NMFS List of Issues Unresolved in BDCP Administrative Draft

(4/2/2012)

This is NMFS' official list of "red flag" issues related to the administrative draft effects analysis for the BDCP. This document replaces in total our preliminary draft document distributed previously. We consider the following to be serious issues that may have the potential to trigger a finding of insufficiency if not resolved prior to final submittal, and/or resolution of the issue may have a significant effect on conclusions, and therefore the overall design of the project. We have also included recommendations for addressing these issues, where appropriate, and we are available and would like to work towards solutions to these issues. We understand that ICF may be already working to resolve a number of these issues, and/or that resolution may be contained in a portion of the documents that have not yet been provided for review.

A more thorough set of "line-by-line" review comments on Chapters 3 & 5 are also being provided to ICF and the IMT.

- **Hood Diversion Bypass Flows**

  The Effects Analysis of the Preliminary Proposal (PP) raises concerns over reduced flows downstream of the North Delta diversions, especially in winter and spring months. These flows relate to:

  A. Increased frequency of reversed Sacramento River flows at the Georgiana Slough junction. The January 2010 PP rules included a provision that north Delta pumping would not increase these reverse flows. Calsim II results provided by CH2M-Hill indicate that the PP will increase the percent of time Sacramento River flows are reversed, causing increased entrainment of juvenile salmonids into the Central Delta. If the frequency of reverse flows increases due to the PP, then the diversion amounts allotted under the PP could not be implemented. The DSM2 analysis of reverse flows in the DPM suggests that tidal marsh restoration in the Delta will nearly offset both the effects of sea-level rise and large water diversions from the Sacramento River, a conclusion which needs much more explanation in the EA (see comment on tidal marsh effects).

  B. Long-term viability of sturgeon populations. There are concerns that Sacramento River flow reductions will impact the reproductive success of white and green sturgeon, which have been documented to produce strong year classes mostly in years with high flows in April and May (AFRP study). We do not know if this has been addressed in revised Appendix C.

  1. Further explanation and analysis of the reverse flow issue.

  2. Work with the Services to find a diversion scheme that is still likely to be permittable after adequate modeling and analysis has been conducted.

- **Salmonid Net Effects**

  All salmonid species are grouped together, with no separate evaluations for the separate ESUs of Chinook salmon or for steelhead. It is important for the net effects analysis to describe individual ESUs/species, and provide full consideration of the life-history diversity and timing exhibited by each ESU/species. We also need the Sacramento River populations and San Joaquin populations for Spring-run Chinook, Fall-run Chinook, and Central Valley steelhead summarized by river basin, prior to the roll-up by ESU/DPS. Steelhead life-history and ecology especially warrant a separate evaluation. "Net effects" is useful for comparing alternative operations, but will not provide the robust effects analysis needed for ESA purposes (see comment on ESA baseline).

  Separate all Chinook by ESU, by San Joaquin and Sacramento populations, and separate steelhead in all analyses and discussion.

- **ESA Baseline, Future Conditions, and Climate Change**

  In order to conduct the ESA jeopardy analysis on the PP, the baseline condition and projections of future baseline conditions, including effects of climate change, need to be re-written to be consistent with the 2009 Biological Opinion and current case law. ESA regulations define the environmental baseline as "the past and present impacts of all Federal, State, or private actions and other human activities in the action area, the anticipated impacts of all proposed Federal projects in the action area that have already undergone formal or early section 7 consultation, and the impact of State or private actions which are contemporaneous with the consultation in process." Implicit in this definition is a need to anticipate the future baseline, which includes future changes due to natural processes and climate change. For the ESA jeopardy analysis we add the effects of the proposed action to the environmental baseline to determine if there will be an appreciable reduction in the likelihood of survival and recovery of the species (by reducing its reproduction, numbers or distribution).

Upstream effects associated with climate change need to be in the baseline and future conditions, with any effects of the project (in the Delta or associated with upstream operations) added to that future condition to determine jeopardy. A project proposed in this type of baseline conditions needs to more than offset its effects in order to alleviate a jeopardy finding.

- **Analysis of Water Temperature Impacts**

  Lethal and sub-lethal water temperature thresholds need to be examined at a finer scale. Currently the effects analysis relies heavily on a Reclamation water temperature model which can only estimate monthly values, which have limited value for predicting project effects on fish. In addition, the effects analysis has only presented frequencies of temperature threshold exceedances, while the magnitude and duration of exceedance is also very important. We do not know if this has been addressed in revised Appendix C.

  1. Provide tables and probability plots of magnitude and duration of temperature exceedances at certain upstream locations, by water year type and month.
  2. Technical discussion with Reclamation and CH2MHill about how to post-process data.
  3. Investigate the use of SWFSC's Sacramento River temperature model to predict project effects and make hindcasts of empirical temperatures.
  4. Investigate the use of the new American River temperature (and storage and flow?) model

- **Assumption of Habitat Restoration CM Success**

  In several places, the EA assumes that adverse impacts of the PP will be offset by unsubstantiated benefits of habitat restoration. The EA assumes that all restoration will be successful and work as predicted, with little or no evidence to support this prediction and no attempt to analyze the potential outcomes of less than perfect success.

  1. It is imperative to avoid language such as "This conservation measure will…", because the anticipated CM outcomes are based on conceptual thinking, not execution. To be able to comprehensively think through the adaptive management and monitoring plan, implementers need to try to anticipate a range of responses that must be managed in order to be prepared for the uncertainty of the response.
  2. Alternative outcome scenarios should be evaluated to bracket the range of possible outcomes from proposed habitat restoration.

- **Overreliance on Real-time Operations and Adaptive Management**

  In several places, the EA assumes that adverse impacts of the PP will be fully resolved through the implementation of real-time operations and adaptive management. This may not always be possible. For example, long-term trends towards reduced carryover storage may not be able to be mitigated using real-time operations. How adaptive management might work in this situation has not been fully assessed. There are going to be limitations on what adaptive management and real time operations can accomplish.

  Examine recent (five to ten years) real-time management of the cold water pool in Shasta Reservoir to determine both the effectiveness of real-time operations and a range of adaptive management options.

- **North Delta Diversion Effects**

  Mortality rates from predation and other screening effects are difficult to predict, as there is a high level of uncertainty associated with predation and other effects on juvenile salmonids. The estimate of <1% loss at all 5 screens is not sufficient without giving additional consideration to higher estimates of mortality (GCID empirical studies showed a 5% per screen loss rate, much higher than the <1% used in the DPM).

1. Bracket the analysis of screen related mortality around a 5% per screen loss assumption.
2. Investigate the use of DWR's hydrodynamic model to assess local flow alterations at the proposed diversion structures, including the creation of predator holding areas. Specific questions are whether the model can simulate on-bank structures and the additional hydrodynamic effects of active pumping.

- **Predator Control Conservation Measure**

  We agree that predation is a significant risk factor to the listed species, but the assumed positive results of this CM are questionable and unsupported (see F.5.4.1.4 in Appendix F). As an example, localized control of striped bass may not be feasible as this species exists throughout the Plan area and are highly mobile. Few specific details have been presented on how the CM will be implemented, and an aggressive predator removal program could result in significant incidental take of listed species. Due to the high level of uncertainty, we find it very unlikely that we could rely on this measure for any benefits during the permit process.

  Remove this CM measure from the plan, and move it to an experimental research program and link to adaptive management. Reflect this appropriately in the EA.

- **Delta Passage Model**

  DPM is used as the sole predictor of smolt survival in baseline and PP scenarios. However, the assumptions, inputs, and results are still being validated and reviewed. The datasets used in this model are very limited and largely based on results from hatchery late-fall run Chinook, which are then being applied to other runs of Chinook.

  Continue refinement and development of DPM. Weigh validity of results against those of other models and relationships. The use of Newman, 2003 may be another tool to use for assessing the survival of fall and spring run smolts through the Delta.

- **Deficient Analysis of Fry Passage/Survival**

  Because the DPM model is only for smolt sized fish, the salmonid analysis is insufficient as it provides no information on fry-sized salmonid passage/survival**.**

  Add qualitative analysis of fry survival based on best available data. Perhaps add time/added mortality to a modified version of an updated DPM model.

- **PTM Runs Inadequately Capture Altered North Delta Hydrodynamics**

  PTM model runs did not include conditions in which ND diversions would be at the upper limits of allowable pumping (high proportion of total river flow). The technical memo from NMFS and USFWS highlighted the issue and the resolution to the problem. We will need additional modeling runs to adequately assess ND diversion impacts on salmonid travel time and route entrainment.

  Do additional PTM analysis following guidelines outlined in NMFS/USFWS memo.

- **D1641 Export/Inflow Ratio**

  Combined north and south Delta exports under the PP exceed the current D-1641 Delta Export/Inflow standard. (The PP calculation method measures Sac River inflow below the North Delta diversions and does not include ND diversions as part of total exports).

  1) *Provide summary analysis of differences between PP and EBC by month and water year type using alternate E/I calculations.*
  2) *Show resulting flow data for both calculation methods.*

- **Yolo Bypass**

  Yolo Bypass has great potential for fisheries benefits, but the current EA may be overstating the benefits without adequate studies or data to support these conclusions. Without project specific plans to help quantify the effects, concerns remain about issues such as sturgeon passage, juvenile salmonid survival under lower flow regimes, ability to get juveniles into the floodplain through notch and reduction of flows in the mainstem Sacramento River to accommodate additional flooding in Yolo Bypass. Also, some races/runs of salmon may not have access to Yolo Bypass.

Provide project specific plans and consider the risks of managing the floodplain under lower flows related to issues above.

- **Channel Margin Habitat**

  Altered flows resulting from the North Delta diversions may result in reduced water levels affecting the percentage of time that current wetland and riparian benches are inundated.

  Compare anticipated water levels under future scenarios with those in the design documents of restored wetlands and riparian benches to analyze potential dewatering of those features.

- **Construction and Maintenance Impacts**

  The EA does not adequately address the potential for adverse impacts on sturgeon, fall-run Chinook adults, and steelhead adults, which are generally present in the project area during the proposed in-river work windows described for construction and maintenance of North Delta facilities.

  Discuss ways of minimizing impacts and implementing mitigation for species not protected by work windows.

- **Tidal Marsh Impacts on Riverine Flow**

  The effect analysis assumes that restored tidal marsh will act to decrease flow reversals, which has not been well explained. It seems that tidal marsh restoration was modeled as a single configuration; there has been no description of that configuration to indicate how they were implemented in the hydrodynamic models. Therefore, there is a lot of uncertainty regarding model results.

  Document changes to hydrodynamic models that were implemented to characterize tidal marsh restoration.

- **Cumulative Effects Show Long-Term Viability Concerns for Salmon**

  The analysis indicates that the cumulative effects of climate change along with the impacts of the PP may result in the extirpation of mainstem Sacramento River populations of winter-run and spring-run Chinook salmon over the term of the permit.

  1) Incorporate operational criteria into the PP that will protect and conserve suitable habitat conditions in the upper river for the species under the 50 year HCP (these operational criteria should be designed to meet the performance criteria in the NMFS BiOp RPA).
  2) Convene a 5-agency team of experts specialized in Shasta operations and temperature management to develop the above described operational criteria.

- **Holistic Estuarine Evaluation**

  The effect analysis should examine synergistic and cumulative ecological impacts associated with reducing inflows to an estuary that is already severely degraded, and discuss the importance that water quantity, quality, and the natural hydrograph have to the ecosystem, as well as the direct impacts on native fish species. So far, the impacts to fish have mostly been examined in a piecemeal fashion (e.g., examining impacts of flow reduction on adult homing).

  Incorporate a holistic evaluation of impacts on the estuarine ecosystem. Include discussion of the importance of water quantity, quality, and the natural hydrograph to the ecosystem, and the direct impact that changes to these conditions have on native fish species.

- **Burden of Proof**
  Deference should be given to known population drivers and documented relationships (e.g., sturgeon recruitment relationship with flows is well documented, though the exact mechanism is not completely understood). Since flow is a key component of habitat for aquatic species, do not assume that it can be substituted for by other actions.
  Do not assume that incremental benefits in a conservation measure will compensate for known population drivers related to flow.

- **Incomplete Analyses and Documentation**
  The full appendices were not released concurrently with Chapter 5 which makes review of the results problematic.
  Provide all appendices/analysis simultaneously so Services can have all pertinent information used in Effects Analysis summaries without having to backtrack weeks later.

- **Insufficient Biological Goals and Objectives**
  The conservation measures are sometimes defining the BDCP species objective s, which is insufficient. 30% juvenile through-Delta survival is not a suitable goal for a 50 year conservation plan.
  The BDCP objectives should be biological, species-level outcomes.

- **OMR Flows Unimproved in Drier Water Years**
  Improved OMR flows under the PP occur during wetter years when OMR is less of an issue for covered fish. PP OMR flows are often worse than, or similar to, EBC in drier years. Sacramento Basin fish are most vulnerable to entrainment into the central Delta in drier years when Sacramento River flows have the potential to reverse and OMR levels are below -2,500 cfs. San Joaquin basin fish are best protected by increased Vernalis flows and/or a HORB which the PP does not address.
  1. *Analyze the risk in different water year types and with different flow levels in the Sacramento River.*
  2. *Implement Scenario-6 to help address the adverse impacts seen under the PP.*

- **Non-Physical Barriers**
  Assessment of non-physical barriers is inadequate, and the potential negative effects of predation associated with non-physical barriers haven't been assessed.
  Include analysis of potential adverse effects of non-physical barriers.

- **Carry-over of OCAP RPA's on technological improvements to the South Delta Facilities**
  By not carrying forward technological fixes in the South Delta called for in the OCAP RPAs into the Conservation Measures, we would expect the effects analysis to specifically flag this and analyze it as a degradation to future conditions (as compared to the baseline which should include the RPA improvements).
  Add south Delta technological improvement RPA's to Conservation Measures

- **Feasibility of 65K acres of Habitat Restoration**
  Recent evaluation of land available for habitat restoration indicates potential roadblocks to acquiring all the land proposed in the PP. DWR's own analysis suggests that 65K acres is very unlikely.
  Analyze the potential effects of partial implementation of habitat restoration and incorporate alternative actions or measures to compensate for this possibility.

BUREAU OF RECLAMATION
2800 Cottage Way, E-1604
Sacramento, California 95825

DEPARTMENT OF WATER RESOURCES
1416 Ninth Street, Room 1115-1
Sacramento, California 95814

August 2, 2016

William Stelle
Regional Administrator, West Coast Region
National Marine Fisheries Service
7600 Sand Point Way Northeast
Seattle, WA 98115

Subject: Request for Reinitiation of Section 7 Consultation Addressing Coordinated Long-Term Operation of the Central Valley Project (CVP) and State Water Project (SWP)

Dear Mr. Stelle:

On June 4, 2009, the National Marine Fisheries Service (NMFS) issued its biological opinion (2009 BiOp) on the Coordinated Long-term Operation of the CVP and SWP (LTO). The purpose of this letter is to request reinitiation of consultation with NMFS, as provided for under Section 7 of the Endangered Species Act (ESA), on the LTO. This request is 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. We expect this consultation to update the system-wide operating criteria for the LTO consistent with Section 7 requirements and to review the existing Reasonable and Prudent Alternative (RPA) included in the 2009 Biological Opinion (2009 BiOp) to determine the continued substance and efficacy in meeting the requirements of Section 7 of the ESA. Consistent with this reinitiation request, U.S. Bureau of Reclamation (Reclamation) and the California Department of Water Resources (DWR) will also seek reinitiation of consultation from the U.S. Fish and Wildlife Service (FWS) on the LTO.

During this reinitiated consultation, the CVP and SWP will continue to operate pursuant to the requirements of the 2009 BiOp until a new opinion on the LTO is issued. In addition, Reclamation will be requesting that NMFS commence the Amendment process for the 2009 BiOp RPA (section 11.2.1.2 Research and Adaptive Management page 9 of the 2011 amendment) through a separate letter. Lastly, because we believe an open and transparent science process is essential to effective conservation, the Collaborative Science and Adaptive Management Program (CSAMP) and Collaborative Adaptive Management Team (CAMT) processes can provide important input to the reinitiated consultation. In addition, we plan to involve and have the benefit of the Delta Science Program and its processes.

For this reinitiated consultation, Reclamation and DWR will coordinate with NMFS and FWS to prepare a Consultation Agreement (CA), expected October 31, 2016, that will outline the tasks, process, and schedule to complete a biological assessment (BA) and BiOp. Additionally, the directors of Reclamation, DWR, FWS, NMFS, and the California Department of Fish and Wildlife (DFW) will meet in late 2016 to discuss progress and next steps. We believe it is appropriate to include DFW in the development of the CA to ensure consistency with legal requirements for those listed species covered in the BiOp that are also listed under the California Endangered Species Act. We expect the CA to outline the specific steps involved and agency roles in developing the proposed action, the scientific framework for the effects assessment, and preparation and review of drafts of the BA and BiOp, including independent scientific review.

Please let us know of any assistance we can provide to expedite the consultation. Please feel free to contact Ms. Janice Piñero at (916) 414-2428 or Ms. Cindy Messer at (916) 653-0901 with questions related to the LTO and BA documents.

Sincerely,

David Murillo
Regional Director
Bureau of Reclamation

Date: 8/2/16

Mark W. Cowin
Director
Department of Water Resources

Date: 8/2/2016

cc: U.S. Fish and Wildlife Service (Ren Lohoefener)
California Department of Fish and Wildlife (Charlton Bonham)

DRAFT TECH MEMO

Oct 29, 2012

BAY DELTA CONSERVATION PLAN:

Proposed Interim Delta Survival Objectives for Juvenile Salmonids

NOAA Fisheries, Southwest Region, Central Valley Office

EXECUTIVE SUMMARY

The purpose of this memorandum is to introduce Interim Juvenile Salmonid Delta Survival Objectives (Interim Survival Objectives) and to explain the process used to develop them. Bay Delta Conservation Plan (BDCP) covered salmonids are defined as winter-run, spring-run, fall-run and late-run Chinook salmon and steelhead spawning in the Sacramento and San Joaquin rivers. Although empirical data on current through-Delta survival for each of the covered salmonids are not available, there are some survival data for selected species on which to base initial survival objectives for the BDCP to make a meaningful contribution to recovery. This memo also serves to introduce a framework for revising and refining objectives for Delta survival. The objectives presented are interim, and will be refined as additional data become available. These BDCP survival objectives would provide 50% of the total improvement in overall survival necessary to meet target cohort replacement rates (CCR). The remaining 50% of the necessary improvements in juvenile survival are expected to be achieved through recovery actions distributed throughout the salmonid life-cycle.

A simple deterministic, stage-based life cycle model and ultimate CRRs of 1.4 for spring-run, fall-run, late fall-run Chinook salmon and steelhead, and 1.5 for winter-run Chinook salmon were used to develop the Interim Survival Objectives. We established a progressive schedule of intermediate CRR targets through the span of the BDCP permit period to simulate the expected progressive improvements in salmonid survival as BDCP benefits are realized through plan implementation. This timeline starts with the signing of the Record of Decision (Year-0), with the primary benefits from BDCP implementation expected to commence following initial operation of the North Delta Diversion in Year-10. Using average fish generations (3-years) as the unit of time, we identified intermediate time steps at BDCP Year-19 (three generations after initiation of dual conveyance) with a CRR target of 1.2; Year-28 (another three fish generations) with a CRR target of 1.3; and a final time step at Year-40 (four more generations) with a CRR of 1.4, for spring-run, fall-run, and late fall-run Chinook salmon and steelhead. CRR targets of 1.3, 1.4, and 1.5 at the same respective time steps were used for winter-run Chinook salmon based on recognition of their endangered status. The intermediate and final Interim Survival Objectives relating to these CRR targets are summarized in **Table 1** below.

Current Delta survival estimates for Chinook salmon and steelhead originating in the Sacramento River range from 0.35 to 0.50. The calculated Interim Survival Objectives for winter-run Chinook salmon are 0.52, 0.54, and 0.57 for the BDCP Year-19, -28, and -40 time steps, respectively. For spring-run Chinook salmon, the calculated Interim Survival Objectives are 0.49, 0.52, and 0.54, respectively. The calculated Interim Survival Objectives for fall-run Chinook salmon are 0.42, 0.44,

and 0.46, respectively. The calculated Interim Survival Objectives for late fall-run Chinook salmon are 0.49, 0.51, and 0.53, respectively. Using a current survival of 0.45, the calculated Interim Survival Objectives for Sacramento River steelhead (Battle Creek population) are 0.54, 0.56, and 0.59 for the BDCP Year-19, -28, and -40 time steps, respectively. The Battle Creek population was selected as representative of Sacramento River steelhead, as the survival studies will likely use hatchery steelhead smolts from Coleman National Fish Hatchery, which is located on Battle Creek.

