SCIENCE WORK PLAN

Shasta RPA Adjustment

Contents

Introduction and Objectives

Plan Description

This draft Science Work Plan (Work Plan) is part of the documentation pursuant to proposed amendment of Reasonable and Prudent Alternative (RPA) Action Suite I.2 of the National Marine Fisheries Service (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 Work 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 & SWP operations in general. Furthermore, the Work Plan is intended to compliment the objectives and actions already identified in Reclamation's Draft Workplan for Shasta and Trinity Division Seasonal Operational Water Temperature Modeling (Modeling Workplan), focusing on the physical conditions and operational modeling for the Shasta and Trinity Division of the CVP.

Plan Objectives

The purpose of this Work Plan includes:

- Identifying near-term monitoring, biological modeling, and analysis and synthesis needs to improve fish and water management decision-making regarding Action Suite I.2 (collectively, Shasta RPA)
- Reducing uncertainty on the conditions necessary to achieve desired fish and water management goals
- Coordinating activities between agencies, stakeholders, and other interested parties.

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

Concurrent Effort

Reclamation is currently updating its water temperature modeling framework that is 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 model are similar to the existing HEC-5Q 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, refined by the Modeling Workplan, complement the objectives of this Work Plan, in that they are intended to reduce the uncertainty of achieving conditions necessary to meet fish and water management goals in a given year.

Background

In 2014 and 2015, Reclamation and NMFS used Action I.2.3.C to manage Shasta Division operations as part of the response to drought conditions and 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 performance 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 19th, 2017, NMFS provided Reclamation with a draft amendment to the 2011 amended RPA related to Action Suite I.2 in the LTO BiOp. In that letter, NMFS cited work including drought operation of Shasta and Keswick reservoirs, drought conditions, and new science and temperature survival models; as rationale for amending RPA action I.2 prior to reinitiating consultation. The draft amendment to the RPA would transition from using performance measures to an objective-based management approach that is intended to ensure that operations are managed to criteria that are more biologically meaningful. The proposed criteria, 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, dated January 25th and March 22nd, 2017, Reclamation reviewed the draft amendment and hydrologic indicators, suggesting 2017 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 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 redd during the 2017 temperature management season. Further; Reclamation recommended a thorough analysis of the pilot study that evaluates the impacts of the concepts contained in 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 development of a Science Work Plan to address uncertainties and areas of science-based controversy regarding Shasta operational requirements for ESA-listed salmonids. This document provides the Shasta RPA Adjustment Science Work Plan for near term activities to improve understanding of how physical conditions relate to achieving the biological objectives described within NMFS' January 19th letter and the draft amendment. For temperature management on the Sacramento River related to Shasta Dam facilities this Work 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.

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 Work Plan. Further, this Work 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 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 requires a focus on the egg to fry stage, and Shasta Division operations which focus on water cold and oxygenated enough that there is optimal temperature dependent survival over the most downstream winter-run redd for the duration of the egg incubation to emergence of the last winter-run redd. From the past few years, it is clear 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, 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 Doolan, Grantham et al. (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 from an ecosystem caught in a critical drought to very wet conditions. Ultimately, these scenarios should establish the potential consequences of these choices and are 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 examples, wetter conditions should provide an opportunity for rebuilding the winter-run Chinook salmon population by avoiding many of the impacts caused by Shasta temperature and flow operations. Also, managers can consider whether these climatic and reservoir conditions are necessitating decisions for temperature management, flow release, and management of others stressors to protect, restore, or simply maintain winter-run Chinook salmon populations. 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 necessitates greater protective efforts to improve survival and growth of the one remaining population.

