Hypotheses referenced by the "H-number" are identified in the conceptual model 1 (CM1) narrative. Management actions are denoted by stars and are described in Table 1.

Figure Y.

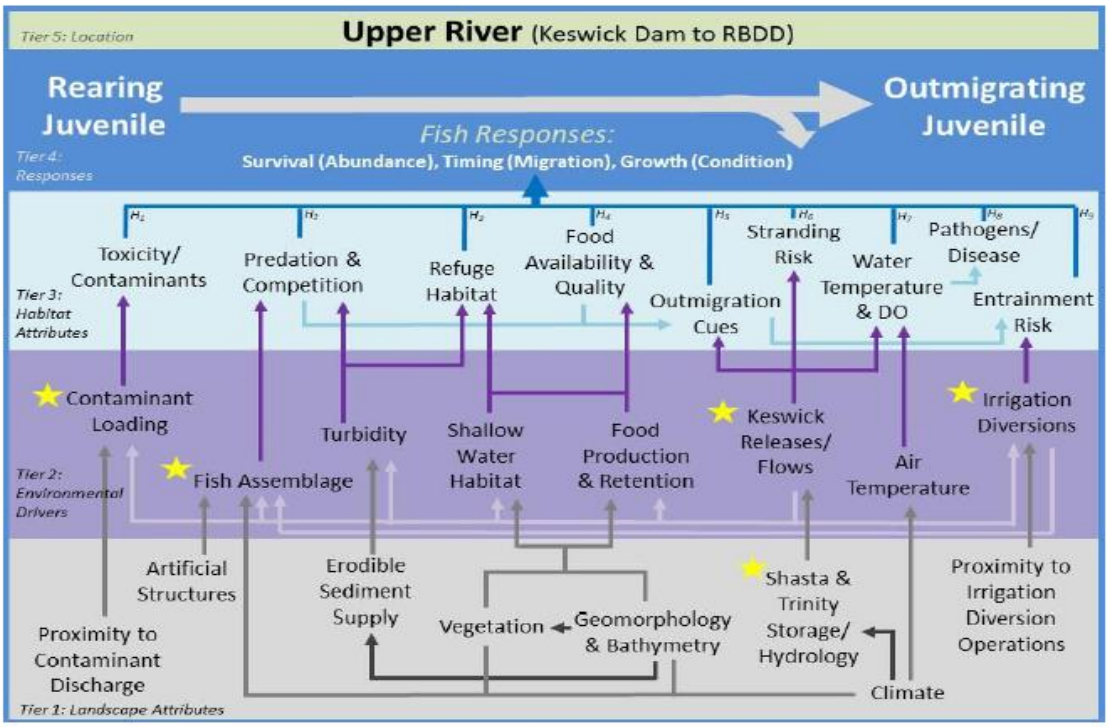

Figure 4. Conceptual model of drivers affecting the transition of SRWRC from rearing juvenile to outmigrating juvenile in the Upper Sacramento River. Hypotheses referenced by the "H-number" are identified in the conceptual model 2 (CM2) narrative. Management actions are denoted by stars and are described in Table 1.

Figure Z.

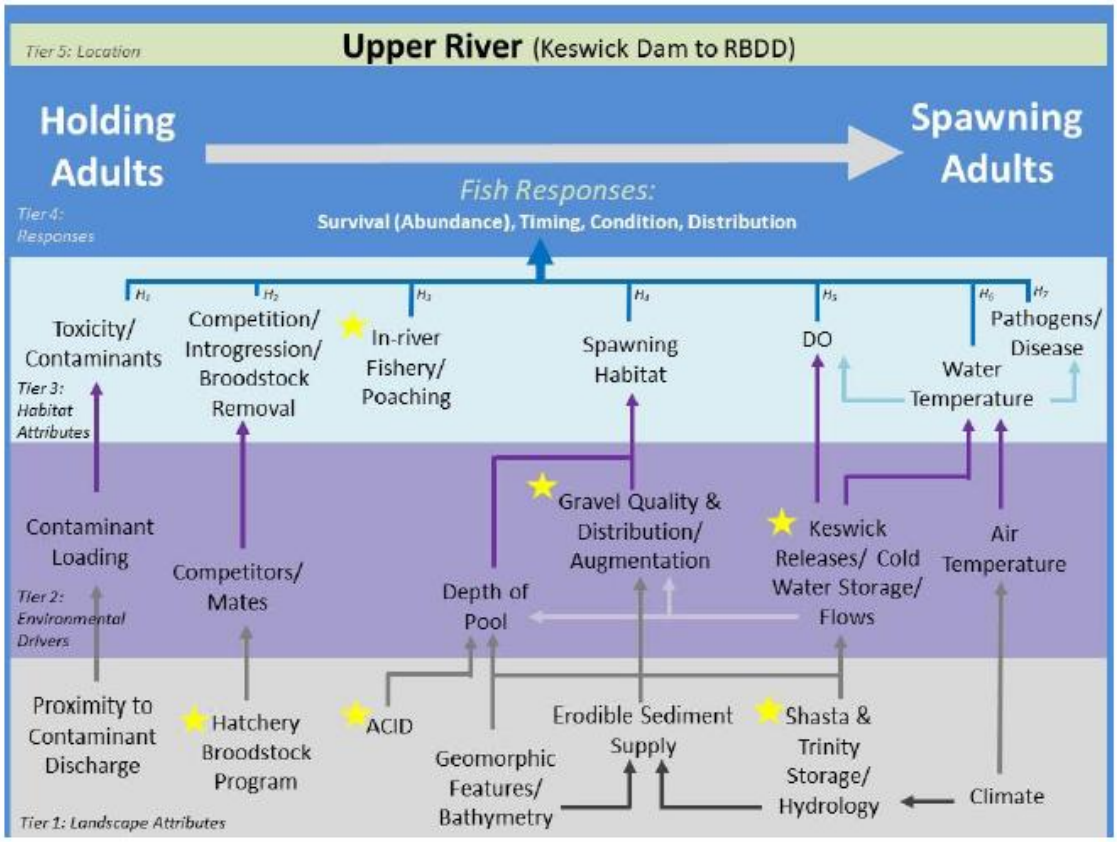

Figure 9. Conceptual model of drivers affecting SRWRC from holding adults to spawning adults in the Upper Sacramento River. Hypotheses referenced by the "H-number" are identified in the conceptual model 7 (CM7) narrative. Management actions are denoted by stars and are described in Table 1.