Current Delta survival rates for Chinook salmon and steelhead originating in the San Joaquin River range from 0.02 to 0.10 (VAMP Annual Reports, R. Buchanan pers. comm.). For fall-run Chinook salmon current survival was set at 0.05 and the calculated Interim Survival Objectives are 0.27, 0.29, and 0.31 for the BDCP Year-19-year,-28, and -40 time steps, respectively. Using an initial survival estimate of 0.07, the calculated Interim Survival Objectives for San Joaquin spring-run Chinook salmon are 0.33, 0.35, and 0.38, respectively. For San Joaquin steelhead, the current survival was set at 0.10, and we calculated Interim Survival Objectives of 0.44, 0.47, and 0.51, respectively. NMFS anticipates periodically reviewing and updating these Interim Survival Objectives as new empirical data become available, and plans to work collaboratively with resource agencies and stakeholders to monitor progress toward meeting the objectives.

For all species, these Interim Survival Objectives represent 50% of the estimated increase in Delta survival required to achieve the modeled CRRs, based on improvements in through-Delta survival alone. That is, we held pre- and post-Delta survival constant, and calculated the improvement in Delta survival needed to achieve the target CRRs, and assigned half of that improvement as the objective for BDCP conservation measures. The balance of the improvements required to achieve the modeled CRRs are expected to be derived from other recovery actions distributed throughout the entire range of covered salmonids, which could occur upstream, in the Delta, or in the ocean.

Table 1. Estimated current Delta survival rates and proposed Interim Delta Survival Objectives for each of the BDCP covered salmonids.

Species	Population	Estimated Through-Delta Survival	Interim BDCP Delta Survival Objectives:		
			After 19 Years	After 28 Years	After 40 Years
Chinook salmon	Sac winter-run	0.40	0.52	0.54	0.57
	Sac spring-run	0.40	0.49	0.52	0.54
	Sac fall-run	0.35	0.42	0.44	0.46
	SJ fall-run	0.05	0.27	0.29	0.31
	Sac late fall-run	0.40	0.49	0.51	0.53
	SJ spring-run	0.07	0.33	0.35	0.38
Steelhead	Sacramento	0.45	0.54	0.56	0.59
	San Joaquin	0.10	0.44	0.47	0.51

INTRODUCTION

Chinook salmon and steelhead in the Sacramento and San Joaquin rivers have been in decline for over 100 years, and two Evolutionarily Significant Units (ESUs) of Chinook salmon (Sacramento River winter-run and Central Valley spring-run) and a single Distinct Population Segment (DPS) of steelhead (California Central Valley) are listed as threatened or endangered under the federal Endangered Species Act. Two additional populations of Central Valley Chinook salmon (fall-run and late fall-run) have been combined in a single ESU by the National Marine Fisheries Service and are currently classified as a Species of Concern.

One of several factors responsible for salmonid decline and limiting their recovery is high mortality of juvenile salmonids as they pass through the labyrinth of canals, channels, and sloughs comprising the Sacramento-San Joaquin Delta (hereafter the Delta). Water quality and physical habitat in the Delta have been severely degraded over time, and populations of non-native predators have become well established. Exacerbating the perilous journey through the Delta are the two industrial scale pumping facilities located in the southern Delta that provide water for a large portion of California's human population and irrigation of arid agricultural lands located in the country's most populous state. Not only are fish entrained at the pumping facilities, but the sheer volume of water exported can substantially affect the hydrodynamics of the central Delta.

In order to make a meaningful contribution to recovery of Central Valley salmonids, NMFS is working with interested parties to develop the Bay Delta Conservation Plan (BDCP). A key component of the BDCP is establishment of biological goals and objectives which will help guide conservation measures and the adaptive management process. Among these goals and objectives, one of the most important is the effort to improve migratory conditions and survival of juvenile salmonids passing through the Delta. Additional BDCP actions, such as efforts to restore salmonid habitat in the Delta and improve overall ecosystem productivity, will also be considered as measures contributing to recovery, but have separate objectives not considered here.

The purpose of this memorandum is to introduce Interim Juvenile Salmonid Delta Survival Objectives for each of the BDCP covered salmonids and to explain the approach used to develop these Objectives. Although empirical data on through-Delta survival for each of the covered salmonids are not available, there are survival data for selected populations and life stages, and in total there exists a body of information upon which to base initial scientific judgments about baseline survivals and the percentage improvement required for the BDCP to make a meaningful contribution to recovery. An equally important purpose of this memorandum is to introduce a simple deterministic, stage-based life cycle approach to define BDCP objectives, periodically review and update them, and monitor progress toward achieving the intermediate and final Cohort Replacement Rate (CRR) milestones. Although further consideration and effort is needed to inform these targets, it is imperative to establish interim objectives in order to guide monitoring and the management decision-making process in the near term.

BACKGROUND

Species and Populations. There are four generally recognized runs of Chinook salmon in California's Central Valley that are endemic to either the Sacramento or San Joaquin rivers, or both: winter-run, spring-run, fall-run, and late fall-run Chinook salmon (*Oncorhynchus tshawytscha*), and multiple geographically defined populations of steelhead (*Oncorhynchus mykiss*) (*Meyers et al*. 1995, Busby et al. 1996). For the purposes of the BDCP, covered salmonids are defined as winter-run, spring-run, fall-run and late fall-run Chinook salmon, and steelhead spawning in the Sacramento and San Joaquin rivers (collectively referred to as California Central Valley Steelhead). As noted above, the Central Valley spring-run Chinook salmon ESU is listed as threatened and the Sacramento River winter-run Chinook salmon ESU is listed as threatened. Spring-run Chinook salmon were historically present in both the Sacramento and San Joaquin rivers but have been extirpated from the San Joaquin and will be reintroduced over the next several years. Historically, winter-run Chinook salmon were only present in the Sacramento River, spawning in the upper tributaries above the current location of Shasta Dam. Fall-run Chinook salmon are present in both rivers. It is uncertain whether the San Joaquin River ever supported a late fall-run Chinook salmon population (Yoshiyama et al. 1998).

As defined by their Endangered Species Act (ESA) listing, the Sacramento River winter-run Chinook salmon ESU includes all naturally spawned populations of winter-run Chinook salmon in the Sacramento River and its tributaries, as well as winter-run Chinook salmon reared at the Livingstone Stone National Fish Hatchery. Designated critical habitat for the Sacramento winter-run Chinook salmon includes: the Sacramento River from Keswick Dam downstream to Chipps Island at the westward margin of the Sacramento-San Joaquin Delta, all waters from Chipps Island westward to Carquinez Bridge, and all waters of San Pablo Bay north of the San Francisco/Oakland Bay Bridge.

The Central Valley spring-run Chinook salmon ESU includes all naturally spawned populations of spring-run Chinook salmon in the Sacramento River and its tributaries in California, including the Feather River. One artificial propagation program, the Feather River Hatchery spring-run Chinook salmon program, is considered part of the ESU. Designated critical habitat for the Central Valley spring-run Chinook salmon ESU includes 1,158 miles of stream habitat in the Sacramento River basin and 254 square miles of estuary habitat in the San Francisco-San Pablo-Suisun Bay complex.

The California Central Valley (CCV) steelhead DPS includes all naturally spawned populations of steelhead in the Sacramento and San Joaquin rivers and their tributaries. Two artificial propagation programs–the Coleman National Fish Hatchery and Feather River Hatchery steelhead programs–are considered to be part of the DPS. Designated critical habitat includes 2,308 miles of stream habitat in the Central Valley and an additional 254 square miles of estuary habitat in the San Francisco-San Pablo-Suisun Bay complex.

Life histories. From a life history perspective, California's Central Valley supports perhaps the most diverse populations of Chinook salmon in the world. Named for their adult run-timing, but displaying substantial diversity throughout their life cycles, the four runs of Chinook salmon and

Central Valley steelhead enter the Delta at different sizes, at different times, and reside for variable time periods, although there is overlap among populations. **Table 2** summarizes life history information for the covered salmonids based on information synthesized from a variety of sources, including Vogel and Marine (1991), Fisher (1994), and Williams (2006).

Current Delta Survival Estimates. Despite efforts by many researchers to estimate juvenile salmonid survivals in the Delta over the past several decades, only recently have the necessary tools and statistical models become available to rigorously address the task. At this time the most robust Delta survival estimates are limited to late fall-run hatchery Chinook salmon emigrating from the Sacramento River, and to a lesser extent fall-run hatchery Chinook salmon emigrating from the San Joaquin River. However, population-specific estimates are needed for all Chinook salmon and steelhead populations migrating from the Sacramento and San Joaquin rivers. Accordingly, these initial survival objectives and the percentage improvements are necessarily interim, with the expectation that they will be revised as new empirically derived survival estimates become available. The following are brief summaries of the studies that were considered in developing baseline survival estimates.

Michel 2010–Estimated survival of Sacramento River juvenile late fall-run Chinook salmon for three consecutive years between 2007 to 2009 using acoustic tag methods; 200 to 300 fish were tagged and released per year and detected at multiple locations during their downstream migration. Late fall-run Chinook were selected because of their availability at Coleman National Fish Hatchery as yearling smolts at a size large enough to carry an acoustic tag (minimum size 160 mm). In 2007, tagged fish were released into Battle Creek at Coleman National Fish Hatchery in January. In the two subsequent years tagged fish were released in the upper mainstem Sacramento River in January. Final detection locations were at the Golden Gate Bridge, at which point the migrants were considered to have entered the ocean. Total survival from RKm 518 to RKm 2 ranged from 3.1 to 6.1%; the 3-year average was 3.9%. Partitioning the migration route into sections, the upper reaches (RKm 581 to 325) supported the lowest survival; the lower riverine reaches supported the highest survival (RKm 325 to 169); and the Delta and estuary (RKm 169 to 2) supported intermediate lower survival. Based on an estimated 93.7% survival per 10 Km of Delta (RKm 169 to 70), Delta survival was 52.6%. This estimate is consistent with those of Perry et al. cited below.

Perry et al. 2009; Perry 2010; Perry et al. 2012a; Perry et al.2012b–Estimated Delta survival of acoustically-tagged late fall-run hatchery Chinook salmon in a series of studies conducted between 2007 and 2010. Survival estimates ranged from a low of 0.174 (SE 0.031) for a release made in December 2007 to a high of 0.543 (SE 0.070) release made in January 2007. The arithmetic average of ten survival estimates was 38%. Most of these releases were made in relatively dry water years (except for 2010), but still represent some of the best estimates of Delta survival presently available, and were used to select baseline survivals of 0.40 to 0.50 for Sacramento River Chinook salmon and steelhead for the purposes of developing interim survival objectives.

Kjelson and Brandes (1989) and Brandes and McLain (2001)—Working under the Interagency Ecological Program for the Sacramento-San Joaquin Delta (IEP), conducted numerous mark-recapture studies in the lower Sacramento River, lower San Joaquin River, and Delta beginning in the early 1970s. Based on available technology and methods they used single- and paired-releases of coded-wire-tagged hatchery fall-run Chinook salmon and relied on a mid-water trawl near Chipps Island and Antioch and ocean harvest data for recapture locations/sources. Paired-release estimates were reported as relative survivals, whereas single release estimates were reported as "survival indices." Although results of these studies, summarized in Kjelson and Brandes (1989), Brandes and McLain (2001), Newman and Rice (2002) and Newman (2008) made a substantial early contribution to understanding survival bottlenecks in the Delta, the more recent studies employing acoustically-tagged smolts have yielded more precise information on Delta and within-Delta route-specific survivals. In general, the recapture rates of coded wire tagged (CWT) fish in all of these studies were quite low, and survival estimation required multiple assumptions regarding recovery efficiency. Accordingly, NMFS placed greater emphasis on the more recent estimates to inform selection of baseline survivals. However, even acoustic telemetry estimates are not without limitations. For instance, survival measured using acoustic tags can be biased high if tagged fish are eaten by predators that subsequently move past receiver locations. Presently, there is no definitive way of determining if a tag detected at a receiver is in a live target species or in a predator.

VAMP Studies—Are a series of studies conducted under the aegis of the Vernalis Adaptive Management Program (VAMP), and provide the best available insight into survival of San Joaquin fall-run Chinook salmon during their sojourn through the Delta. A cornerstone of the San Joaquin River Agreement (SJRA) and commitment to implement the State Water Resources Control Board (SWRCB) 1995 Water Quality Control Plan (WQCP) for the lower San Joaquin River and the San Francisco Bay-Delta Estuary, the VAMP studies were initiated in 2000 and conducted annually through 2011. A primary objective of the VAMP was to document how salmon survival changes in response to alterations in San Joaquin River flows and State Water Project (SWP)/Central Valley Project (CVP) exports with the installation of the Head of Old River Barrier (HORB). Studies conducted through 2006 employed CWT hatchery fall-run Chinook and Chipps Island mid-water trawl recoveries to estimate survival. Because of a shortage of hatchery fish and concern over high incidental take of Delta smelt in the mid-water trawl, the approach to estimating survival shifted to acoustic tagging and a release-detection framework to estimate survival, route selection, and detection probabilities among three migration pathways through the Delta. Results from 2010 and 2011 were considered to establish baseline Delta survivals of San Joaquin Chinook salmon and steelhead of 0.05 and 0.10.

GENERAL APPROACH AND ASSUMPTIONS

Meaningful improvements in Delta survival of juvenile salmonids must be measureable and contribute to recovery. Accordingly, baseline survivals must be established and routine monitoring implemented to track progress toward achieving the survival objectives. Because migration through the Delta is only one of several life stages where survival improvements will be required for species recovery, many additional studies and detailed life cycle models will be required. These studies are needed to identify life stage-specific survival rates, prioritize opportunities to improve life stage-specific survival rates, and ultimately the needed changes throughout the freshwater, estuarine, and ocean phases of the salmonid life cycle that will allow recovery of these species. Furthermore, actions not directly linked to Delta survival, such as supporting life history diversity and improving salmon growth and condition while emigrating, may also contribute to recovery. There is limited scientific understanding to weigh and compare effectiveness of such actions, which necessitates a flexible initial approach when allocating recovery efforts.

Although detailed, species-specific life cycle models are a preferred method of estimating the contributions of habitat changes and changes to life stage-specific survival, particularly in the context of recovery, those available at this time have limitations when focusing on the BDCP actions. For example, the Oncorhynchus Bayesian Analysis (OBAN) Model is just now being modified to consider reduced Sacramento River flow expected with construction and operation of a North Delta Diversion. As a retrospective statistical model, any predictions it makes based on conditions outside of those observed could have low confidence. The Interactive Object-Oriented Simulation (IOS) Model appears somewhat insensitive to changes in environmental conditions. Neither model uses empirical survival estimates from Red Bluff Diversion Dam to the ocean to validate their results, as survival to the ocean is not measured. Finally, results from the two models, as reported in the BDCP Effects Analysis of February 2012, were not consistent; whereas OBAN predicted significant impacts from increased upstream water temperatures, IOS predicted declines largely due to changing conditions in the ocean. Ongoing efforts will be focused on further development and application of these and other models to inform revisions to current objectives. Furthermore, through the adaptive management process and monitoring further development of objectives will occur.

Accordingly, to develop these Interim Survival Objectives we employed a simplified Excel spreadsheet approach in which we divided the life cycles into Pre-Delta, Delta, and Post-Delta life phases and assigned average survivals to each phase (**Table 3**). By populating the model with species-specific fecundities and selecting target CRRs that will substantially contribute to recovery, we estimated changes in Delta survivals needed to achieve the target CRRs at multiple time steps. To monitor progress, we established a BDCP timeline for interim and final CRR targets beginning with the signing of the Record of Decision (Year-0), and construction and initial operation of the Northern Delta Diversion to support dual conveyance beginning in Year-10. Using average fish generations (3-years) as the unit of time, we identified intermediate time steps at BDCP Year-19 (three generations past dual conveyance) and a CRR target of 1.2; another intermediate time step at Year-28 (another three generations) and a CRR target of 1.3; and a final time step at Year-40 (four more generations) and a CRR target of 1.4, for spring-run, fall-run, and late fall-run Chinook salmon and steelhead. CRR targets of 1.3, 1.4, and 1.5 at the same respective time steps were used for winter-run Chinook salmon based on recognition of their endangered status. These CRR targets were selected to put the covered salmonids on a population growth trajectory to achieve the previously published BDCP Global Goals (BDCP 2012) identified in **Table 4**. While the selection of CRRs was integral to calculating Interim Survival Objectives that represent a meaningful contribution to recovery, it is the through-Delta survival rates assigned to the BDCP that constitute the Objectives.

The general approach to establishing these Interim Survival Objectives follows:

1. Compile life stage-specific survival estimates for each of the covered salmonids; sort by Sacramento and San Joaquin river populations;
2. Consolidate and reduce survival estimates to three life phases: Pre-Delta, Delta, and Post-Delta;
3. Populate an Excel spreadsheet model with pre-, through-, and post-Delta survival estimates and calculate CRRs (or more precisely 3-Year Replacement Rates) for each covered salmonid under current Delta conditions;
4. Solve for the through-Delta survival needed to achieve a CRR of 1.2 (1.3 for winter-run) after BDCP Year-19, a CRR of 1.3 (1.4 for winter-run) after BDCP Year-28, and a CRR of 1.4 (1.5 for winter-run) after BDCP Year-40;
5. Take one-half of the necessary increase in Delta survival needed to meet these CRRs, add this to the baseline rate, and set the sum as the Interim Survival Objectives for each covered salmonid;
6. Assign responsibility for actions needed to achieve the Interim Survival Objectives to the BDCP. The remaining improvement in survival required to achieve the target CRRs (i.e., the balance after the BDCP survival improvement) is expected to accrue from other recovery actions implemented throughout the entire range of the species, and the percentage improvement will depend on the life phase affected.

The life stage-specific survival estimates were compiled from a variety of existing sources, including the NMFS winter-run Juvenile Production Estimate (JPE), recent acoustic tag survival studies, and trends in escapement and harvest records. Currently, the only empirical estimates of Delta survival are for Sacramento River late fall-run Chinook and San Joaquin River fall-run Chinook salmon; however, estimates based on acoustic tag studies for other Sacramento and San Joaquin species are expected to be available over the next five years. Where species-specific data were available they were used directly. More often, this was not the case, and adjustments were made based on how different life history characteristics would be expected to influence survival. In making these adjustments we assumed the following:

- Yearling migrants are expected to be actively smolting and will migrate more rapidly downstream through the Delta than will subyearling migrants. At a larger size smolts will also be less vulnerable to predation.
- The longer a salmonid life-stage resides in the Delta the higher the mortality.
- The later in the spring a salmonid life-stage transits the Delta the higher the mortality (because of warming temperatures and more active predators).

Specific examples of these kinds of adjustments were considered for steelhead spawning and rearing in Battle Creek and the American River. Battle Creek steelhead likely exhibit a lower tributary growth rate than American River steelhead, but exhibit higher survival to the smolt stage than do American River steelhead. In contrast, American River steelhead tend to smolt at a larger size, but exhibit lower tributary survival (Sogard et al. 2012). The larger-sized American River smolts would be expected survive Delta transit and ocean entry at a higher rate than the smaller Battle Creek steelhead smolts (Ward and Slaney 1988, Bond et al. 2008). While these kinds of assumptions and adjustments are no substitute for species-specific empirical data, they were necessary to constructing a life cycle context in which to approximate needed improvement to achieve sustainability and establish survival objectives.

Cohort replacement rates were used to establish a life cycle context for estimating changes in life stage-specific survivals needed to increase abundance and reduce risk, and to estimate the overall increase in Delta passage survival needed to achieve them. In their simplest form, CRRs use age-structured returns to calculate the number of returning adults in one generation produced by the previous generation. A CRR of 1.0 indicates a population is exactly replacing itself, not growing but also not declining in abundance. A CRR less than 1.0 indicates the population is not replacing itself and hence declining, and a CRR greater than 1.0 indicates the population is growing. For the purposes of establishing these Interim Survival Objectives we used the terms CRR and 3-Year Replacement Rates (3-YRRs) interchangeably, but acknowledge that to simplify this analysis we assumed an equal escapement of males and females, and assume all adults return at age 3. Neither of these assumptions markedly affect their use in our simplified model used to estimate the magnitude of needed life stage-specific improvements. We used CRRs of 1.2, 1.3, and 1.4 (1.3, 1.4, and 1.5 for winter-run) to calculate survival rates that need to be progressively achieved over the life of the BDCP, with check-ins at BDCP Year-19, -28, and -40. These CRR targets are generally accepted as representative of healthy population dynamics, but are not necessarily NMFS final recovery goals, and will be refined and revisited as further information becomes available. As noted above, one-half of the improvement in survival necessary to meet these CRR targets is expected to be achieved by the BDCP in the Delta.