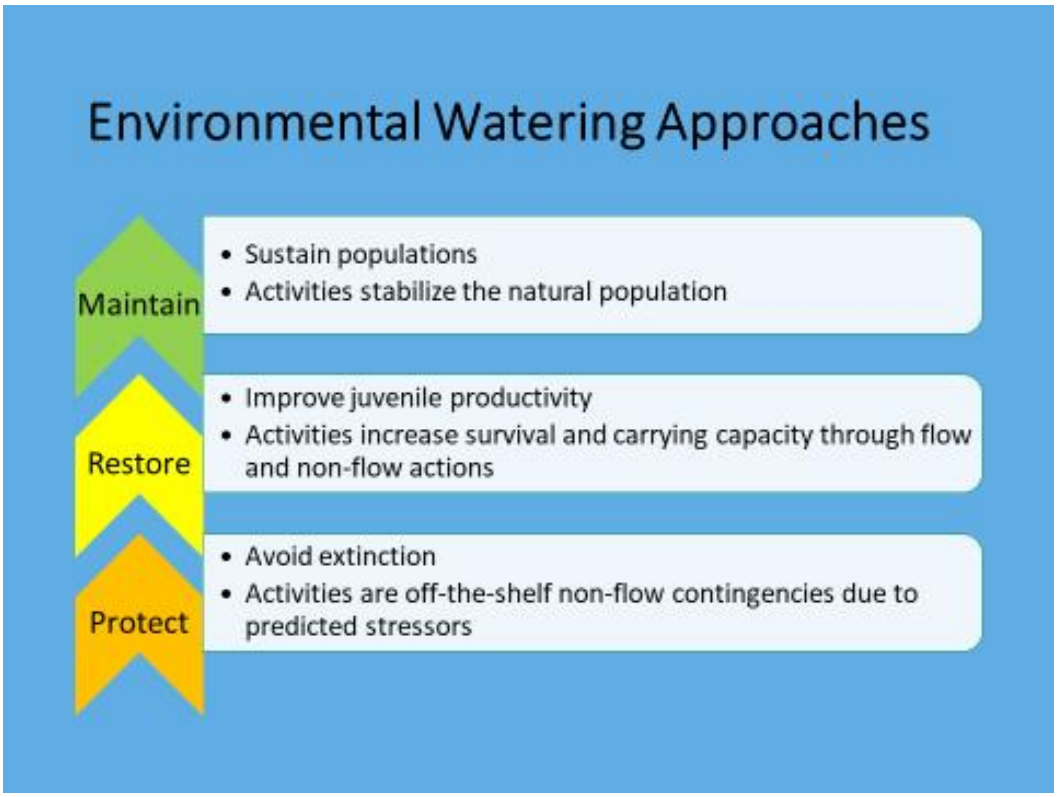

Figure 1: Example Environmental Watering Approach, with condition-based species objectives.

By implementing an objective-based management approach that uses a conceptual model for winter-run Chinook salmon, like the one described by Windell, Brandes et al. (2017) tiered linkages provide a foundation for developing hypotheses regarding ESA-listed species and Shasta Division operations. The Windell model identified 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.

SAIL (read the appendix)

Stakeholder Involvement and Outreach

Objective:

Maintain transparency and interaction with stakeholders through outreach activities.

Roles and Responsibilities:

- Reclamation and NMFS to convene Shasta RPA workshops soliciting stakeholder input on management questions.
- Reclamation and NMFS to present at the bi-annual LOBO 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 PIs 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 SWPs did not protect listed species performance. 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.

Question List:

- 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 maintain a reasonable level of protection for a subsequent year?
- What are the bounds of feasibility (Shasta storage, Climate) driving coldwater 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?
    - Can we manage pre-spawning flows to 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?

Methods:

(example research, studies, and/or monitoring that could be used to address this particular category of management question)

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

Objective:

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

Question List:

- 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?

Methods:

(example research, studies, and/or monitoring that could be used to address this particular category of management question)

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.

Question List:

- 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

Methods:

(example research, studies, and/or monitoring that could be used to address this particular category of management question)

Structural Modification and Facilities (engineering studies)

Objective:

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

Question List:

- What long-term monitoring infrastructure is necessary in order to track temperature-dependent mortality?
- Structural modifications or adjustments:
    - Establish permanent temperature logger at Shasta Reservoir and tailwaters below dams.
    - Can the TCD (i.e. tarping, lower side gates) be modified to improve release temperatures?
    - Can penstock operations be modified to improve release temperatures?