The current cohort replacement rates for each covered salmonid were not explicitly matched to empirical data, but instead were set to levels below 1.0, but not so low as to predict rapid extinction of the species. This matches the slow but steady decline observed in these species over the last several decades. The San Joaquin species were an exception to this, as they had very low CRRs, largely due to the very low current Delta survival estimates used in the model. This suggests that the San Joaquin populations may currently be considered dependent populations, i.e., they are supported by a combination of hatchery fish, strays, and episodic successful natural reproduction.

Explicitly matching the predicted current cohort replacement rate to empirical data could be done in a future version of the model, but there are several challenges to doing so. One is to decide on the year or range of years of empirical data to match, and the CRRs for some species such as winter-run Chinook salmon have fluctuated greatly over the last 10–20 years. Another is to account for the large proportion of hatchery fish present in most escapement estimates, which is not currently part of the model. The large proportion of hatchery fish in most Central Valley salmonid species has the effect of keeping CRRs higher than they would be if the stock was solely comprised of naturally produced fish. The other effect is to increase the annual variation in escapement, as the return of hatchery fish stocked in the bays is largely dependent upon ocean survival, which can vary dramatically, as seen in the crash of Sacramento River fall-run Chinook salmon from 2007–2009.

With regard to incorporating interannual variability in the model, we considered using a method such as drawing a random number from a distribution with a specified mean and variance to the survival rates, both in the Delta and at other stages. Ultimately, we decided such an approach would still be focused around the mean survival rates, and since the shape of such a survival distribution is unknown at this time, it would require us to make more assumptions in a process that is already rich in assumptions, and would likely complicate the interpretation of the objectives without adding much value.

In selecting the specific CRRs for Year-19, Year-29, and Year-40 time steps, we also considered the relationships among the target CRRs and the previously established BDCP Global Abundance Goals for these species. In developing these projections we made the conservative assumption that the populations would respond slowly (i.e., remain near baseline CRRs) during the first 9 years following dual conveyance (BDCP Year-19). Beginning in BDCP Year-20 and extending for the next 20 years to BDCP Year-40, we estimated abundance based on the target CRR of 1.2 (1.3 for winter-run). Finally, we estimated abundance at BDCP Year-50, using the target CRR of 1.4 (1.5 for winter-run) for the period between BDCP year 41 and 50. The results of these projections and comparisons to the BDCP Global Abundance Goals are summarized in **Table 4**. Based on these projections, the estimated abundance of seven of the eight covered salmonids considered in this analysis would remain below their Global Abundance Goals at year 40, at which point abundance would be expected to increase rapidly over the next 10 years under a target CRR of 1.4 (1.5 for winter-run), leading to seven of the eight covered salmonids exceeding their global goal by the end of the BDCP permit period.

Of the eight covered salmonids, only the San Joaquin spring-run Chinook salmon was not projected to meet their global abundance target, but as there is no currently existing population, this projection is highly speculative. It is also clear from these projections that the future existence of naturally sustaining populations of San Joaquin River fall-run Chinook salmon and steelhead is uncertain. To the extent that our current placeholder survival estimates and CRRs are generally accurate, five additional generations at CRRs well below replacement would place both populations at high risk of extirpation. However, NMFS anticipates more immediate improvements in survival of San Joaquin-origin Chinook salmon and steelhead to accrue based on early conservation actions, including RPAs required by the NMFS and U.S. Fish and Wildlife Service Biological Opinions, improved Delta inflows, habitat restoration projects such as Dutch Slough, and improvements in water quality from the upgraded Sacramento Regional Wastewater Treatment Plant.

Finally, among ESA listed species, it is an exceptionally rare circumstance for a single factor affecting a single life stage to be a survival bottleneck such that eliminating the bottleneck will put the species on a trajectory to recovery, and the role of Delta survival in the demise of CV Chinook salmon and steelhead is no exception. However, because it is well established that the magnitude of mortality during Delta passage can be high (e.g., Brandes and McLain 2001, VAMP studies), it is highly unlikely that CV salmonids can be recovered without major improvement in Delta survival. This is particularly the case for salmon and steelhead emigrating from the San Joaquin River and transiting the southern Delta. In recognition that the BDCP cannot be responsible for producing the entire increase in survival deemed necessary to achieve sustainability, these Interim BDCP Survival Objectives are approximately one-half of the estimated overall improvement needed to achieve the long term CRR targets. This is based on the assumption that other restoration and recovery efforts will result in substantial improvements in survival throughout the salmonids range.

INTERIM SURVIVAL OBJECTIVES

Because salmonids emigrating from the Sacramento and San Joaquin rivers enter the Delta at different locations, they traverse the Delta via different routes, and are subject to different sources and magnitudes of mortality. Accordingly, baseline survival estimates and survival objectives are considered separately for the different watersheds. Further, because improvements in Delta survivals are expected to accumulate over time, survival objectives are presented in multiple time steps during the expected 50-year timeline of the BDCP: BDCP Year-19 (19 years after the signing of the BDCP ROD and 9 years after the start of dual conveyance); BDCP Year 28 (9 years or 3 fish generations after the initial time step); and BDCP Year-40 years (12 years or 4 fish generations after the second time step when many of the habitat restoration and other BDCP benefits are expected to be realized throughout the Delta.

Table 5 presents the Interim Juvenile Salmonid Delta Survival Objectives for Chinook salmon and steelhead originating in the Sacramento and San Joaquin rivers, respectively.

Current Delta survival estimates for Chinook salmon and steelhead originating in the Sacramento River range from 0.35 to 0.50 (Michel, 2010; Perry et al. 2009; Perry 2010; Perry et al. 2012a; Perry et al. 2012b). The calculated Interim Survival Objectives for Sacramento River winter-run Chinook salmon are 0.52, 0.54, and 0.57 for the BDCP Year-19, Year-28, and Year-40 time steps, respectively. For Sacramento River spring-run Chinook salmon, the calculated Interim Survival Objectives are 0.49, 0.52, and 0.54 for the BDCP Year-19, Year-28, and Year-40 time steps. The calculated Interim Survival Objectives for fall-run Chinook are 0.42, 0.44, and 0.46 for the same respective time steps. Finally, Interim Survival Objectives for Sacramento late fall-run Chinook salmon are 0.49, 0.51, and 0.53 for the same BDCP Year-19, Year-28, and Year-40 time steps.

For steelhead, we initially calculated Interim Survival Objectives for the American River and Battle Creek populations separately, based on expected differences associated with life history variation. However, as noted above we used the Battle Creek population to be representative of the Sacramento River steelhead as they are the most likely to be used to monitor survival. For the Battle Creek population of steelhead the current survival was set at 0.45 and the calculated Interim Survival Objectives were 0.54, 0.56, and 0.59 for the BDCP Year-19, Year-28, and Year-40 time steps.

Current Delta survival rates for Chinook salmon and steelhead originating in the San Joaquin River range from 0.05 to 0.10. For San Joaquin River fall-run Chinook salmon the current survival was set at 0.05 and the calculated Interim Survival Objectives were 0.27, 0.29, and 0.31 for the BDCP Year-19, Year-28, and Year-40 time steps, respectively. For San Joaquin River spring-run Chinook salmon the estimated initial survival is 0.7 and the Interim Survival Objectives are 0.33, 0.35, and 0.38 for the BDCP Year-19, Year-28, and Year-40 time steps. For San Joaquin River steelhead, the current survival was set at 0.10, and the calculated Interim Survival Objectives were 0.44, 0.47, and 0.51. for the same BDCP time steps.

There are several other factors that might be considered in further defining or revising these Interim Survival Objectives, including scaled objectives based on wet and dry years. However, at this point we are reluctant to more finely define or scale survival objectives until additional species-specific survival estimates are collected over a range of hydrologic conditions. However, as new information becomes available, the potential to define wet- and dry-year expectations should be revisited.

Climate change was not explicitly considered in developing these Interim Survival Objectives, but it may necessitate changes in the objectives at some future point. For example, if higher river temperatures reduce instream survival or ocean survival decreases, then higher Delta survival would be required to maintain the status quo.

ACHIEVABILITY OF INTERIM DELTA SURVIVAL OBJECTIVES

Although the use of this simple life stage-specific deterministic model and target CRRs facilitated defining Interim Survival Objectives in a life cycle context, it does not address how achievable these objectives are within any one specific life stage, and particularly the through-Delta life stage. It is obviously important to set objectives that are consistent with putting these populations on a trajectory of sustainability, but unless these objectives are reasonably achievable they have limited value. To address this question, we reviewed preliminary analyses conducted by Chuck Hanson (Hanson Environmental, Inc.) which evaluated a time series of previous Delta survival estimates and relationships between those survival estimates and CRRs. Hanson conducted separate analyses for San Joaquin River-origin fall-run Chinook salmon and Sacramento River-origin fall-run Chinook salmon.

For fall-run Chinook salmon originating in the San Joaquin River and tributaries, Hanson used Delta survival estimates based on VAMP CWT tag recoveries in the Chipps Island trawl and in ocean fisheries between 1995 and 2006. These data included through-Delta survival estimates that in some years exceeded the Interim Survival Objectives for San Joaquin fall-run Chinook salmon, thus substantiating that they had been historically achieved. Moreover, his analyses showed a positive correlation between Delta survivals and CRRs, and the time series of 5-year geometric mean CRRs between 1999 and 2007 (0.27 to 1.68) included CRRs in the range of 1.2–1.4 that we used as target CRRs to estimate Delta survival improvements.

Hanson's preliminary analyses of Delta survival of fall-run Chinook salmon originating in the Sacramento River and tributaries were also based on CWT recoveries. However, these survival estimates were based on survival indices rather than absolute survivals, and release locations in the Sacramento River were more variable than the uniform release location at Mossdale used for the San Joaquin River. Despite these differences, his conclusions were largely the same. Between 1996 and 2010, survival estimates for several release groups of fall-run Chinook salmon exceeded the Interim Delta Survival Objective of 0.42 and 0.46, again indicating that they are achievable. Further, although the 5-year geometric mean CRRs for Sacramento River fall-run Chinook have mostly been below the BDCP Year-19 CRR target of 1.2, the CRRs ranged from about 1.2 to 2.0 between 1993 and 2002, thus validating the achievability of our 1.2 to 1.4 CRR targets. In additional exploratory analyses, Hanson calculated 5-year geometric mean CRRs for spring-run Chinook during the period 1975 to 2008 that exceeded 1.2. Similarly, he identified a 12-year period in the 1990s and early 2000s during which 5-year geometric mean CRRs for winter-run Chinook ranged from 1.2 to over 2.5.

ESTIMATED CONTRIBUTION TO RECOVERY

Few if any ESA listings are the result of a single physical, chemical, or biological factor, and decline of Central Valley salmonids is no exception. Further, there is no requirement or expectation that this or any Habitat Conservation Plan will address, let alone resolve, all of the factors causing a species' decline. However, there is a requirement that a Habitat Conservation Plan will demonstrably contribute to the recovery of a covered species.

By using CRR targets of 1.2, 1.3, and 1.4 (1.3, 1.4, and 1.5 for winter-run) for the BDCP Year-19, -28, and -40 time steps, and then using 50% of the estimated Delta survival improvements needed to achieve these CRR as the Interim Survival Objectives, NMFS is ensuring that these objectives will make a substantive contribution to recovery. For winter-run Chinook salmon we selected CRRs of 1.3, 1.4, and 1.5 as this population is listed as endangered under the ESA, and is currently at very low escapement levels. Because of these low initial escapement levels, population projections using lower CRRs of 1.2, 1.3, and 1.4, respectively resulted in population estimates that were still well below the global abundance objective after 50 years. It is also reasonable to expect BDCP to achieve higher rates of improvement for winter-run Chinook salmon because their needs were heavily considered in the design of many of the conservation measures proposed in the BDCP, including the North Delta Bypass rules, the Yolo Bypass improvements, and temperature and flow requirements in the Sacramento River below Keswick Dam.

MONITORING AND EVALUATION AND ADAPTIVE MANAGEMENT

Because of the limited availability of empirical information to inform the development of the initial baseline survival estimates, NMFS used data from recent acoustic tag survival studies of hatchery-reared late fall-run Chinook salmon as a starting point from which to estimate baseline survival for the remaining salmon and steelhead populations. NMFS acknowledges the limitations of this approach, but in balancing the risks to ESA-listed species, we considered it better to proceed with interim targets and recognize the need to periodically review these baseline estimates and document progress toward the 19-, 28, and 40-year objectives. As new empirical survival estimates for CV species become available, NMFS is prepared to review and revise these Interim Juvenile Salmonid Delta Survival Objectives as appropriate. For example, Philip Sandstrom (University of California at Davis, personal communication) has recently completed an acoustic tagging study of Sacramento River steelhead that will help inform estimating steelhead survival in the Delta. In addition, Sean Hayes (NMFS, SWFSC Lab, personal communication) is scheduled to begin a winter-run Chinook salmon acoustic tagging study in the Sacramento River beginning in 2013. Further, the USBR has recently initiated acoustic tagging studies with steelhead in the San Joaquin River. Data from several years of acoustic tagging studies of San Joaquin fall-run Chinook salmon are expected to be available shortly. All of these studies are expected to greatly improve not only the estimates of baseline survival in the Delta for these populations, but also allow a more focused consideration of operations and conditions that can contribute to improvements in survival.

There remain numerous questions regarding factors that limit survival of juvenile salmonids migrating in the Sacramento and San Joaquin rivers. Empirical data on juvenile survival in both the pre-Delta and post-Delta stages is lacking for many species. BDCP monitoring should include programs to estimate survival from the fry-to-smolt and smolt-to-adult stages. Counting juveniles produced upstream will require rotary screw traps with efficiency estimates, and will likely require novel methods to estimate steelhead parr and smolt numbers. Central Valley hatchery programs should routinely estimate smolt to adult return rates (SARs) for each smolt class, and consider both adults returning to the hatchery and spawning in the river. One often noted but neglected question is whether improved rearing habitat in the Delta could lead to longer residences times and lower survival rates for juvenile salmonids, but be offset by the survivors being larger and exhibiting higher ocean survival rates. The analytical framework we introduce here is flexible enough to accommodate such a change by adjusting the post-Delta survival element of the equation, which will lower the required though-Delta survival needed to reach the same long-term goal, and result in lower BDCP Delta survival objectives.

Future work should also include development of methods to incorporate new recovery actions attributable to habitat restoration and other recovery activities into models that can contribute information to updating these BDCP Interim Juvenile Salmonid Survival Objectives. One particularly important near-term step to implementing the BDCP Juvenile Salmonid Survival Objectives will be developing regional agreements on geographic boundaries for estimating through-Delta survivals, and appropriate technologies for collecting the required empirical data.

Finally, it is imperative that all of the stakeholders with an interest in the Delta, whether it is viewed primarily as a source of water or as an ecosystem supporting threatened and endangered species (or both), continue to work collaboratively to establish a monitoring program to improve the accuracy and precision of through-Delta survival estimates and monitor progress toward achieving these Interim Survival Objectives. This will require, at a minimum, establishing a more expansive network of acoustic arrays for monitoring Delta entry and exit and identifying survival bottlenecks, and deployment of more efficient trapping systems to better understand the numbers and timing of naturally migrating juvenile salmonids.

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Table 2. Life History Summaries Highlighting Timing and Duration of Delta Residence, and Fish Size During Delta Passage. Information compiled from Vogel and Marine (1991), Fisher (1994) and Williams (2006).

Population/ Species	Spawning	Average Fecundity	River Rearing and Juvenile Migration	Delta Residence and Duration	Size in Delta (mm FL)	Ocean Residence	Adult Migration
Winter-run Chinook	May through August	5,232	July through March	November through April	60-130mm	2 to 3 years 91% return at age-3	January through May
Spring-run Chinook	August through October	5,300	November through April	Fry: Dec–Feb Smolts: Mar–May	Dec–Feb: 36–79mm Mar–May: 68–132mm	3 years 74% return as age-4 to Butte Creek	March through August
Fall-run Chinook	October through December	4,497	January through June	December through March	35–90mm	2 to 5 years Most return at age-3	July through December
Late fall-run Chinook	January to March	4,600	April thru December	Smolts: Oct–Feb Fry: April–May	Oct–Feb: 80–191mm April–May: 31–38mm	2 to 4 years 57% return at age-3; 41% return at age-4	November through March
Steelhead	Jan through April	5,000	Rear entire year in rivers. Emigrate in Jan–June (peak is Feb–April)	(Days to weeks) No good evidence that they rear in the Delta	150–350mm (most 200–300mm)	1–3 ocean years at maiden spawning	Spawners: Sept–April Kelts: Jan–May

Table 3. Pre-Delta, Delta, and Post-Delta Survival Estimates use to Estimate Initial Cohort Replacement Rates

Watershed	Species	ESU/DPS/population	Pre-Delta	Delta	Post-Delta
Sacramento River and Tributaries	Chinook salmon	Winter-run	0.0365	0.40	0.0226
		Spring-run	0.0432	0.40	0.0198
		Fall-run	0.056	0.35	0.0198
		Late fall-run	0.0367	0.40	0.0245
	Steelhead	Sacramento	0.0214	0.45	0.0360
San Joaquin River and Tributaries	Chinook salmon	Fall-run	0.0564	0.05	0.0226
	Chinook salmon	Spring-run	0.0432	0.07	0.0198
	Steelhead	San Joaquin	0.0257	0.10	0.0360

Table 4. Projected Change in Abundance of CV Salmonids under the 1.2, 1.3, and 1.4 CRR Targets after 19, 28, 40, and 50 years (1.3, 1.4, and 1.5 for Winter-Run Chinook Salmon), and their Relation to the BDCP Global Goals. The global goal for fall-run Chinook salmon is 750,000 total for Central Valley.

Species	Time (yrs)	Conveyance	No. Generations	CRR	Delta Survival	Initial Size	Ending Size	Global Goal (naturally spawned)
Sac winter-run	1–10	single	3.3	0.86	0.40	1,153	556	
Sac winter-run	11–19	dual	3.0	1.08	-	709	895	
Sac winter-run	20–28	dual	3.0	1.30	0.63	895	1,953	
Sac winter-run	29–40	dual	4.0	1.40	0.68	1,953	7,413	
Sac winter-run	41–50	dual	3.3	1.50	0.73	7,413	28,795	23,800 by 2060
Sac spring-run	1–10	single	3.3	0.91	0.40	7,422	5,363	
Sac spring-run	10–19	dual	3.0	1.05	-	5,363	6,274	
Sac spring-run	20–28	dual	3.0	1.20	0.59	6,274	10,845	
Sac spring-run	29–40	dual	4.0	1.30	0.64	10,845	30,794	
Sac spring-run	41–50	dual	3.3	1.40	0.68	30,794	93,651	59,000 by 2060
Sac fall-run	1–10	single	3.3	0.88	0.35	100,291	65,430	
Sac fall-run	10–19	dual	3.0	1.04	-	65,430	73,775	
Sac fall-run	20–28	dual	3.0	1.20	0.48	73,775	128,091	
Sac fall-run	29–40	dual	4.0	1.30	0.52	128,091	363,269	
Sac fall-run	41–50	dual	3.3	1.40	0.56	363,269	1,121,028	562,500 by 2060
Sac late fall-run	1–10	single	3.3	0.85	0.40	11,000	6,348	
Sac late fall-run	10–19	dual	3.0	1.00	-	6,348	6.820	
Sac late fall-run	20–28	dual	3.0	1.20	0.57	6,820	11.798	
Sac late fall-run	29–40	dual	4.0	1.30	0.62	11,798	33,821	
Sac late fall-run	41–50	dual	3.3	1.40	0.67	33,821	104,295	68,000 by 2060
Sac Steelhead	1–10	single	3.3	0.87	0.45	7,600	4,699	
Sac Steelhead	10–19	dual	3.0	1.00	-	4,699	5,202	
Sac Steelhead	20–28	dual	3.0	1.20	0.63	5,202	9,064	
Sac Steelhead	29–40	dual	4.0	1.30	0.68	9,064	25,772	

Species	Time (yrs)	Conveyance	No. Generations	CRR	Delta Survival	Initial Size	Ending Size	Global Goal (naturally spawned)
Sac Steelhead	41–50	dual	3.3	1.40	0.73	25,772	79,566	11,000 by 2060
SJ Spring-run	1-10	single	3.3	0.16	0.07	1,000	2	
SJ Spring-run	10–19	dual	3.0	1.00	-	1,000	1,000	
SJ Spring-run	20–28	dual	3.0	1.20	0.59	1,000	1,729	
SJ Spring-run	29–40	dual	4.0	1.30	0.64	1,729	4,940	
SJ Spring-run	41–50	dual	3.3	1.40	0.69	4,940	15,169	30,000 by 2060
SJ Fall-run	1–10	single	3.3	0.13	0.05	5,754	6	
SJ Fall-run	10–19	dual	3.0	1.00	-	5,754	5,754	
SJ Fall-run	20–28	dual	3.0	1.20	0.48	5,754	9,928	
SJ Fall-run	29–40	dual	4.0	1.30	0.52	9,928	28,265	
SJ Fall-run	41–50	dual	3.3	1.40	0.56	28.265	86,710	187,500 by 2060
SJ Steelhead	1–10	single	3.3	0.16	0.07	300	1	
SJ Steelhead	10–19	dual	3.0	1.00	-	300	300	
SJ Steelhead	20–28	dual	3.0	1.20	o.59	300	519	
SJ Steelhead	29–40	dual	4.0	1.30	0.64	519	1,484	
SJ Steelhead	41–50	dual	3.3	1.40	0.69	1,484	4,561	1,700 by 2060

Table 5. Sacramento-San Joaquin through-Delta Salmonid Survival Objectives. For each species, we estimated current through-Delta survival rates, the Delta survival rates needed to meet a CRR of 1.2 and 1.4 (1.3 and 1.5 for winter run), and the interim Delta survival objectives. The interim Delta survival objectives are the current survival rate plus one half of the increase in survival rate required if Delta survival alone was used to achieve the CRR targets.

Species	Population	Estimated Current Through-Delta survival	Delta Survival Rate to Achieve CRR's after 19, 28, and 40 years	Interim Delta Survival Objectives after 19, 28 and 40 years
Chinook salmon	Sac winter-run	0.40	0.63; 0.68; 0.73	0.52; 0.54; 0.57
	Sac spring-run	0.40	0.59; 0.64; 0.68	0.49; 0.52; 0.54
	Sac fall-run	0.35	0.48; 0.52; 0.56	0.42; 0.44; 0.46
	Sac late fall-run	0.40	0.57; 0.62; 0.67	0.49; 0.51; 0.53
	SJ fall-run	0.05	0.48; 0.62; 0.67	0.27; 0.29; 0.31
	SJ spring-run	0.07	0.59; 0.64; 0.69	0.33; 0.35; 0.38
Steelhead	Sacramento	0.45	0.63; 0.68; 0.73	0.54; 0.56; 0.59
	San Joaquin	0.10	0.78; 0.85; 0.91	0.44; 0.47; 0.51

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
Silver Spring, MD 20910

MEMORANDUM FOR: Eileen Sobeck
Assistant Administrator for Fisheries

FROM: Donna S. Wieting Donna S. Wieting
Director, Office of Protected Resources

SUBJECT: Revised Guidance for Treatment of Climate Change in NMFS Endangered Species Act Decisions

I recommend you approve and sign the revised Guidance for Treatment of Climate Change in NMFS Endangered Species Act (ESA) decisions. Upon your signature, the attached document will be sent to the NMFS Leadership Council for implementation and awareness.

You sent guidance to the Leadership Council in December 2015 to assist NMFS ESA managers incorporate climate change information in ESA analysis and decision making. The Office of Protected Resources (OPR) has since revised the guidance in cooperation with the Office of General Counsel to provide greater clarity throughout the document, in particular with respect to standards for identifying the best available science, developing future projections, and applying the principle of institutionalized caution. As new information becomes available and our experience with applying the guidance matures, OPR will continue to update and revise the guidance as needed.

This revised guidance has been discussed at length by science, policy, and legal experts within NMFS. Ultimately, it will help the agency make even better ESA management decisions.

I concur: 6/17/16

I do not concur: ______

Further discussion: ______

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
1315 East-West Highway
Silver Spring, Maryland 20910

THE DIRECTOR

MEMORANDUM FOR: NMFS Leadership Council

FROM: Eileen Sobeck
Assistant Administrator for Fisheries

SUBJECT: Revised Guidance for Treatment of Climate Change in NMFS Endangered Species Act Decisions

This memorandum directs Regional Administrators to implement the attached revised guidance for considering information relating to climate change and associated uncertainty in the context of Endangered Species Act (ESA) decisions made by the National Marine Fisheries Service (NMFS). Regional Administrators should implement this guidance in coordination and consultation with the Office of Protected Resources (OPR).

The guidance has been updated since I sent it to the Leadership Council in December 2015. The revisions provide greater clarity throughout the document, including in particular with respect to standards for identifying the best available science, developing future projections, and applying the principle of institutionalized caution. The guidance is intended for NMFS internal use only.

I am directing OPR to continue to lead the development of further policy analysis and recommendations where called for in the attached guidance. As new climate change information becomes available and our experience with applying the guidance matures, OPR will update and revise the guidance.

THE ASSISTANT ADMINISTRATOR
FOR FISHERIES

The Guidance

Introduction

When the Endangered Species Act (ESA) became law in 1973, climate change was not a widely recognized issue. Since that time climate change has become a key lens through which resource management decisions must be evaluated and addressed. Over the past several years, NMFS staff have been working to develop standard approaches for incorporating climate change related information into agency decisions. The courts have affirmed the importance of considering climate change in determinations and decisions under the ESA, despite the uncertainty that makes predicting specific impacts from climate change challenging.

Resource managers are frequently called upon to make decisions in the face of uncertain information on any number of issues, and NMFS is adept at doing so. A changing climate further complicates the conservation of protected resources, due in large part to the uncertainty of the rate and magnitude of climate-related changes and the response of various organisms to those changes. The question of how much risk is acceptable to listed species is raised in most ESA decisions, even without climate change considerations. Due to the nature and magnitude of the risk added by potential climate change effects and the associated increase in uncertainty due to climate change, it is useful for NMFS to adopt policy guidance to manage this risk consistently and explain the basis for the choices the agency makes.

The ESA requires use of the best available science[1] in reaching particular decisions, but gives deference to the exercise of informed agency discretion where scientific uncertainty exists if the agency provides a well-reasoned explanation that is based on consideration of all relevant factors; takes into account all relevant available information; and explains the relative weight assigned to competing sources of information. While it requires that decisions not be based on mere generalizations or speculation, the best available science standard does not require that information be free from uncertainty. Nor does it require a higher degree of specificity, or fineness of scale in projections, than existing climate studies allow. For example, to support listing a species on the basis of climate change related impacts, we must have information particular to that species to demonstrate that it will be impacted by climate change, such as through a reduction of suitable habitat within its known range. It is not necessary, however, to have projections at a particular geographic scale or to have a complete understanding of the biological reasons for and extent of the species' sensitivity to climate change. The alternative to developing guidance is the current practice of making these decisions on a case-by-case basis, possibly leading to duplicative efforts and inconsistencies across NMFS management units and across different ESA decisions.

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[1] For ESA listing decisions [Section 4(b)(1)(A)] and biological opinions [Section 7(a)(2)], the complete standard is "best scientific and commercial data available" and for critical habitat determinations [Section 4(b)(2)], the "best scientific data available". NMFS is using "best available science" as a shorthand in these instances. The best available science requirement does not apply to all ESA decisions, such as 90-day findings on petitions to list species or to revise a critical habitat designation.

Our experiences with recent ESA listing decisions *(e.g.,* ice seals and corals) have reinforced the importance of agency climate change policy guidance to better support our ESA resource managers in agency analyses and decision-making. NMFS resource managers have identified seven key climate change considerations as those needing immediate attention and guidance - climate change emission scenarios; time periods for projecting anticipated climate change effects; addressing the adequacy of international and national policies and regulations; considerations for critical habitat designations; weighing the beneficial and adverse effects of actions; designing appropriate management action recommendations; and requirements in permitting and project designs.

NMFS has developed the attached guidance to address these needs. This document is supported by the analysis conducted by the NMFS Endangered Species Act and Climate Working Group Policy Subgroup and provides guidance for managers with respect to the seven key climate change issues described above. This guidance will reduce confusion and duplication of effort, support greater consistency, efficiency, and effectiveness, and ultimately help the agency make better and more defensible ESA management decisions. As new information becomes available, NMFS will revisit and consider adjusting this guidance as needed.

Seven Policy Considerations

1. Consideration of future climate condition uncertainty

For ESA decisions involving species influenced by climate change, NMFS will use climate indicator values projected under the Intergovernmental Panel on Climate Change (IPCC)'s Representative Concentration Pathway 8.5 when data are available. When data specific to that pathway are not available, we will use the best available science that is as consistent as possible with RCP 8.5.

The IPCC' s Fifth Assessment Report (AR5) presents four Representative Concentration Pathways (RCPs) to assess future climate changes, risks, and impacts. The RCPs are used for making projections based on population size, economic activity, lifestyle, energy use, land use patterns, technology, and climate policy. They describe four different 21st century pathways of greenhouse gas (GHG) emissions and atmospheric concentrations, air pollutant emissions, and land use: RCP 2.6, RCP 4.5, RC P6 and RCP 8.5. The four pathways cover a wide spectrum of GHG emission scenarios including significant reduction (RCP 2.6), two different stabilization levels (RCP 4.5 and RCP 6), and a continued increase (RCP 8.5). Of these, RCP 8.5 assumes that the fewest mitigation measures will be put into place. The IPCC did not identify any scenario as being more likely to occur than any other. However, as with any technical issue regarding resource management that involves uncertainties, we must choose a reasonable management approach that takes into account current knowledge and allows for revisiting the approach as new information emerges. In cases of significant uncertainty, it is appropriate to assume conditions similar to the *status quo* until new information suggests a change is appropriate. Therefore, as a practical way forward, and consistent with the approach taken for the 2014 coral listing analysis and decision, we will evaluate conditions as projected under RCP

8.5 when data are available to allow such evaluation. When data specific to that pathway are not available, we will use information that is most consistent with the underlying direction of that pathway (*i.e.*, assuming a lower rather than higher level of effective mitigation efforts). Likewise, we assumed conditions similar to the *status quo* in our 2008-2012 listing analyses and decisions for ribbon, spotted, ringed, and bearded seals (although those analyses predated IPCC's development of the scenarios discussed in AR5).

2. Selecting a climate change projection timeframe

A. **When predicting the future status of species in decisions under ESA Sections 4, 7, and 10, NMFS will project climate change effects for the longest time period over which we can reasonably foresee the effects of climate change on the species' status.**

B. **When evaluating effects of the action in Sections 7 and 10 decisions, NMFS will use the time period corresponding to the duration of direct and indirect effects of the action.**

Current climate change information indicates that both uncertainty of climate projections and the degree of risk to many species from climate change increase over time. NMFS does not need to know with precision the magnitude of change over the relevant time period if the best available information allows NMFS to reasonably project the directionality of climate change and overall extent of effects to the species or its habitat. For decisions after the initial listing decision, NMFS is mindful to apply the principle of institutionalized caution which originates in legislative history of Section 7; however, it would be inappropriate to apply that principle, or the related concept of "benefit of the doubt," in the context of making a listing determination, because a species must first be determined to qualify for listing on the basis of the best available scientific and commercial information before the protections of the Act may be applied.

When dealing with Section 4 decisions *(e.g.,* listing and recovery), NMFS's policy guidance is to project effects over the longest possible period for which credible projections are available[2] in order to ensure the best available science is fully considered. For Sections 7 and 10 decisions, NMFS's policy guidance is to project climate effects over the timeframe of the action's direct and indirect effects. It will usually be the case that consideration is not limited to only the duration of the specified activity, but also to its continuing effects for the foreseeable future. For example, where a construction activity is the subject of consultation, we must consider not only the effects caused from the construction itself, but also the effects of the resulting structure once completed. Similarly, in the case of consultations on permits or other authorizations that are likely to be renewed, it can be appropriate to analyze the project over some period of time beyond the initial authorization period to the fullest extent possible (based on the information available and the ability to predict impacts with an acceptable degree of accuracy).

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[2] NMFS has used periods as long as 100 years for particular determinations. However, the appropriate time period will vary based on a particular species and threat.

3. Evaluating the adequacy of existing regulatory mechanisms to reduce greenhouse gas emissions

When addressing the adequacy of existing regulatory mechanisms in status reviews, listing decisions, and recovery plan analyses, NMFS will cite to or draw from previous NMFS findings, updated as appropriate in light of developments in this area, to describe the adequacy of existing global and national climate change regulatory mechanisms.

The "adequacy of existing regulatory mechanisms" is a factor for consideration in evaluating a species' status under section 4(a)(1)(D) of the ESA. The scientific consensus is that the main cause of climate change is GHG emissions. Reducing GHG emissions would require national and global efforts; therefore any consideration of the adequacy of existing regulatory mechanisms for species impacted by climate change must include consideration of the effectiveness of national and international regulatory mechanisms. NMFS is required to consider only existing mechanisms and whether those mechanisms are sufficient to counter the threat; we should not speculate about what kinds of regulation may be implemented in the future. Further, because information on developments in the area of national and international efforts to address climate change will not vary across NMFS regions or as relevant to specific NMFS decisions, it would not be efficient or informative to develop new analyses for each decision. Where the agency has already completed a thorough analysis that was based on a review of the then-current literature on climate change and has not been overtaken by significant new information, it is reasonable and efficient to cite to or draw from the existing analysis, updating it as appropriate. The 2014 corals listing decision, for example, reflects a thorough synthesis of the literature available through 2014. NMFS will consider revising this guidance as developments occur in this area.

4. Critical habitat designation in a changing climate

When designating critical habitat, NMFS will consider proactive designation of unoccupied habitat when there is adequate data to support a reasonable inference that the habitat is essential for the conservation of the species because of the function(s) it is likely to serve as climate changes.

Climate change is likely to modify habitats in ways that may make some previously occupied habitat unsuitable and some unoccupied habitat suitable. The ESA provides that unoccupied areas can be designated as critical habitat if such areas are essential for the conservation of the species. Information in the administrative record documenting likely impacts from climate change may support a determination that, for a particular species, unoccupied habitat is essential for its conservation. Areas outside the geographic area occupied by the species could become substantially more valuable for species conservation in the face of habitat changes and/or species movement prompted by climate change. As noted in the recent amendments to the joint regulations governing designation of critical habitat, climate change has made it more important to be proactive in designating unoccupied habitat as critical in appropriate cases. *See* 81 FR 7414 (Feb. 11, 2016).

5. Consideration of future beneficial effects

When NMFS is confident of the relative magnitude of both beneficial and adverse effects, the agency will treat them like any other effects; and when less confident of the relative magnitude of effects, it will give more weight to the negative effects to account for the consequences to the species of making a detrimental decision.

For certain species, climate change may result in some potentially beneficial effects such as, for example, new suitable habitat being created in northern, deeper, or higher elevation areas. Listing decisions, recovery plans, interagency consultations and other ESA decisions all must evaluate potentially beneficial or offsetting effects of climate change as part of the decision-making process. When the best available information is fairly certain as to the relative magnitude of beneficial to adverse effects, NMFS will treat them as either predominantly beneficial or adverse in accordance with that information; when uncertain of the relative magnitude of effects, more weight will be given to the detrimental effects in decisions made after the initial listing determination. This is consistent with the principle of institutionalized caution, discussed above.

6. Responsiveness and effectiveness of management actions in a changing climate

Where appropriate, NMFS section 7 consultations and section 10 permits covering a long time period during which climate change is likely to exacerbate the adverse effects of an action, should incorporate an adaptive management approach that includes:

- **adequate monitoring of climate and biological variables;**
- **identification of appropriate triggers related to those variables; and**
- **identification of protective measures that can be implemented without reinitiating when triggers are reached or, alternatively, identification of triggers that inform the decision to reinitiate.**

We are most certain of our treatment of climate change and the efficacy of responsive conservation actions in the near term. However, ESA decisions often require NMFS to make determinations regarding actions of long durations. Adaptive management approaches should be implemented, where appropriate, to allow NMFS to better respond to climate change effects over time. The agency will develop further guidance for each ESA action type to address the added uncertainty that climate change brings to those actions and whether and how adaptive management can be an effective tool to address these uncertainties over time.

7. Incorporating climate change into project designs

NMFS will review its internal guidance and structural design criteria *(e.g.,* West Coast Region Anadromous Salmonid Passage Facility Design Criteria) to ensure that the criteria are adequate for ESA-listed species in light of anticipated future climate conditions.

NMFS will analyze how effects on listed species from project designs may change over the life of the project, considering reasonably foreseeable climate change effects. NMFS will consider how climate change can affect the degree to which projects NMFS evaluates under

its statutory authorities may accommodate future as well as current needs of ESA-listed species. When structural criteria applied by other agencies are not sufficient, NMFS will engage with those agencies to attempt to find solutions.

Commonly in the context of section 7 consultations, NMFS must evaluate the effects of projects for which the action agency's proposed construction design has been based on historical environmental conditions. Projects constructed according to designs that do not anticipate future climate conditions may fail, causing adverse effects to listed species. Designs for structures as simple as a dock or as complex as a fish passage facility or a levee system may vary significantly and can have important consequences for species conservation. In evaluating the soundness of design criteria, NMFS will consider whether the project, once constructed, is likely to continue to serve its purposes relative to the conservation of listed species in light of changing climatic conditions into the foreseeable future.

Communication among NMFS regions and with action agencies on project design, as with many other issues relating to ESA implementation, can lead to adoption of more effective designs for numerous structures that present challenges in light of the likely effects of climate change. As a relatively new factor to consider in project design for species conservation, climate change provides an impetus for more efficient communication within NMFS and with action agencies. NMFS will place a high priority on collaboration regarding project design in the face of climate change.

Foundational Work

In 2008 NOAA conducted two workshops that focused on 1) climate and NOAA's living marine resource management requirements; and 2) strengthening NOAA's capacity to address marine and coastal impacts of climate change. A 2008 Technical Memorandum [3] was published that describes approaches to incorporating climate change into NOAA's stewardship responsibilities for living marine resources and coastal ecosystems. The Technical Memo called for the establishment of an ESA working group to develop standard operating procedures for incorporating climate impacts in NOAA's mandated management processes, specifically ESA actions.

The NMFS Endangered Species Act and Climate Working Group was established in 2010 as a result of the Technical Memo recommendation and was led by NOAA's Office of Science and Technology. Members included Headquarters and regional office representatives of Protected Resources, General Counsel and Habitat Conservation. The purpose of the group was to develop best scientific and technical practices for incorporating climate change into ESA decisions. The group found that in some cases legal and policy questions needed to be answered first if technical practices were to be used most effectively in management decisions. Until now, NMFS has had a variety of formal and less formal guidance documents to inform ESA implementation but none expressly to address climate change in ESA implementation.

The ESA's directive to use the best available science in certain decisions was the foundation of both the technical and policy approaches developed by the Climate Working Group and the Policy Subgroup. The group conducted case studies and evaluated current practices for integrating impacts of climate change science into ESA decisions, publishing their results in a special section of the journal *Conservation Biology*[4]. The case studies fell into three categories of ESA-related conservation planning: (1) long-term risk assessment *(e.g.,* decisions to list or delist species or designate critical habitat); (2) long-term planning and prioritization *(e.g.,* recovery planning and conservation strategies); and (3) shorter-term projections and evaluation of immediate impacts *(e.g.,* action-specific evaluations).

Based on results of their studies, the Working Group identified a significant need for policy approaches to guide the use of scientific and technical information in cases where scientific uncertainty exists. Based on this recognition, the Working Group developed a paper "Legal and Policy Issues and Proposed Actions Regarding Climate Change and ESA Determinations" (April 2014) to identify specific questions to be answered by policy guidance to support agency resource managers make choices among potentially conflicting sources of information and data.

The Working Group paper identifies seven key climate change policy questions that have been identified by NMFS ESA managers that, if left unaddressed, will limit our ability to manage risk consistently and explain our decisions effectively. The paper recommends policy responses or further action needed to narrow the policy choice for these seven questions.

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[3] Griffis, R. B., R. L. Feldman, N. K. Beller-Simms, K. E. Osgood, and N. Cyr (editors). 2008. Incorporating Climate Change into NOAA's Stewardship Responsibilities for Living Marine Resources and Coastal Ecosystems: A Strategy for Progress. U.S. Dep. Commerce, NOAA Tech. Memo. NMFS-F/SPO-95, 89 p.