Monitoring

Core

Compliance monitoring in the Sacramento Division focuses on measuring biotic and abiotic data that link operations of the CVP projects 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, Windell et al. 2017), and additional efforts will like be associated with the Salmon Resiliency Strategy activities that are expanding habitat into historical habitats in this region. These additional efforts are likely to include new efforts to measure not just the abundance and distribution of these salmonids but also add to our understanding of the use (life history diversity, condition) of these areas but also 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 portion of the CVP.

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, Section 11.2.1.3 Monitoring and Reporting item 8.a. on page 585. The restoration effectiveness monitoring task is a CVPIA funded activity.	adult

Constant Fractional Marking/Tagging Program for Coleman and Nimbus Fish Hatcheries Chinook Salmon	Not specifically, but 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. The project is an element of the RPA Action I.2.6 Restore Battle Creek for Winter-Run, Spring-Run, and CV Steelhead.	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. The project is an element of the RPA Action I.2.6 Restore Battle Creek for Winter-Run, Spring-Run, and CV Steelhead.	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 CV 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 CV 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	I.7.1	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 TMs
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; review panel scheduled Fall 2017
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-desired 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	model	Technical Team meeting continuing in Fall 2017

Documentation

Objective:

Documentation of assumptions, prioritization, performance, models used, and recommendations for next steps.

Tasks:

- Development of documentation for management question category.

Deliverables:

Documentation, in a consistent format, of each management question category to be included in overall documentation of the framework (e.g. environmental watering approach).

Peer Review

Objectives:

Provide for peer review of research results and overall framework.

Tasks:

- Upon completion of new/refined management criteria, research and/or data development, conduct peer review

Deliverables:

Summary/documentation of peer review on study results/conclusions.

Implementation

Objective:

Incorporate refined metrics into the Shasta RPA, including the overall framework.

Tasks:

- Establish biological objectives (protect, maintain and recover).
- Implement temperature management procedures based on the established biological objectives.

Deliverables:

Technical memorandum outlining the process by which biological objectives have been established and implemented. Final revised Shasta RPA amendment that incorporates the environmental watering approach.

Task Management and Timeline

Implementation of Tasks

Timeline/Phasing of Task

Final version of Science Plan	**November-December 2017**
Study prioritization and planning	January- June 2018-2020
Study funding and implementation	October 2018- September 2021
Study Status Reporting	Semiannually 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

Doolan, J., et al. (2016). "Managing Water for the Environment During Drought."

Johnson, R. C., et al. (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).

Windell, S., et al. (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.