[4] Conservation Biology. 2013. 27(6):1137-1233.

The NMFS Protected Resources Board reviewed the Working Group's paper and advised that the recommendations should be further developed and eventually become agency guidance. Based on the Working Group's questions, this guidance specifically addresses seven key policy considerations that are fundamental to addressing listing decisions, critical habitat determinations, recovery planning, Section 7 consultation, and other ESA decision-making.

Agency	Programs, Projects, and Policies	Comments
State Water Resources Control Board	Update to Bay-Delta Water Quality Control Plan: Phase IV	Evaluating and potentially establishing water quality criteria and flow objectives that protect beneficial uses on tributaries to the Sacramento River. Approximate date of completion is 2018.
U.S. Bureau of Reclamation, U.S. Fish and Wildlife Service, National Marine Fisheries Service, Department of Water Resources and Department of Fish and Wildlife	Interagency Drought Contingency Strategy	Specific to 2015, but reasonably forseeable to occur in similar form in future extreme drought years. Includes the Drought Contingency Plan (see below), as well as other drought-related measures.
U.S. Bureau of Reclamation, Department of Water Resources, and State Water Resources Control Board	Drought Contingency Plan	Specific to 2015, but reasonably forseeable to occur in similar form in future years.
West Sacramento Area Flood Control Agency	Southport Sacramento River Early Implementation Project	The project implements flood risk–reduction measures along the Sacramento River South Levee in West Sacramento. The project brings the levee up to Federal and state flood protection standards, and provides substantial ecosystem restoration (floodplain habitat) and public recreation benefits. Final EIR/EIS completed in 2014/2015, 90% design completed in 2014.
US Bureau of Reclamation and Department of Water Resources	Yolo Bypass Salmonid Habitat Restoration and Fish Passage Implementation Plan	Plan submitted to NMFS in October 2012; ongoing environmental compliance and implementation process as required by the NMFS 2009 BiOp.
San Joaquin County and California Department of Transportation	Woodward Island Bridge Project (Ferry Ramp Replacement) over Middle River	Currently undergoing ESA-related agency consultation.
US Bureau of Reclamation	Shasta Lake Water Resources Investigation	Draft EIS published 2013. Alternatives include dam modifications (e.g., raising) and ecosystem restoration (e.g., spawning gravel placement).
Delta Stewardship Council	Delta Plan	Became effective with legally-enforceable regulations on September 1, 2013.
U.S. Army Corps of Engineers, San Francisco District/Port of Stockton	San Francisco Bay to Port of Stockton Deepening Project	The Corps is assessing the feasibility of deepening the existing 35-foot channel from the San Francisco Bay to the Port of Stockton to realize significant transportation cost savings. The Program Phase One would deepen the western reach only, with the eastern reach deepened in a second phase. Program and project under development. Preliminary documentation to support a draft EIS/EIR is in process.

Agency	Program/ Project	Status	Description of Program/ Project	Effects on Fish
State Water Resources Control Board	Update to Bay-Delta Water Quality Control Plan: Phase IV	Planning	Evaluating and potentially establishing water quality criteria and flow objectives that protect beneficial uses on tributaries to the Sacramento River.	Analysis not yet completed. Approximate date of completion is 2018.
U.S. Bureau of Reclamation, Department of Water Resources, and State Water Resources Control Board	Drought Contingency Plan (includes Emergency Drought Barriers project)	Completed for 2015; reasonably forseeable to occur in future years with drought.	Modification of Bay-Delta Water Quality Objectives (e.g., Delta outflow and electrical conductivity requirements) and requirements from 2008/2009 SWP/CVP BiOps to balance supplying human needs, repelling saltwater in the Delta, and providing for cold water needs of Chinook salmon.	Modifications to Delta Cross Channel operations and installation of Emergency Drought Barriers would increase potential for downstream migrating fish to enter the interior Delta (lowering survival). Modification of channel flow requirements (e.g., for San Joaquin River at Vernalis) may reduce survival based on increased travel time/distance. Temporary modification of OMR flow criteria (e.g., < -5,000 cfs) may increase entrainment susceptibility, although intensive monitoring would be done to limit such changes to periods with lower risk. Reduced Delta outflow may reduce delta smelt abiotic habitat and increase potential for negative effects from flow-related stressors (e.g., *Microcystis*).
California Department of Water Resources	North Bay Aqueduct Alternate Intake Project	Notice of Preparation completed in 2009.	A new alternate intake structure and pump station to draw water from the Sacramento River with state-of-the-art, positive barrier fish screens; a new pipeline segment to convey the water from the alternate intake to a point of connection with the existing NBA near the North Bay Regional Water Treatment Plan. Operations of the NBA (although not at the Alternative Intake site) are included the modeling of the action alternatives; Alternative 4A does not include operations of the NBA as a covered activity.	As noted for all alternatives except Alternatives 4A, 2D, and 5A (which do not include operations of the NBA Alternate Intake Project), creation of a new point of diversion on the Sacramento River for the NBA would reduce entrainment of fish less than 25 mm occurring in the Cache Slough subregion.

11D.4 Alternative 4

11D.4.1 Sacramento River at Keswick

Table 1. Mean Monthly Water Temperatures (°F) for Alternative 4 Model Scenarios in the Sacramento River at Keswick, Year-Round

Alternative 4: Sacramento River at Keswick						
Month	WYT	EXISTING CONDITIONS	NAA	H1	H3	H4
JAN	W	46	47	47	47	47
	AN	46	48	48	48	48
	BN	47	48	48	48	48
	D	47	48	48	48	48
	C	47	48	48	48	48
	All	46	48	48	48	48
FEB	W	45	47	47	47	47
	AN	46	47	47	47	47
	BN	46	47	47	47	47
	D	46	48	48	48	48
	C	46	48	48	48	48
	All	46	47	47	47	47
MAR	W	46	47	48	47	47
	AN	46	48	48	48	48
	BN	47	48	48	48	48
	D	47	49	49	49	49
	C	48	50	50	49	50
	All	47	48	48	48	48
APR	W	47	49	49	49	49
	AN	48	50	50	50	50
	BN	48	50	50	50	50
	D	48	50	50	50	50
	C	49	51	51	51	51
	All	48	50	50	50	50
MAY	W	49	50	50	50	50
	AN	49	51	51	50	51
	BN	49	51	51	51	51
	D	49	51	51	51	51
	C	51	53	53	53	53
	All	49	51	51	51	51
JUN	W	50	51	51	51	51
	AN	50	51	51	51	51
	BN	50	51	51	51	51
	D	50	52	52	52	52
	C	53	55	55	55	55
	All	50	52	52	52	52

Alternative 4: Sacramento River at Keswick						
Month	**WYT**	**EXISTING CONDITIONS**	**NAA**	**H1**	**H3**	**H4**
JUL	W	51	52	52	52	52
	AN	51	52	52	52	52
	BN	51	52	53	52	52
	D	51	54	54	54	54
	C	54	59	59	59	58
	All	51	53	54	54	53
AUG	W	52	54	54	54	54
	AN	52	54	55	55	54
	BN	52	54	55	55	54
	D	53	56	56	56	55
	C	57	64	64	64	63
	All	53	56	56	56	56
SEP	W	53	55	56	55	55
	AN	54	56	57	56	56
	BN	54	56	57	57	57
	D	55	59	59	59	59
	C	60	66	66	66	66
	All	55	58	58	58	58
OCT	W	54	57	56	57	57
	AN	54	57	56	57	57
	BN	54	57	57	58	57
	D	55	58	58	59	59
	C	56	60	60	60	60
	All	54	58	57	58	58
NOV	W	53	55	55	55	55
	AN	52	55	54	55	55
	BN	53	55	55	55	55
	D	53	56	55	56	56
	C	54	56	56	56	56
	All	53	55	55	55	55
DEC	W	49	50	50	50	50
	AN	49	51	51	51	51
	BN	50	52	52	52	52
	D	50	52	52	52	52
	C	51	52	52	52	52
	All	50	51	51	51	51

11D.4 Alternative 4

11D.4.1 Sacramento River at Keswick

Table 1. Mean Monthly Water Temperatures (°F) for Alternative 4 Model Scenarios in the Sacramento River at Keswick, Year-Round

Alternative 4: Sacramento River at Keswick						
Month	**WYT**	**EXISTING CONDITIONS**	**NAA**	**H1**	**H3**	**H4**
JAN	W	46	47	47	47	47
	AN	46	48	48	48	48
	BN	47	48	48	48	48
	D	47	48	48	48	48
	C	47	48	48	48	48
	All	46	48	48	48	48
FEB	W	45	47	47	47	47
	AN	46	47	47	47	47
	BN	46	47	47	47	47
	D	46	48	48	48	48
	C	46	48	48	48	48
	All	46	47	47	47	47
MAR	W	46	47	48	47	47
	AN	46	48	48	48	48
	BN	47	48	48	48	48
	D	47	49	49	49	49
	C	48	50	50	49	50
	All	47	48	48	48	48
APR	W	47	49	49	49	49
	AN	48	50	50	50	50
	BN	48	50	50	50	50
	D	48	50	50	50	50
	C	49	51	51	51	51
	All	48	50	50	50	50
MAY	W	49	50	50	50	50
	AN	49	51	51	50	51
	BN	49	51	51	51	51
	D	49	51	51	51	51
	C	51	53	53	53	53
	All	49	51	51	51	51
JUN	W	50	51	51	51	51
	AN	50	51	51	51	51
	BN	50	51	51	51	51
	D	50	52	52	52	52
	C	53	55	55	55	55
	All	50	52	52	52	52

Alternative 4: Sacramento River at Keswick						
Month	**WYT**	**EXISTING CONDITIONS**	**NAA**	**H1**	**H3**	**H4**
JUL	W	51	52	52	52	52
	AN	51	52	52	52	52
	BN	51	52	53	52	52
	D	51	54	54	54	54
	C	54	59	59	59	58
	All	51	53	54	54	53
AUG	W	52	54	54	54	54
	AN	52	54	55	55	54
	BN	52	54	55	55	54
	D	53	56	56	56	55
	C	57	64	64	64	63
	All	53	56	56	56	56
SEP	W	53	55	56	55	55
	AN	54	56	57	56	56
	BN	54	56	57	57	57
	D	55	59	59	59	59
	C	60	66	66	66	66
	All	55	58	58	58	58
OCT	W	54	57	56	57	57
	AN	54	57	56	57	57
	BN	54	57	57	58	57
	D	55	58	58	59	59
	C	56	60	60	60	60
	All	54	58	57	58	58
NOV	W	53	55	55	55	55
	AN	52	55	54	55	55
	BN	53	55	55	55	55
	D	53	56	55	56	56
	C	54	56	56	56	56
	All	53	55	55	55	55
DEC	W	49	50	50	50	50
	AN	49	51	51	51	51
	BN	50	52	52	52	52
	D	50	52	52	52	52
	C	51	52	52	52	52
	All	50	51	51	51	51

11D.4.2 Sacramento River at Jelly's Ferry

Table 1. Mean Monthly Water Temperatures (°F) for Alternative 4 Model Scenarios in the Sacramento River at Jelly's Ferry, Year-Round

Alternative 4: Sacramento River at Jelly's Ferry						
Month	**WYT**	**EXISTING CONDITIONS**	**NAA**	**H1**	**H3**	**H4**
JAN	W	45	47	47	47	47
	AN	45	47	47	47	47
	BN	45	46	47	46	47
	D	45	47	47	47	47
	C	45	47	47	47	47
	AVG	45	47	47	47	47
FEB	W	46	47	47	47	47
	AN	46	48	48	48	48
	BN	46	48	48	47	48
	D	46	48	48	48	48
	C	47	49	49	49	49
	AVG	46	48	48	48	48
MAR	W	48	49	50	49	49
	AN	49	51	51	51	51
	BN	49	51	51	51	51
	D	50	51	51	51	51
	C	50	52	52	52	52
	AVG	49	51	51	51	51
APR	W	51	53	53	53	53
	AN	53	55	55	55	55
	BN	53	54	54	54	54
	D	52	54	54	54	54
	C	52	54	54	54	54
	AVG	52	54	54	54	54
MAY	W	54	57	57	57	57
	AN	55	57	56	56	56
	BN	54	57	56	56	57
	D	54	56	55	55	56
	C	55	57	57	57	57
	AVG	54	57	56	56	56
JUN	W	55	56	56	56	56
	AN	55	56	55	55	56
	BN	54	56	55	56	56
	D	54	56	56	56	56
	C	56	58	58	58	58
	AVG	55	56	56	56	56
JUL	W	56	57	57	57	57
	AN	55	56	56	56	56
	BN	55	56	57	57	56
	D	55	57	58	58	58
	C	57	62	62	62	61
	AVG	55	57	58	58	57

Alternative 4: Sacramento River at Jelly's Ferry						
Month	**WYT**	**EXISTING CONDITIONS**	**NAA**	**H1**	**H3**	**H4**
AUG	W	56	59	59	59	58
	AN	56	58	59	59	58
	BN	56	58	59	59	58
	D	56	59	60	60	59
	C	59	67	66	67	66
	AVG	57	60	60	60	60
SEP	W	56	57	59	58	57
	AN	57	59	60	59	59
	BN	57	60	60	61	60
	D	58	63	62	62	62
	C	61	67	67	67	66
	AVG	58	61	61	61	60
OCT	W	54	57	57	57	57
	AN	54	57	57	57	57
	BN	55	57	57	58	57
	D	55	58	58	59	58
	C	56	60	59	60	59
	AVG	55	58	58	58	58
NOV	W	51	53	52	53	53
	AN	51	53	53	53	53
	BN	51	54	53	53	53
	D	51	54	53	54	54
	C	52	55	54	54	54
	AVG	51	53	53	53	53
DEC	W	47	48	48	48	48
	AN	47	48	48	48	48
	BN	47	49	49	49	49
	D	47	49	49	49	49
	C	47	49	49	49	49
	AVG	47	48	49	48	48

THE SECRETARY OF THE INTERIOR
WASHINGTON

AUG 30 2016

MEMORANDUM FOR THE PRESIDENT

FROM: SECRETARY SALLY JEWELL Sally Jewell
DEPUTY SECRETARY MICHAEL CONNOR

SUBJECT: Update on California Water Issues

Background

This memorandum will update you on key developments concerning ongoing water operations in California, as well as the development of long-term strategies to improve water supply reliability and environmental protections.

California's State Water Project (SWP) and the Bureau of Reclamation's Central Valley Project (CVP) are among the largest water conveyance systems in the world, delivering about 9-10 million acre-feet of water in non-drought years to farms, cities, and in support of environmental needs throughout the State. Since most precipitation falls in the northern part of the State and most water use is in the southern part, the combined systems must convey vast amounts of water each year through the San Joaquin-Sacramento Delta into Federal and State canals that carry the water to the agricultural Central Valley and metropolitan areas in Southern California. Over time, many factors including water operations have caused a serious decline in the world-renowned Bay-Delta ecosystem and the salmon and other fish populations dependent on it. In recent years, a number of scientists and water managers have concluded that, particularly in view of projected sea level rise and other climate impacts affecting water supplies, the Federal and State water conveyance system through the Delta must be upgraded or modified to ensure reliable water supplies and help restore a healthy Bay-Delta ecosystem.

To meet these twin goals, Governor Brown has proposed constructing a major new infrastructure project consisting of two large-capacity tunnels running from north of the Delta to the Federal and State aqueducts south of the Delta. This project, known as "Cal WaterFix" (CWF), would provide an additional means of pumping water from north to south which would enhance the flexibility and reliability of the SWP and CVP and help restore some of the natural outflow of water through the Bay-Delta. Once permitted, CWF would likely take 10-15 years to construct. Accordingly, there continues to be great attention focused on current water operations and the impact of environmental regulations under the Endangered Species Act (ESA). For that reason, we would expect that there will be continued attempts by members of Congress to legislate in this area, although there does not appear to be much consensus among California's congressional delegation. Senator Feinstein has worked closely with the Department of the Interior (Interior) to develop legislation that would improve water supply while not amending the ESA. The House of Representatives, however, continues to propose legislation that would override existing environmental protections under the ESA.

May – August 2016 Operations of the Central Valley Project

While hydrologic conditions have improved somewhat during the current year, California continues to feel the effects of this historic drought. Consequently, operation of the CVP and SWP this summer has required a highly complex balancing act to preserve the water allocations issued last spring while meeting the legal requirements of National Oceanic and Atmospheric Administration (NOAA) and the Fish and Wildlife Service (FWS) to protect highly endangered Delta smelt and winter-run Chinook salmon. Complicating matters is the continued downward trajectory of the endangered Delta smelt, whose population last year hit a record low level, and is down an additional 90 percent this year. Some experts are opining that the fish may be well on its way to extinction. Endangered winter-run Chinook are in a similarly perilous state since low water levels and excessive temperatures on the Sacramento River in 2014 and 2015 resulted in the loss of over 90 percent of the population both years, underscoring the urgent importance of preserving this year's salmon run.

To maximize salmon protections, NOAA requested Reclamation reduce releases from Shasta Reservoir in the early summer to preserve large amounts of cold water in storage to dedicate for use in maintaining temperatures in the Sacramento River during the late summer. With respect to Delta smelt, FWS asked Reclamation to acquire hundreds of thousands of acre feet of water to release to increase environmental flows through the Delta in the hope of boosting Delta smelt populations. The salmon protective actions have been successfully implemented this summer while the Delta smelt actions were only able to be partially implemented based on the water available for acquisition. Both of these actions put pressure on the water supplies available for agricultural and other purposes resulting in ongoing concerns over constrained water allocations in California's Central Valley.

Reinitiation of Consultation for Long-Term Operations

The rapid decline of the Delta smelt prompted two significant recent actions. First, in early July, after discussion with Interior, the California Natural Resources Agency released the Delta Smelt Resiliency Strategy (Strategy). The purpose of the Strategy is to help sustain Delta smelt populations over the near term through a number of actions which include partnering with Reclamation to provide substantial additional environmental flows in spring/summer of 2017 and 2018, and a collaborative and transparent science process to support improved habitat conditions for the smelt. Second, Reclamation and California's Department of Water Resources requested reinitiation of consultation under the ESA on the effects of water project operations by the CVP and SWP on both Delta smelt and winter run chinook salmon. The reinitiation process will likely lead to new or amended biological opinions that will increase protections for these species. The current schedule calls for completion of this consultation by early spring of 2018, but it is acknowledged that such a schedule is very ambitious. As noted, the Strategy is intended to improve ecological conditions for the fish while the ESA consultation process moves forward and employs the best-available science. The timeframe being contemplated should allow the new Administration time to establish itself before new biological opinions are issued that could lead to further reductions in water availability south of the Delta.

Cal Water Fix

The CWF is a major civil works project (estimated cost of $16 billion) that requires a complex set of analyses in order to proceed under the National Environment Policy Act (NEPA) and the ESA. The Department's goal has been to complete these analyses, which have been underway since 2007, before the end of this Administration. However, a number of complications in the past several months such as the declining status of endangered fish, as well as other Federal and State issues, have combined to make it unlikely that the necessary reviews will be completed during your Administration.

It is likely that the Governor will assert that Interior failed to adequately and timely address concerns over the declining Delta smelt populations, which, in his estimation, is the main reason the schedule for completing Federal review of Cal Water Fix is being extended beyond January 2017. While it is correct that the need to address declining Delta smelt populations have created scheduling complications, there are an additional number of technical, legal, and state regulatory issues that have added to the complications. Requests by the State of California have also had impacts on the schedule. Most notably, the State rejected a proposal by Interior to complete our permitting work by the end of 2016 by simply focusing the analysis on the construction of CWF. Instead, the State has insisted that the analysis include future water operations, which is much more complicated. Overall, the issues need to be addressed in a manner to ensure a credible and legally defensible decision is rendered given the certainty of litigation that will ensue.

Despite these difficulties, as a result of discussions within the last couple of weeks among senior Federal staff and the Governor and his team, it appears there is general agreement on proceeding with a schedule that will conclude the NEPA and ESA processes being carried out by both Interior and NOAA towards the end of March 2017. While the State does not view such a schedule as optimal (i.e., within your Administration), it does allow for completion of the analysis in time to be used by the State to address State law requirements that are also critical to the permitting process.

As a final matter, we would note that high-level State officials have repeatedly represented that the State would disengage from other priority initiatives (e.g., Salton Sea restoration which is closely associated with Colorado River drought planning, as well as the Desert Renewable Energy Conservation Plan) because of their concerns that the Administration is not completing work on CWF in a timely manner. Although the State has recently softened its rhetoric, the message to Governor Brown should he raise these other initiatives is that the Administration and Interior will continue to press forward on all of these important issues and that when California disengages from these other initiatives, they are negatively impacting their own interests. Moreover, your Administration has provided a substantial amount of high-level attention to CWF and has worked closely with the State on a strategy that will support the Governor's goals, even if the timeline is not optimal.

Maria Rea - NOAA Federal

From: Maria Rea - NOAA Federal
Sent: Thursday, December 15, 2016 11:12 AM
To: Katherine Cheney - NOAA Federal; Christina Durham; Jim Milbury; Garwin Yip; Brycen Swart
Subject: Shasta messaging

2017 Amendment: This amendment is based on the following considerations:

1. Operations of Shasta and Keswick reservoirs were the subject of multiple annual reviews. Shasta operations were one of the main focuses in the 2015 annual review.
2. 2014 and 2015, the third and fourth years of drought conditions (*e.g*., dry hydrology, high air temperatures), resulted in extremely challenging operations of Shasta and Keswick reservoirs that resulted in many lessons learned on what to consider in the development and implementation of both the February forecast process and the May temperature management plan process.
3. The main conclusion that NMFS has made is that the Shasta RPA actions are not performing as we thought it would when we wrote the 2009 CVP/SWP operations Opinion. The performance metrics in RPA Action I.2.1 have not been met. Even more important, the level of incidental take in 2014 and 2015 was greater than analyzed or authorized in 2009 when the RPA was developed. Therefore, a reinitiation trigger has been met. In light of this, Reclamation recently requested reinitation of the CVP/SWP operations consultation. NMFS expects that reconsultation will provide a comprehensive analysis of integrated operations.
4. New science and models, for example, the River Assessment for Forecasting Temperature decision support tool and the temperature-dependent mortality model, are available that should be included in the forecasting and temperature management process.
5. Finally, since the 2011 amendment, there have been clarifications and adaptive management changes made that are reflected in this 2017 amendment to update the RPA.

NMFS has amended the RPA to reflect new best available scientific and commercial information and to ensure that take authorizations associated with RPA Action Suite I.2 are still valid, based on lessons learned from water years 2014-2016. The amendment is consistent with the Opinion's underlying analysis and conclusions. Rationale provided for the specific amendments explain the need for the amendments and how they meet the objectives of the specific RPA actions.

This amended RPA supercedes the 2009 RPA with 2011 amendments. Amendments to the Shasta RPA actions will be issued in a phased approach. As mentioned above, the current amendment is needed to reflect new best available scientific and commercial information, and lessons learned from operations during the drought conditions throughout water years 2014-2016. There is also ongoing collaborative science being developed through monitoring work, and refinement of temperature forecasting models, that will inform the implementation and likely success of meeting the biological objectives identified for the RPA actions, that may warrant a subsequent amendment. Finally, these new and refined tools and monitoring will be used to inform the reconsultation of CVP/SWP operations.

Maria Rea
Assistant Regional Administrator, California Central Valley Office
NOAA Fisheries West Coast Region
650 Capitol Mall, Suite 5-100
Sacramento, CA 95814
(916) 930-3600
Maria.Rea@noaa.gov

Find us online
www.westcoast.fisheries.noaa.gov

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NOAA FISHERIES

West Coast Region

Sacramento River
Ecological Flow Thresholds for Salmonids Workshop

Brycen Swart

September 29, 2016

Sacramento River

Shasta Division

Central Valley Project

Regulatory Context

- 2009
  - Biological Opinion on the CVP/SWP Long-term Water Operations (OCAP)
  - Jeopardy Determination
  - Shasta Division RPA actions address storage requirements, temperature compliance, drought contingencies, and re-introduction but not flows
- 2016
  - Shasta Division RPA Adjustment – RPA actions are not avoiding jeopardy
  - CVP/SWP Long-term Operations Re-initiation
- SWRCB – Bay-Delta Water Quality Control Plan

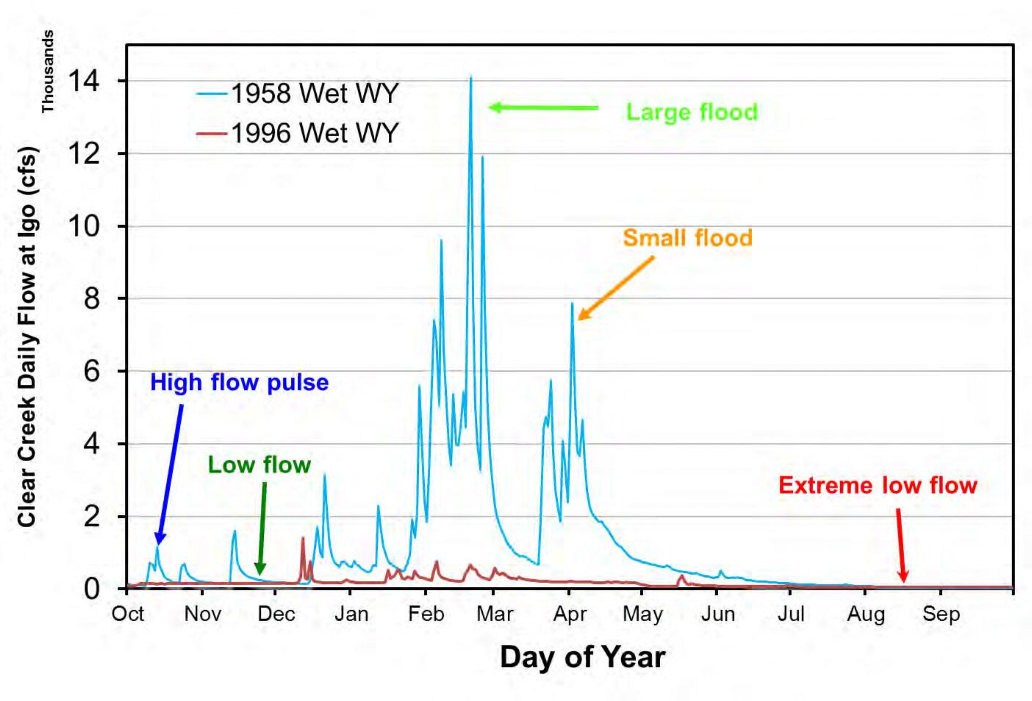
Current Flow Management

Minimum Flow Requirements

Period	Reclamation-CDFW MOA (1960)		Water Rights 90-5 (1990)	NMFS BiOp (1993)
Water Year Type	**Normal**	**Critically Dry**	**Normal**	**All**
January 1–February 28(29)	2,600	2,000	3,250	3,250
March 1–March 31	2,300	2,300	2,300	3,250
April 1–April 30	2,300	2,300	2,300	No Requirement
May 1–August 31	2,300	2,300	2,300	No Requirement
September 1–September 30	3,900	2,800	3,250	No Requirement
October 1–November 30	3,900	2,800	3,250	3,250
December 1–December 31	2,600	2,000	3,250	3,250

Flow Regime Approach

Mimic “natural”, climatically-driven variability of flows from year to year and from season to season



- Magnitude
- Timing
- Duration
- Frequency
- Rate of change

Principles for Flow Regime Approach

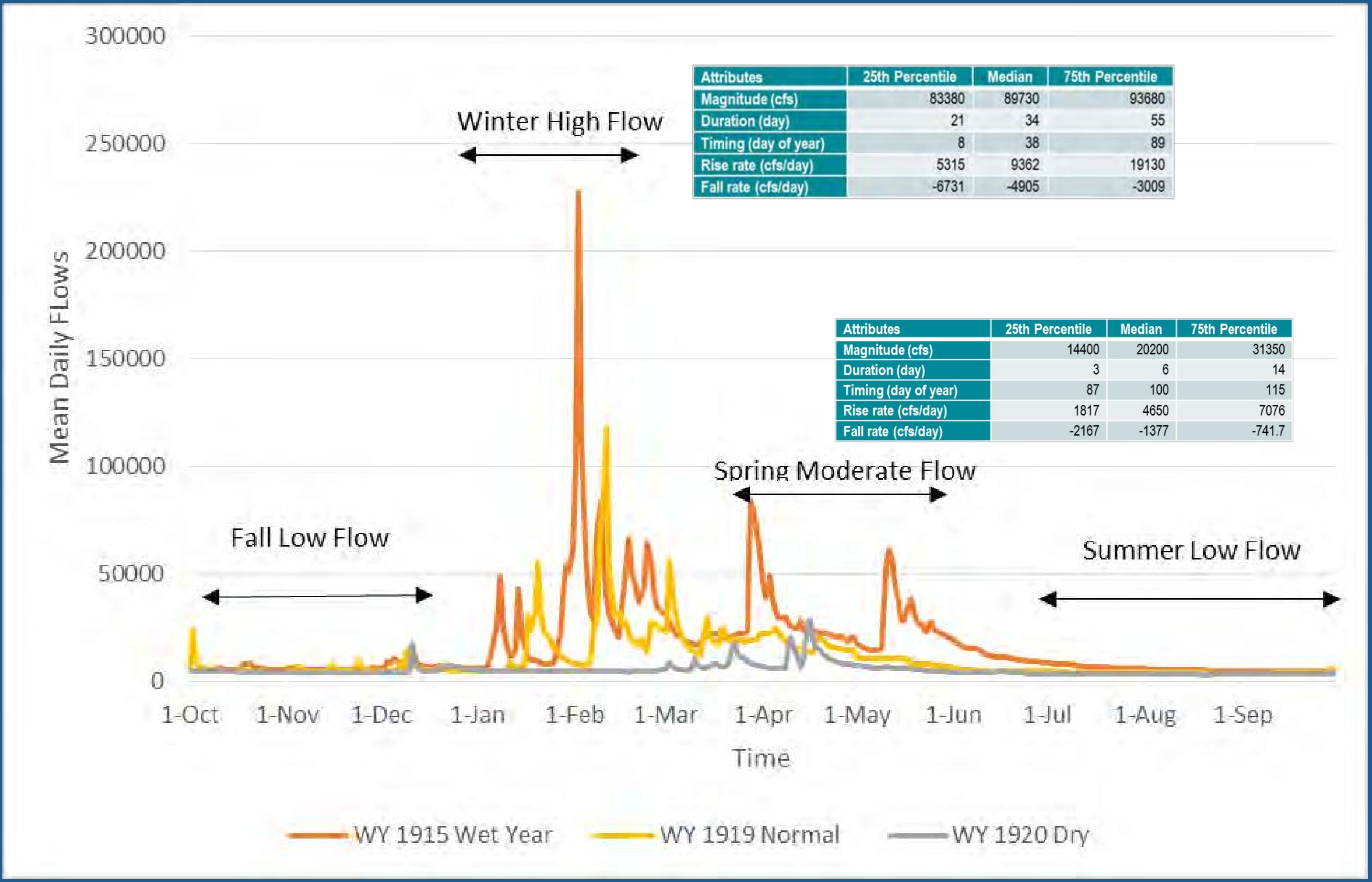
- Flow determines the extent and type of physical habitat, which in turn determines the types of living organisms in that habitat.
- Aquatic species have evolved in such a way as to be well adapted to the natural flow regime to which they have been historically exposed.
- Maintenance of natural patterns of high flows, low flows and flow variation is essential to the viability of native riverine species.
- The alteration of flow regimes contributes to the invasion and success of exotic (non-native) species in rivers.

(Bunn and Arthington, 2002)

Implementing Flow Regime Approach

- Collect flow data and analyze them
- If there is a period of time when flows were measured before major human modifications occurred, that time period is used to set the baseline or natural, unmanaged flow conditions.
- If no such data exists, use other data (e.g., similar unimpacted rivers or unimpaired flow) to establish historic conditions.
- Set recommended flows throughout the year, providing flow recommendations for each hydrologic season (e.g. low flow, snowmelt, rainy season).

Pre-Dam Natural Flow



Attributes	25th Percentile	Median	75th Percentile
Magnitude (cfs)	83380	89730	93680
Duration (day)	21	34	55
Timing (day of year)	8	38	89
Rise rate (cfs/day)	5315	9362	19130
Fall rate (cfs/day)	-6731	-4905	-3009

Attributes	25th Percentile	Median	75th Percentile
Magnitude (cfs)	14400	20200	31350
Duration (day)	3	6	14
Timing (day of year)	87	100	115
Rise rate (cfs/day)	1817	4650	7076
Fall rate (cfs/day)	-2167	-1377	-741.7

Median Monthly Flows

Changes in Flood Flows

Period	1.5-Year Flood	2-Year Flood	5-Year Flood	10-Year Flood
Period 1 (1892-1937)	89730	130000	153000	206000
Period 2 (1946-1959)	54600	85700	97400	125000
Period 3 (1960-1993)	50500	77500	101000	123000
Period 4 (1994-2014)	41400	73200	88800	105000
% Reduction (P1 and P2)	39%	34%	36%	39%
% Reduction (P1 and P3)	44%	40%	34%	40%
% Reduction (P1 and P4)	54%	44%	42%	49%

Changes in Spring Pulse Flows

Attributes	Period 1 (1892-1937)	Period 2 (1946-1959)	Period 3 (1960-1993)	Period 4 (1994-2014)
Magnitude (cfs)	20200	14800		
Duration (day)	6	2		
Timing (day of year)	100	112		
Frequency (per year)	1.5	1	0	0
Rise rate (cfs/day)	4650	2715		
Fall rate (cfs/day)	-1377	-2788		

Environmental Thresholds and Requirements

	Magnitude	Duration	Timing	Frequency	Source
Bed Mobilization	24,000 - 120,000	12 hour peak flow	Between Feb 20 - March 20	3 to 4 years	Cain 2008, DWR 2001, Kondolf 2000, Stillwater 2006
Bank Erosion and Channel Migration	15,000 - 60,000	?	Prior to late March	2 to 4 years	Stillwater 2007, Larsen 2007
Floodplain Inundation and Rearing Habitat Flows	>25,000	30 - 60 days	Feb 15 to April 30	Dry to Wet Water Year Types	Harrell 2008, DWR 2008
Riparian Flows	23,000 - 30,000	72 day recession period	April to May	Above Normal and Wet Years	Roberts 2003, Kondolf 2007, Cain 2008

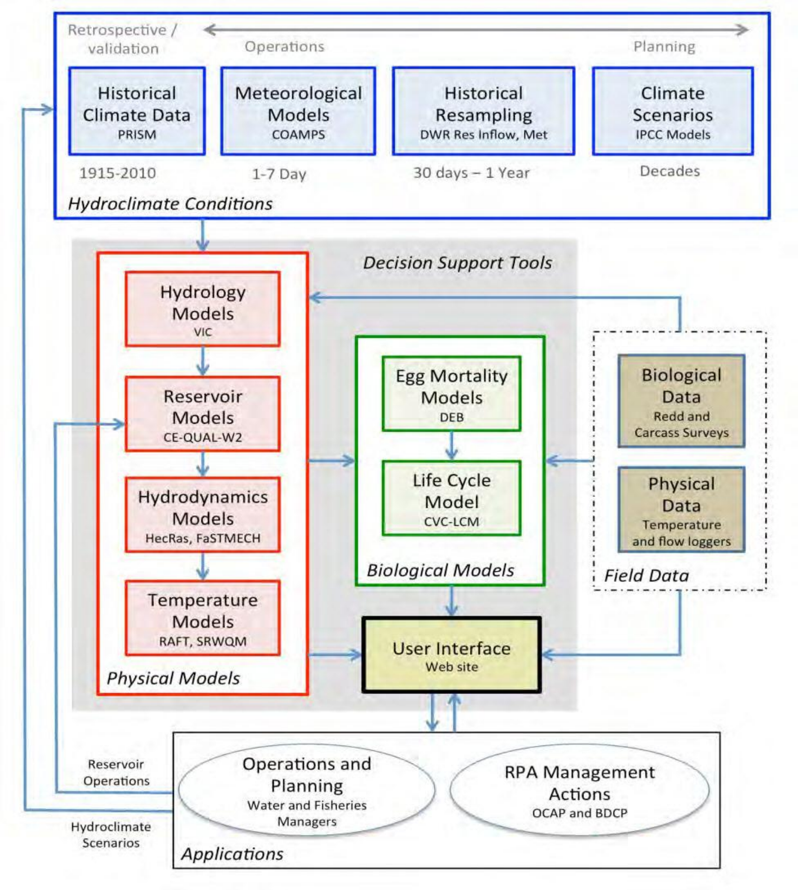
Potential Flow Recommendations

		Water Year Type				
	Timing	**Critical**	**Dry**	**Below Normal**	**Above Normal**	**Wet**
Bed Mobilization	Mid Feb – Mid Mar		35,000	65,000	85,000	105,000
Floodplain Inundation	Feb - Apr (45 days)			25,000	35,000	45,000
Riparian Establishment Flow	Apr				23,000	37,000
Fall Base Flow	Sep - Nov	5,250	5,250	5,250	5,250	5,250
Winter Base Flow	Dec - Feb	4,500	6,000	6,500	7,000	8,000
Spring Base Flow	Mar - May	10,000	12,000	12,500	14,000	14,000
Summer Base Flow	Jun - Aug	8,000	8,000	8,000	8,000	8,000

Next Steps

- Incorporate regression analysis of salmonid abundance with instream flow
- Refine flow recommendations
- CALSIM, SRWQM, and RAFT modeling

Validation



Retrospective / validation

Operations

Planning

Hydroclimate Conditions

Historical Climate Data
PRISM
1915-2010

Meteorological Models
COAMPS
1-7 Day

Historical Resampling
DWR Res Inflow, Met
30 days – 1 Year

Climate Scenarios
IPCC Models
Decades

Decision Support Tools

Physical Models

Hydrology Models
VIC

Reservoir Models
CE-QUAL-W2

Hydrodynamics Models
HecRas, FaSTMECH

Temperature Models
RAFT, SRWQM

Biological Models

Egg Mortality Models
DEB

Life Cycle Model
CVC-LCM

Field Data

Biological Data
Redd and Carcass Surveys

Physical Data
Temperature and flow loggers

User Interface
Web site

Applications

Operations and Planning
Water and Fisheries Managers

RPA Management Actions
OCAP and BDCP

Reservoir Operations

Hydroclimate Scenarios

Thanks! Any Questions?

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
West Coast Region
1201 NE Lloyd Boulevard, Suite 1100
PORTLAND, OREGON 97232-1274

January 19, 2017

Mr. David Murillo
Regional Director
Mid-Pacific Region
U.S. Bureau of Reclamation
2800 Cottage Way, MP-3700
Sacramento, California 95825-1898

RE: Proposed Amendment to the Reasonable and Prudent Alternative of the 2009 Opinion

Dear Mr. Murillo:

On June 4, 2009, NOAA's National Marine Fisheries Service (NMFS) issued a biological and conference opinion (Opinion) on the long-term operations of the Central Valley Project (CVP) and State Water Project (SWP). The NMFS 2009 Opinion concluded that the CVP/SWP operations were likely to jeopardize the continued existence of several federally listed species under NMFS's jurisdiction and destroy or adversely modify designated critical habitat. Consequently, NMFS provided a reasonable and prudent alternative (RPA) that met the criteria of 50 CFR 402.02. On April 7, 2011, NMFS issued a 2011 amendment of the 2009 RPA[1].

On August 2, 2016, the U.S. Bureau of Reclamation (Reclamation) requested using the adaptive management provision in the 2009 Opinion (section 11.2.1.2) related to Shasta Reservoir operations. The basis for this request included recent, multiple years of drought conditions, new science and modeling, and data demonstrating the low population levels of endangered Sacramento River winter-run Chinook salmon and threatened Central Valley spring-run Chinook salmon.

The purpose of this letter is to transmit a proposed amendment to the 2011 amended RPA related to Shasta Reservoir operations (RPA Action Suite I.2). Please consider this proposed amendment as a draft, which we expect to be subject to further discussion and refinement. This proposed amendment was developed in consultation with Reclamation and represents substantial agreement between our two agencies, while recognizing that differing technical views remain in some areas. The proposal is based on the following:

1. This proposed amendment is a necessary step in a science-based adaptive management process.
2. This proposed amendment is part of a phased approach that will inform the CVP-SWP Long-term operations reconsultation.

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[1] http://www.westcoast.fisheries.noaa.gov/publications/Central_Valley/Water_ocap_opinion_2011_amendments.pdf

3. Reclamation agrees to implement a pilot approach for temperature management in summer 2017 as part of the amendment process.
4. Reclamation and NMFS will undertake additional modeling and analyses during 2017 and beyond to support an amended RPA.
5. Reclamation and NMFS will initiate a structured stakeholder engagement process that will inform the amendment process.