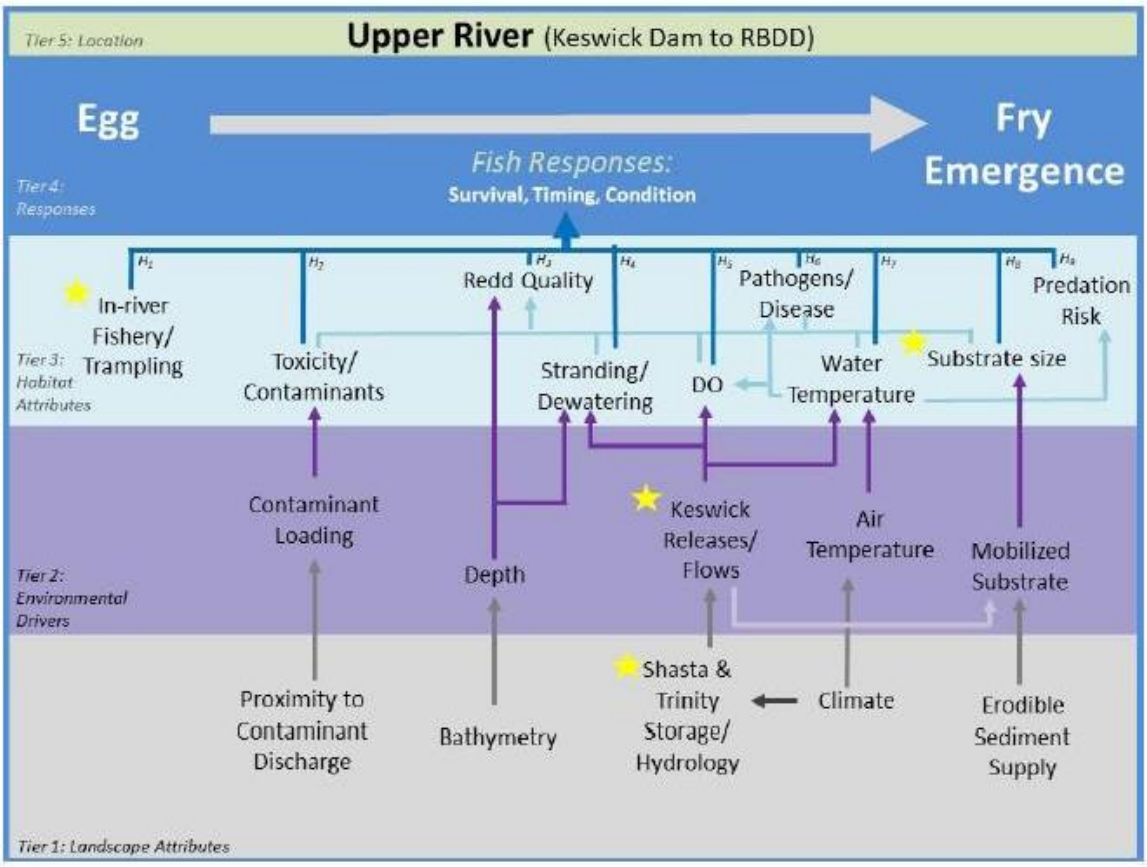

Figure 3. Conceptual model of drivers affecting the transition of SRWRC from egg to fry emergence in the Upper Sacramento River. Hypotheses referenced by the "H-number" are identified in the conceptual model 1 (CM1) narrative. Management actions are denoted by stars and are described in Table 1.

Figure Y.