Enclosure 1 provides a "track changes" version of the relevant pages of the 2011 RPA, modified to reflect the proposed changes. Enclosure 2 provides a clean version of the proposed revised RPA with the 2017 amendment text. Enclosure 3 provides a draft administrative record memorandum that includes a more detailed description of the scientific basis and rationale for the changes contained in Enclosure 1. Enclosure 4 contains an initial scope of work for proposed model improvements and analyses prepared by NMFS.

1. *This proposed amendment is a necessary step in a science-based adaptive management process.* Science-based adaptive management allows for changes in response to new information. The draft RPA developed by NMFS is based on the following considerations:

    A. Operations of Shasta and Keswick reservoirs. Operations of these reservoirs have been the subject of multiple annual reviews. In particular, Shasta operations were a main focus of the 2015 annual review, and the independent review panel (IRP) recommendations called for supplementation, and ultimate replacement, of the tools (both numerical models and field equipment) currently used to manage temperature releases. The IRP also urged the agencies to continue efforts to connect hydrologic conditions to fish and macroinvertebrate life history requirements and to describe a new set of storage and release scenarios into the future. These recommendations were made to increase reliability (accuracy, resolution, and redundancy) of the data guiding water operations in Shasta Reservoir and the Sacramento River.[2]

    B. Drought Conditions. Water years 2014 and 2015 were the third and fourth consecutive years of drought conditions (*e.g.*, dry hydrology, high air temperatures). These conditions precipitated extremely challenging operations of Shasta and Keswick reservoirs that resulted better understanding on what information to consider in the development and implementation of both the initial forecast process and the May temperature management plan process.

    C. New Science and Temperature Survival Models. Since the 2011 RPA amendment was issued, new models have become available to describe the conditions necessary to provide suitable water temperatures for winter-run Chinook spawning, egg incubation, and fry emergence throughout the temperature management season. Another newly available model evaluates the potential temperature-dependent mortality of winter-run Chinook salmon from any given operational scenario.

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[2] http://deltacouncil.ca.gov/sites/default/files/2015/12/LOBO%20IRP%202015%20Report.pdf

D. Request for Reinitiation. On August 2, 2016, Reclamation requested reinitiation of the entire CVP/SWP operations consultation, citing new information related to multiple years of drought and recent data demonstrating extremely low population levels of endangered Sacramento River winter-run Chinook salmon. In an August 17, 2016, response letter to Reclamation, NMFS agreed to reinitiate consultation. NMFS anticipates that this reinitiation may take several years, and views this amendment as a necessary bridge to that future completed consultation.

E. Increased efficiency and effectiveness. In reviewing the current RPA language, NMFS has determined that there are efficiencies that can be gained by fine-tuning the biological metrics and the process to achieve those metrics. This draft amendment has the potential to increase both biological effectiveness of the RPA and water supply reliability by realizing operational efficiencies.

2. *An amendment is part of a phased approach that will inform the CVP-SWP Long-term operations reconsultation.* This draft amendment is intended for implementation though a phased approach. With Reclamation's commitment to implement the temperature management pilot project in 2017 (with associated analysis and monitoring), NMFS believes that ongoing reconsultation will provide a venue to conduct a comprehensive analysis of integrated system operations, including any additional changes made following stakeholder outreach and input. Evaluating the performance of these new metrics in 2017 will significantly improve our ability to responsibly develop a new biological opinion as we progress through reconsultation.

3. *Reclamation agrees to implement a pilot approach for temperature management in summer 2017 as part of the amendment process.* Our understanding is that Reclamation has agreed to implement a pilot program for Shasta Reservoir temperature management [highlighted in RPA Actions I.2.3(3) and I.2.4] in the proposed amendment in water year 2017. The remainder of the changes in this proposed amendment are subject to further refinement. Our understanding is that Reclamation intends to share the entirety of this proposed 2017 RPA amendment externally. In this vein, we expect the metrics in this proposed 2017 amendment to be the start, not the end, of a conversation about how to refine and optimize management of Shasta resources for temperatures and other needs. We also believe that operating to some of the changes this year, within more favorable hydrologic conditions seen so far in water year 2017, will afford us a needed opportunity to examine how new metrics perform.

4. *Reclamation and NMFS will undertake additional modeling and analyses during 2017 and beyond to support an amended RPA.* NMFS and Reclamation are both committed to developing a Joint Science and Modeling Plan to begin in water year 2017. More specifically, Reclamation has committed to developing an analysis throughout the 2017 water year to evaluate the system-wide impacts of revised temperature management values, locations, and metrics on CVP operations, the environment, and/or impacts to other ESA listed species. In addition, Enclosure 4 includes a proposed science workplan developed by the NMFS-Southwest Fisheries Science Center (SWFSC) for further discussion between our agencies and stakeholders.

5. *Reclamation and NMFS will initiate a structured stakeholder engagement process that will inform the amendment process.* We share Reclamation's commitment to stakeholder engagement and agree to work jointly with Reclamation to ensure that dialog occurs prior to finalizing the amendment. To further meaningful stakeholder engagement and discussions, NMFS proposes the following schedule for stakeholder workshops for the remainder of this water year. These workshops will be co-led by NMFS and Reclamation.

   - February 23: seek input on the initial science and modeling workplan
   - April 20: seek input on draft temperature pilot plan components and modeling
   - June 22: review final 2017 temperature management pilot plan and status report on system-wide modeling
   - September 21: discuss 2017 pilot results with feedback to prepare for the annual review of the long-term operations biological opinions, and present system-wide modeling results and other analyses.

In summary, NMFS believes that this approach, to implement the 2017 pilot temperature management study and associated analyses while continuing to discuss portions of the remainder of the proposed amendment, is necessary to continue to ensure that operations of the CVP and SWP avoid jeopardizing endangered and threatened species. All of the proposed changes to the Shasta RPA actions are intended to meet their respective objectives, as stated, in the 2009 Opinion.

I look forward to continued collaboration with Reclamation on implementation of the RPA and jointly learning from the pilot program and accompanying new science and modeling endeavors. If you have any questions regarding this letter, please contact Garwin Yip, of my staff, at (916) 930-3611, or via e-mail at garwin.yip@noaa.gov.

Sincerely,

Barry A. Thom
Regional Administrator

Enclosures:

1. Track Changes Version of the 2009 RPA with 2011 Amendments that Includes Only the Pages that have proposed 2017 Amendments
2. Clean Version of the 2009 RPA with 2011 Amendments Revised to Include the proposed 2017 Amendments
3. 2017 Shasta RPA Proposed Amendment Memorandum
4. NMFS-SWFSC Central Valley proposed water modeling Science Workplan

cc: ARN: 151422-SWR2006-SA00268
FWS – Paul Sousa, Kaylee Allen
DWR – Mark Cowin, Kathy Kelly
CDFW – Chuck Bonham, Scott Cantrell

Enclosure 1

Track Changes Version of the 2011 Amended Reasonable and Prudent Alternative
that Includes Only the Pages that have Salient 2017 Amendments

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2011 Amendment: In the Fall of 2010, the Delta Stewardship Council convened an Independent Review Panel (IRP) to assist in the annual review required in this action[2]. On November 8-9, 2010, the Delta Science Program held a workshop to provide the IRP a forum for presentations and discussion of previously submitted technical reports. Following the workshop, the IRP produced a report that included recommendations for adjustments to the RPA, based on information presented in the review process. The IRP Report was finalized on December 9, 2010 (Anderson *et al*. 2010; http://www.deltacouncil.ca.gov/delta_science_program/events/workshop_OCAP_2010.html). NMFS has amended the RPA consistent with the IRP recommendations and this Opinion's underlying analysis and conclusions[3]. This amended RPA supersedes the 2009 RPA.

2017 Amendment: This amendment is based on the following considerations:

1) Operations of Shasta and Keswick reservoirs were the subject of multiple annual reviews. Shasta operations were one of the main focuses in the 2015 annual review.
2) On August 2, 2016, Reclamation requested reinitiation of the entire CVP/SWP operations consultation, citing new information related to multiple years of drought and recent data demonstrating extremely low population levels of endangered Sacramento River winter-run Chinook salmon[4]. In an August 17, 2016, response letter to Reclamation, NMFS agreed to reinitiate consultation[5].
3) New science and temperature survival models are available to describe conditions that may be necessary to provide suitable winter-run spawning, egg incubation, and fry emergence throughout the temperature management season.
4) Since the 2011 amendment, there have been clarifications and adaptive management changes made that are reflected in this 2017 amendment to update the RPA.

NMFS has amended the RPA to reflect new best available scientific and commercial information and based on observed Sacramento River conditions during the drought years 2014-2016. This amendment is consistent with the 2009 Opinion's underlying analysis and conclusions. Rationale provided for the specific changes within explains the need for the change and how it meets the objectives of the specific RPA actions. This amended RPA supersedes the 2009 RPA with 2011 amendments.

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[2] Under direction from the Secretaries of Commerce and Interior, the NMFS review was expanded to include a review of the implementation of the FWS' 2008 OCAP Opinion. The integrated review provided an opportunity to assure that the NMFS and FWS RPAs worked together in an ecosystem context.

[3] In addition, NMFS has taken this opportunity to correct some errors in the 2009 RPA. All changes are noted and explained in the "Rationale for 2011 amendment" sections accompanying the amendments.

[4] http://www.westcoast.fisheries.noaa.gov/publications/Central_Valley/Water%20Operations/bureau_of_reclamation_s_request_to_reinitiate_the_2009_cvpswp_operations_consultation_-_august_2__2016.pdf

[5] http://www.westcoast.fisheries.noaa.gov/publications/Central_Valley/Water%20Operations/nmfs_response_to_reclamation_s_request_to_reinitiate_the_2009_cvpswp_operations_consultation_-_august_17__2016.pdf

The purpose of the amendment is to set interim operational changes that are necessary at this time, based on aforementioned circumstances, to reflect new best available scientific and commercial information, and lessons learned from operations during the drought conditions throughout water years 2014-2016.

Amendments to the Shasta RPA actions will be issued in a phased approach. The majority of changes have associated monitoring and analytical requirements. These requirements, combined with ongoing collaborative science, and refinement of temperature forecasting models, will iteratively inform implementation of the amended actions in subsequent water years and overall success of meeting the biological objectives identified for the RPA actions, that may warrant a subsequent amendment. Changes made within the 2017 amendment, including new and refined tools and monitoring, will further be used to inform the larger reconsultation of CVP/SWP operations. Reconsultation will provide a comprehensive analysis of integrated operations.

NMFS and Reclamation will establish a research program in coordination with the Delta Science Program and other agencies to address key research and management questions arising from this Opinion. Prior to the beginning of a new calendar year, Reclamation shall submit to NMFS a research plan for the following year, developed in coordination with the above programs and agencies. Reclamation also shall provide NMFS access to all draft and final reports associated with this research. Specific research projects that have been identified as important to begin in the first year and complete as soon as possible are:

Deleted: CALFED

1) Cooperative development of a salmonid lifecycle model acceptable to NMFS, Reclamation, CDFW, and DWR

Deleted: CDFG

2) Temperature monitoring and modeling identified in RPA Action I.1.5

3) Green sturgeon research described in the RBDD actions

4) Rearing habitat evaluation metrics to guide rearing habitat Action 1.6

5) A 6-year acoustic-tagged study of juvenile salmonids out-migration in the San Joaquin River and through the southern Delta identified in Action IV.2.2.

11.2.1.3. Monitoring and Reporting

1) Reclamation and DWR shall participate in the design, implementation, and funding of the comprehensive CV steelhead monitoring program, under development through ERP, that includes adult and juvenile direct counts, redd surveys, and escapement estimates on CVP- and SWP-controlled streams. This program is necessary to develop better juvenile production estimates that form the basis of incidental take limits and will also provide necessary information to calculate triggers for operational actions.

temperature and flow), or are a necessary component of the Salmon Decision Process used to manage Delta operations (*e.g.*, DCC gates and export pumping). Reclamation and DWR shall jointly fund these monitoring locations for the duration of the Opinion (through 2030) to ensure compliance with the RPA and assess the performance of the RPA actions. Most of these monitoring stations already exist and are currently being funded through a variety of sources (*i.e.*, CDFW, USFWS, Reclamation, DWR, CALFED, and Interagency Ecological Program), however, CALFED funding for monitoring ends in 2009 and CDFW funding has been reduced due to budget cuts.

Deleted: CDFG

Deleted: CDFG

a) Upstream: Adult escapement and juvenile monitoring for spring-run, winter-run, and steelhead on the Sacramento River, American River, Feather River, Clear Creek, and Battle Creek. These may be performed through carcass surveys, redd surveys, weir counts, and rotary screw trapping. Unless prevented by circumstances beyond the control of Reclamation, aerial redd counts shall be conducted annually on the mainstem Sacramento River from Keswick Dam downstream to at least Tehama Bridge, from at least April through September. These surveys are necessary to determine the temporal and spatial distribution of winter-run and spring-run Chinook salmon. Exceptions to the annual aerial redd counts are allowed only when requested in writing (including the specific circumstance that may preclude the aerial redd surveys) and upon written concurrence by NMFS.

Commented [NOAA1]: See RPA Action IV.1.1 for rationale regarding deletion of Mill and Deer creeks from juvenile monitoring.

Deleted: Mill Creek, Deer Creek

Rationale for 2011 amendment: Aerial redd counts have been conducted annually at least since 2001. However, in water year 2010, they were conducted later in the winter-run Chinook salmon spawning season, and the SRTTG did not have the benefit of the temporal and spatial distribution data to inform its recommendation of a temperature compliance point. The IRP noted the confusion in the final establishment of the temperature compliance point: "It is not known why the compliance point was established downstream (Jelly's Ferry) when aerial redd surveys in 2010 indicated redds were upstream of Airport Road Bridge." (Anderson *et al*. 2010, page 12, note E).

b) RBDD: Adult counts using the three current fish ladders until the new pumping plant is operational. Rotary screw trapping to determine juvenile Chinook salmon passage or abundance year-round before and after pumping plant is operational. Green sturgeon monitoring, to include adult and juvenile estimates of passage, relative abundance, and run timing, in order to determine habitat use and population size with respect to management of Shasta Reservoir resources.
c) Sacramento River new juvenile monitoring station: The exact location to be determined, between RBDD and Knights Landing, in order to give early warning of fish movement and determine survival of listed fish species leaving spawning habitat in the upper Sacramento River.
d) Delta: Continuation of the following monitoring stations that are part of the IEP: Chipps Island Trawl, Sacramento Trawl, Knights Landings RST, and beach seining

Action Suite I.2. Shasta Operations

Introduction to Shasta Operations: Maintaining suitable temperatures for spawning, egg incubation, fry emergence, and juvenile rearing in the Sacramento River is critically important for survival and recovery of the winter-run ESU. The winter-run ESU has been reduced to a single population, which has been blocked from its historical range above Shasta Dam. Consequently, suitable temperatures and habitat for this population must be maintained downstream of Shasta Dam through management of the cold water pool behind the dam in the summer. Maintaining optimum conditions for this species below Shasta is crucial until additional populations are established in other habitats or this population is restored to its historical range. Spring-run are also affected by temperature management actions from Shasta Reservoir.

The effects analysis in this Opinion highlights the very challenging nature of maintaining an adequate cold water pool in critically dry years, extended dry periods, and under future conditions, which will be affected by increased downstream water demands and climate change. This suite of actions is designed to ensure that Reclamation uses maximum discretion to reduce adverse impacts of the projects to winter-run and spring-run in the Sacramento River by maintaining sufficient carryover storage and optimizing use of the cold water pool. In most years, reservoir releases through the use of the TCD are a necessity in order to maintain the bare minimum population levels necessary for survival (Yates *et al.* 2008, Angilletta *et al.* 2008).

The effects analysis in this Opinion, and supplemental information provided by Reclamation, make it clear that despite Reclamation's best efforts, severe temperature-related effects cannot be avoided in some years. The RPA includes exception procedures to deal with this reality. Due to these unavoidable adverse effects, the RPA also specifies other actions that Reclamation must take, within its existing authority and discretion, to compensate for these periods of unavoidably high temperatures. These actions include restoration of habitat at Battle Creek that may be support a second population of winter-run, and a fish passage program at Keswick and Shasta dams to partially restore winter-run to their historical cold water habitat.

Objectives: The following objectives must be achieved to address the avoidable and unavoidable adverse effects of Shasta operations on winter-run and spring-run:

1) Ensure a sufficient cold water pool to provide suitable temperatures for winter-run spawning, egg incubation, and fry emergence in most years, without sacrificing the potential for cold water management in a subsequent year. Additional actions to those in the 2004 CVP/SWP operations Opinion are needed, due to increased vulnerability of the population to temperature effects attributable to changes in Trinity River ROD operations, projected climate change hydrology, and increased water demands in the Sacramento River system.

Deleted: spawning between Balls Ferry and Bend Bridge

2) Ensure suitable temperature regimes for spring-run spawning, egg incubation, and fry emergence, especially in September and October. Suitable spring-run temperatures will also partially minimize temperature effects to naturally-spawning, non-listed Sacramento River fall-run, an important prey base for endangered Southern Resident killer whales.

Deleted: spring-run

3) Establish a second population of winter-run in Battle Creek as soon as possible, to partially compensate for unavoidable project-related effects on the one remaining population.

4) Restore passage at Shasta Reservoir with experimental reintroductions of winter-run to the upper Sacramento and/or McCloud rivers, to partially compensate for unavoidable project-related effects on the remaining population.

2017 amendment: Appendix 2-A of the CVP/SWP operations Opinion is the "Decision Criteria and Processes for Sacramento River Water Temperature Management." NMFS searched the RPA for Appendix 2-A and did not find any references to it. It appears to be a stand alone document that includes information and requirements that may be inconsistent or confusing in consideration of this RPA, and especially the 2017 amendments to RPA Action Suite I.2. To that end, and through this 2017 amendment, NMFS is rescinding Appendix 2-A from the CVP/SWP operations Opinion, and any compliance requirements within Appendix 2-A are not valid.

Action I.2.1 Objective-Based Management.

Deleted: 1

Deleted: Performance Measures

Objective: The following conceptual objectives were adapted from the multi-year drought sequence experienced in Victoria, Australia (Mount *et al*. 2016[6]), and applied to the following RPA Actions based on water year type. This transition from using performance measures to an objective-based management approach is intended to ensure operations are managed to criteria that are more biologically meaningful.

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[6] 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. June 2016.

	Critically Dry	**Dry**	**Below Normal**	**Above Normal & Wet**
Objectives	PROTECT - Avoid critical loss of population - Avoid catastrophic changes to habitat	MAINTAIN - Maintain river function with reduced reproductive capacity - Manage within dry-spell tolerance	RECOVER - Improve ecological health and resilience - Improve recruitment opportunities	ENHANCE - Maximize species recruitment opportunities - Restore key floodplain linkages - Restore key ecological flows
Priorities	- Undertake emergency flows to avoid catastrophic changes - Carry-over water for critical environments in the following year	- Provide priority flow components - Carry-over water for critical environmental components in the following year	- Provide all in-bank flow components - Provide out-of-bank flows if reach dry-spell tolerance - Carry-over water for large watering events	- Provide all ecological functioning flow components

Based on the above conceptual objectives, NMFS and Reclamation will work together to establish temperature-dependent mortality objectives by water year type, and manage to these objectives, in order to minimize temperature effects associated with operations of the CVP. This 2017 amendment contains an initial set of objectives that may be adjusted in subsequent amendments or the reconsultation of CVP/SWP operations.

To facilitate management to the temperature-dependent mortality objectives and in order to meet the temperature requirements set forth in subsequent actions, NMFS and Reclamation will establish storage targets for minimum peak storage in April/May and at the End-of-September (EOS). Storage targets will help to ensure that the beneficial variability of the system from changes in hydrology will be measured and maintained.

Deleted: operate to a set of performance measures for temperature compliance points and

Deleted: carryover storage,

Deleted: enabling Reclamation and NMFS to assess the effectiveness of this suite of actions over time. Performance measures

Action: Reclamation shall use the following mortaility objectives for forecasting, temperature planning and implementation and shall report on them annually to NMFS. If there is significant deviation from these objectives, then Reclamation shall reinitiate consultation with NMFS.

These objectives are interim in the context of the 2017 amendment and will be reviewed and further assessed within the scope of the workplan for 2017 and the larger reconsultation[7].

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[7] An additional science and modeling workplan is being prepared to support additional analyses of effectiveness of these objectives in achieving biological objectives, and to evaluate possible system-wide re-operational impacts of these objectives.