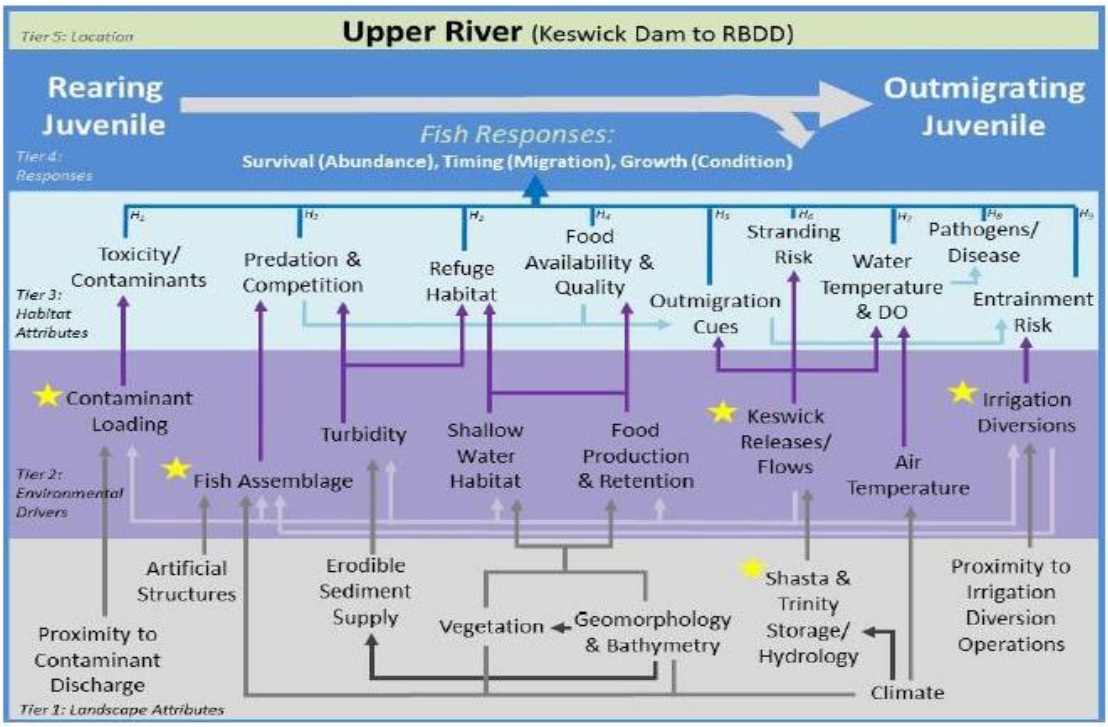

Figure 4. Conceptual model of drivers affecting the transition of SRWRC from rearing juvenile to outmigrating juvenile in the Upper Sacramento River. Hypotheses referenced by the "H-number" are identified in the conceptual model 2 (CM2) narrative. Management actions are denoted by stars and are described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

Figure Z.

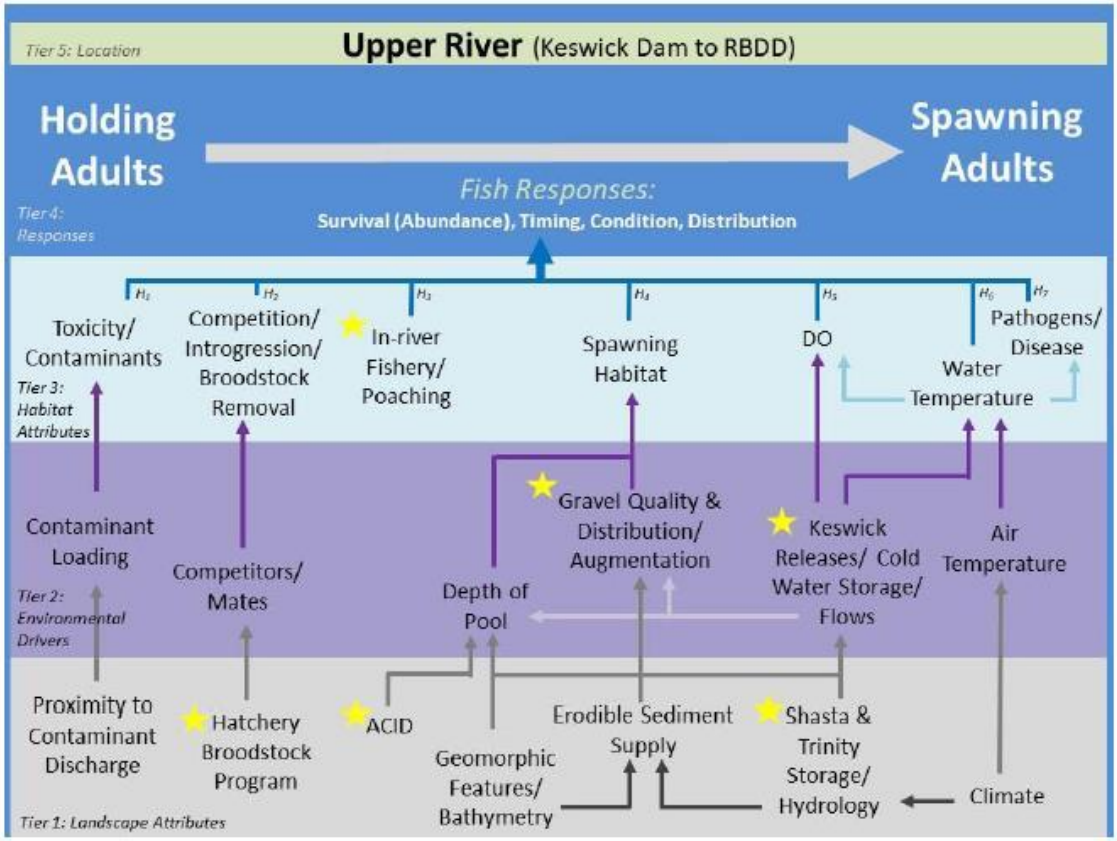

Figure 9. Conceptual model of drivers affecting SRWRC from holding adults to spawning adults in the Upper Sacramento River. Hypotheses referenced by the "H-number" are identified in the conceptual model 7 (CM7) narrative. Management actions are denoted by stars and are described in Table 1.