Temperature-dependent mortality to winter-run Chinook shall not exceed the following:

- Critically dry: <30% mortality
- Dry: <8% mortality
- Below Normal: <3% mortality
- Above Normal: <3% mortality
- Wet: <3% mortality

In order to meet the above temperature-dependent mortality objectives and the requirements set forth in RPA Action I.2.4, Reclamation will target:

- Mimimum storage between April 1 and May 31, based on water year type, in order to meet the temperature-dependent mortality objectives and the requirements set forth in RPA Action I.2.4, below, no less than:
    - Critically dry: 3.5 million acre-feet (MAF)
    - Dry: 3.9 MAF
    - Below Normal: 4.2 MAF
    - Above Normal: 4.2 MAF
    - Wet: 4.2 MAF

- EOS storage, at Shasta Reservoir, based on water year type, no less than:
    - Critically dry: 1.9 MAF
    - Dry: 2.2 MAF
    - Below Normal: 2.8 MAF
    - Above Normal: 3.2 MAF
    - Wet: 3.2 MAF

Should the storage targets above not be met, Reclamation shall provide written documention to NMFS to describe the reasons behind the inability to achieve these storage targets.

Further, should Reclamation be unable meet 1.9 MAF EOS storage, Reclamation shall meet with NMFS to confer and determine additional actions that are needed to protect winter-run Chinook salmon (Action I.2.3.C).

Additional examination of minimum peak April/May and EOS storage in order to meet the temperature-dependent mortality objectives and the requirements set forth in RPA Action I.2.4 will occur in larger reconsultation. The reconsultation will also include analysis and assessment of the impacts of combinations of different, successive water year types on winter-run Chinook salmon survival and mortality.

Rationale for 2017 amendment:

- This 2017 amendment deletes the previous performance measures that were based on temperature compliance locations to be met with prescribed frequency.

- The temperature-dependent mortality objectives take advantage of new scientific models (*e.g.*, Martin *et al*. 2016), and are intended to create the most flexible and effective operations by directly managing to a biologically meaningful objective. The variability in objectives by water year type is based on the variable goals that can realistically be achieved given drier years (when effects will be greater) versus wetter years (when species recovery is possible).
- The minimum peak April/May and EOS storage objectives targets consider hydrology (*i.e.*, water year type), and are provided in order to meet the temperature requirements set forth in the subsequent actions in preserving key aspects of life history and run time diversity. The volumes are taken from those presented in the CVP/SWP operations BA, effects analysis in the Opinion, and NMFS technical memo on historic Shasta operations, and a 2017 Reclamation analysis of the relationships between storage and cold water pool volumes.
- There is an explicit commitment to conduct additional science and modelling and further refine these objectives.

Action I.2.2. November through February Keswick Release Schedule (Fall Actions)

Objective: Minimize impacts to listed species and naturally spawning non-listed fall-run from high water temperatures by implementing standard procedures for release of cold water from Shasta Reservoir.

Action: Depending on EOS storage and hydrology, Reclamation shall develop and implement a Keswick release schedule, and reduce deliveries and exports as detailed below.

Action I.2.2.A Implementation Procedures for EOS Storage at 2.8 MAF and Above

If the EOS storage is at 2.8 MAF or above, by October 15, Reclamation shall convene the SRTTG to consider a range of fall actions. A written monthly average Keswick release schedule shall be developed and submitted to NMFS by November 1 of each year, based on the criteria below. The monthly release schedule shall be tracked through the work group. If there is any disagreement in the group, including NMFS technical staff, the issue/action shall be elevated to the Shasta Water Interagency Management (SWIM) Team [see Action I.2.4(4), below] for resolution.

The workgroup shall consider and the following criteria in developing a Keswick release schedule:

1) Need for flood control space: A maximum 3.25 MAF end-of-November storage is necessary to maintain space in Shasta Reservoir for flood control.

Deleted: The following long-term performance measures shall be attained. Reclamation shall track performance and report to NMFS at least every 5 years. If there is significant deviation from these performance measures over a 10-year period, measured as a running average, which is not explained by hydrological cycle factors (*e.g.*, extended drought), then Reclamation shall reinitiate consultation with NMFS.¶
¶
Performance measures for EOS carryover storage at Shasta Reservoir: ¶
¶
<#>87 percent of years: Minimum EOS storage of 2.2 MAF¶
<#>82 percent of years: Minimum EOS storage of 2.2 MAF and end-of-April storage of 3.8 MAF in following year (to maintain potential to meet Balls Ferry compliance point) ¶
<#>40 percent of years: Minimum EOS storage 3.2 MAF (to maintain potential to meet Jelly's Ferry compliance point in following year)¶
¶
Measured as a 10-year running average, performance measures for temperature compliance points during summer season shall be:¶
¶
<#>Meet Clear Creek Compliance point 95 percent of time¶
<#>Meet Balls Ferry Compliance point 85 percent of time¶
<#>Meet Jelly's Ferry Compliance point 40 percent of time¶
<#>Meet Bend Bridge Compliance point 15 percent of time¶
¶
Rationale: Evaluating long-term operations against a set of performance measures is the only way to determine the effectiveness of operations in preserving key aspects of life history and run time diversity. For example, maintaining suitable spawning temperatures down to Bend Bridge in years when this is feasible will help to preserve the part of winter-run distribution and run timing that relies on this habitat and spawning strategy. This will help to ensure that diversity is preserved when feasible. The percentages are taken from those presented in the CVP/SWP operations BA, effects analysis in the Opinion, and NMFS technical memo on historic Shasta operations. ¶
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2) Need for stable Sacramento River level/stage to increase habitat for optimal spring-run and fall-run redds/egg incubation and minimization of redd dewatering and juvenile stranding.

3) Need/recommendation to implement USFWS' Delta smelt Fall X2 action as determined by the Habitat Study Group (HSG) formed in accordance with the 2008 Delta smelt Opinion. NMFS will continue to participate in the HSG chartered through the 2008 Delta smelt biological opinion. If, through the HSG, a fall flow action is recommended that draws down fall storage significantly from historical patterns, then NMFS and USFWS will confer and recommend to Reclamation an optimal storage and fall flow pattern to address multiple species' needs.

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If there is a disagreement at the workgroup level, actions may be elevated to the NMFS California Central Valley Office Assistant Regional Administrator and resolved through the WOMT's standard operating procedures.

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Rationale: 2.8 MAF EOS storage is linked to the potential to provide sufficient cold water to minimize temperature-dependent mortality in the following year. Therefore, in these circumstances, actions should target the fall life history stages of the species covered by this Opinion (*i.e.*, spring-run spawning, winter-run emigration). The development of a Keswick release schedule is a direct method for controlling storage maintained in Shasta Reservoir. It allows Reclamation to operate in a predictable way, while meeting the biological requirements of the species. The B2IT workgroup, or similar interagency work group, has been used in the past to target actions to benefit fall-run during this time of year using b(2) resources, and, because of its expertise, may also be used by Reclamation to develop this flow schedule. In the past, the B2IT group has used the CVPIA AFRP guidelines to target reservoir releases. Over time, it may be possible to develop a generic release schedule for these months, based on the experience of the work group.

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Action I.2.2.B Implementation Procedures for EOS Storage Above 1.9 MAF and Below 2.8 MAF

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If EOS storage is between 1.9 and 2.8 MAF, then Reclamation shall convene the SRTTG to consider a range of fall actions. Reclamation shall provide NMFS and the work group with storage projections based on 50 percent, 70 percent, and 90 percent hydrology through February, and develop a monthly average Keswick release schedule based on the criteria below. The monthly release schedule shall be submitted to NMFS by November 1.

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Criteria for the release schedule shall include:

1) Maintain Keswick releases between 7,000 cfs and 3,250 cfs to reduce adverse effects on mainstem spring-run and conserve storage for next year's cold water pool.

2) Consider fall-run needs per CVPIA AFRP guidelines, through January, including stabilizing flows to keep redds from de-watering.

3) Be more conservative in Keswick releases throughout fall and early winter if hydrology is dry, and release more water for other purposes if hydrology becomes wet. For example, release no more than 4,000 cfs if hydrology remains dry.

The Keswick release schedule shall follow this or a similar format, to be refined by the workgroup:

	October forecast based on EOS storage	50% hydrology		70% hydrology		90% hydrology	
		Projected storage MAF	Planned release CFS	Projected storage MAF	Planned release CFS	Projected storage MAF	Planned release CFS
Monthly average Keswick release	November						
	December						
	January						
	February						

Reclamation, in coordination with the work group, shall review updated hydrology and choose a monthly average release for every month (November, December, January, February), based on the release schedule. In the event that the updated hydrology indicates a very dry pattern and consequent likely reduction in storage, the work group may advise Reclamation to take additional actions, including export curtailments, if necessary to conserve storage.

If there is a disagreement at the work group level, actions may be elevated to NMFS and resolved through the SWIM Team.

Deleted: WOMT's standard operating procedures

Rationale: It is necessary to be reasonably conservative with fall releases to increase the likelihood of adequate storage in the following year to provide cold water releases for winter-run. This action is intended to reduce adverse effects on each species without compromising the ability to reduce adverse effects on another species. A work group with biologists from multiple agencies will refine the flow schedule, providing operational certainty while allowing for real-time operational changes based on updated hydrology. Over time, it may be possible to develop a generic release schedule for these months, based on the experience of the work group.

Action I.2.2.C. Implementation and Exception Procedures for EOS Storage of 1.9 MAF or Below

If the EOS storage is at or below 1.9 MAF, then Reclamation shall:

release based on biological needs of species); and

b) if it is necessary to curtail combined exports to values more restrictive than 2,000 cfs in order to meet Delta outflow, X2, or other legal requirements, then Reclamation and DWR shall, as an overall strategy, first, increase releases from Oroville or Folsom; and
c) in general, Reclamation shall increase releases from Keswick as a last resort.
d) Based on updated monthly hydrology, this restriction may be relaxed, with NMFS' concurrence.

6) If the hydrology and storage have not improved by January, additional restrictions apply – see Action I.2.4.

Rationale: Per action I.2.1, Reclamation shall target a minimum of 1.9 MAF EOS. However, during a severe or extended drought, 1.9 EOS storage may not be achievable. In this circumstance, Reclamation should take additional steps in the fall and winter months to conserve Shasta storage to the maximum extent possible, in order to increase the probability of maintaining cold water supplies necessary for spawning, egg incubation, and fry emergence for the following summer's cohort of winter-run.

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Assessment of the hydrologic record and CALSIM modeling shows that operational actions taken during the first year of a drought sequence are very important to providing adequate storage and operations in subsequent drought years. The biological effects of an extended drought are particularly severe for winter-run. Extended drought conditions are predicted to increase in the future in response to climate change. While it is not possible to predict the onset of a drought sequence, in order to ensure that project operations avoid jeopardizing listed species, Reclamation should operate in any year in which storage falls below 1.9 MAF EOS storage as potentially the first year of a drought sequence. The CVP storage system is likely to recover more quickly in the winter and spring months if additional storage conservation measures are taken in the fall and winter.

The curtailments to discretionary rice decomposition deliveries and combined export curtailment of 2,000 cfs are necessary to conserve storage when EOS storage is low. These actions were developed through an exchange of information and expertise with Reclamation operators.

This action is consistent with comments from the Calfed Science Peer Review panel. That panel recommended that Shasta be operated on a two-year (as opposed to single year) hydrologic planning cycle and that Reclamation take additional steps to incorporate planning for potential drought and extended drought into its operations.

Action I.2.3. Initial Forecast; March – May 14[8] Keswick Release Schedule (Spring Actions)

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Objective: To conserve water in Shasta Reservoir in the spring in order to provide sufficient water to reduce adverse effects of high water temperature in the summer months for winter-run, without sacrificing carryover storage in the fall.

Actions:

1) Prior to an initial water allocation, Reclamation shall make its initial forecast of deliverable water, shall identify if the objectives in RPA Action I.2.1 can be attained, including minimum peak April/May and EOS storage targets, and analyze the effects of that forecast on the ability to meet the April/May storage targets below. Acknowledging considerable uncertainty in this long-range forecast, the goal is to forecast operations that provide sufficient cold water to meet the objectives 90 percent of the time. Keeping this 90 percent objective in mind, the model shall contain conservative meteorological inputs for hydrology, including, but not limited to precipitation, runoff and snowpack, ambient summer air temperatures, and assumptions or projections of Shasta Reservoir stratification. In the other 10 percent of the time, it may be necessary to revise allocations in the May period, associated with the final temperature plan. Storage targets for forecasting purposes between April 1 and May 31, based on water year type, are to be no less than:
   - Critically Dry: 3.5 MAF
   - Dry: 3.9 MAF
   - Below Normal: 4.2 MAF
   - Above Normal: 4.2 MAF
   - Wet: 4.2 MAF

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Deleted: based on an estimate of precipitation and runoff within the Sacramento River basin at least as conservative as the 90 percent probability of exceedence.

   a) The draft initial forecast shall include:
      i. Projected Shasta cold water pool volume based on a stratification model or hindcasting comparable Shasta volumes; and
      ii. Management plans for Keswick releases August through October in order to minimize the potential for winter-run redd dewatering[9].
   b) NMFS shall be provided at least 3 business days to review the draft forecast.
   c) NMFS shall review the draft initial forecast to determine whether the ESA requirements for temperature and flow management, as necessary, would be met while implementing the forecasted delivery schedule.

Deleted: <#>Subsequent updates of water delivery commitments must be based on monthly forecasts at least as conservative as the 90 percent probability of exceedence.¶
¶
Reclamation shall provide the draft February forecast, and a projection of temperature management operations for the summer months, to NMFS

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[8] Or until the start of winter-run spawning as determined by CDFW aerial redd surveys and carcass surveys, which may be earlier or later than May 14.

[9] The extent of allowable winter-run redd dewatering depends on many factors, including Shasta storage, water year type, strength of the run (which unfortunately is not known until after the season), and CDFW monitoring of the redds most vulnerable to dewatering. Therefore, the extent of dewatering will be based on real-time assessments of the above factors and monitoring.

d) NMFS shall provide a written evaluation to Reclamation prior to Reclamation making the first allocation announcements and for each subsequent month for discretionary contract deliveries.

e) Reclamation will provide to NMFS an initial forecast no later than March 31.

Deleted: shall manage releases from Keswick consistent with the February forecast and subsequent monthly hydrology updates

3) Reclamation shall make releases to maintain a temperature compliance point not in excess of 61.0°F 7DADM at Jellys Ferry from March 1 through May 15.

a) Reclamation will implement a pilot study for up to 3 years using a surrogate temperature target of 58.0°F DAT at Jellys Ferry in lieu of 61.0°F 7DADM and shall implement the same requirements as those contained in the pilot study in Action I.2.4(2)(b-c).

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Deleted: 56 degrees between Balls Ferry and Bend Bridge from April 15

Rationale for 2017 amendment: The initial forecast was required as part of Reclamation's initial allocations planning in order to determine the impact of Shasta management. Additional initial forecast requirements/expectations are based on observed river conditions during drought operations over the last few years, and what may be necessary to provide for suitable winter-run egg and alevin incubation throughout the temperature management season. Additional requirements, which were not included previously, are now included to address the potential for winter-run redd dewatering.

The minimum peak April/May and EOS storage targets consider hydrology (*i.e.*, water year type), and are provided in order to meet the temperature requirements set forth in the subsequent actions in preserving key aspects of life history and run time diversity. The volumes are taken from those presented in the CVP/SWP operations BA, effects analysis in the Opinion, NMFS technical memo on historic Shasta operations, and a 2017 Reclamation analysis of the relationships between storage and cold water pool volumes.

Action I.2.3.A Implementation Procedures if Initial Forecast, Based on 90 Percent Hydrology, Shows Biological Objectives, Storage Targets, and Temperature Management are Achievable

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If all of the following metrics are met, based on the initial forecast, then Reclamation shall announce allocations and operate Keswick releases in March, April, and May consistent with its standard plan of operation. Preparation of a separate Keswick release schedule is not necessary in these circumstances.

Deleted: NMFS will review the draft February forecast to determine whether both a temperature compliance point at Balls Ferry during the temperature control season (May – October), and EOS storage of at least 2.2 MAF, is likely to be achieved. If both are likely,

1) End of April storage ≥ 4.2 MAF
2) End of September storage ≥ 3.2 MAF
3) 51.5°F Keswick release temperature from May 15 through October 31 [this would be used as a surrogate for 55.0°F 7-day average of the daily maximum temperatures (7DADM) at the CCR California Data Exchange Center gaging station upstream of the confluence of Clear Creek on the Sacramento River]; and
4) Full side gate water releases from the Shasta Dam temperature control device no earlier than October 9

Rationale: The 90 percent forecast is a conservative approach for assessing the potential to manage water temperatures and meet EOS targets. If both of these performance metrics are projected to be met at the time of the initial forecast, then no restrictions on allocations due to this suite of actions are necessary.

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Action I.2.3.B Implementation Procedures if Initial Forecast, Based on 90 Percent Hydrology, Shows that Not All of the Metrics in Action I.2.3.A Are Achievable

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1) If the initial forecast, based on 90 percent hydrology, shows that not all of the metrics in Action I.2.3.A, above, are achievable, then Reclamation shall implement the following monthly Keswick release schedule, based on water year type, until the Sacramento River temperature management plan pursuant to RPA Action I.2.4 is finalized[10]:

Water Year Type	Monthly Keswick Releases (cfs)	
	April	May
Critically Dry	4,000	7,500
Dry	6,000	8,000
Below Normal	6,000	9,000
Above Normal	6,500	11,000
Wet	8,000	12,000

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2) The Keswick release schedule shall include the following criteria and actions:
   a) Maintain minimum monthly average flows necessary to meet nondiscretionary delivery obligations and legal requirements.
   b) Provide for flow-related biological needs of spring life stages of all species covered by this Opinion in the Sacramento River and Delta, to the greatest extent possible.
   c) If operational changes are necessary to meet Delta outflow, X2, or other legal requirements during this time, then:

      - CVP/SWP Delta combined exports shall be curtailed to 2,000 cfs if necessary to meet legal requirements while maintaining a 3,250 cfs Keswick Dam release (or other planned release based on biological needs of species); and
      - if it is necessary to curtail combined exports to values more restrictive than 2000 cfs in order to meet Delta outflow, X2, or other legal requirements, then Reclamation and DWR shall, as an overall strategy, first, increase releases from Oroville or Folsom Dam; and
      - in general, Reclamation shall increase releases from Keswick Dam as a last resort.

Deleted: <#>On or before February 15, Reclamation shall reduce Keswick releases to 3,250 cfs, unless NMFS concurs on an alternative release schedule. This reduction shall be maintained until a flow schedule is developed per procedures below.¶
<#>¶
<#>In coordination with NMFS, by March 1, Reclamation shall develop an initial monthly Keswick release schedule, based on varying hydrology of 50 percent, 70 percent, and 90 percent (similar in format to the fall and winter action implementation procedures – see table above). These schedules shall be used as guidance for monthly updates and consultations. ¶
<#>¶
<#>Based on this guidance, Reclamation shall consult with NMFS monthly on Keswick releases. Reclamation shall submit a projected forecast, including monthly average release schedules and temperature compliance point to NMFS every month, within 7 business days of receiving the DWR runoff projections for that month. Within 3 business days of receiving this information from Reclamation, NMFS will review the draft schedule for consistency with the criteria below and provide written recommendations to Reclamation. ¶
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[10] If flood control rules require releases above these monthly average flows, then Reclamation shall inform NMFS of this conflict and discuss it on a Shasta Water Interagency Management Team call to further coordinate releases, as appropriate.

- Based on improvements in updated monthly hydrology, this restriction may be relaxed, with NMFS' concurrence.

3) In addition to Reclamation's forecasted plan of operations, the initial forecast shall include a model run with the following Keswick release schedule based on water year type, in order to assess the comparative performance of alternative plans in their ability to meet temperature criteria:

Water Year Type	Monthly Keswick release schedule (cfs)						
	Apr	May	Jun	Jul	Aug	Sep	Oct
Critically Dry	4,000	7,500	7,500	7,500	7,500	7,000	5,000
Dry	6,000	8,000	10,000	10,000	10,000	7,500	6,000
Below Normal	6,000	9,000	12,000	12,000	12,000	7,500	6,500
Above Normal	6,500	11,000	12,500	14,500	12,000	9,000	7,000
Wet	8,000	12,000	13,500	14,500	12,000	10,000	7,000

Rationale: It is necessary to manage storage for potential dry years, to reduce adverse effects on winter-run egg incubation in summer months, and on spring-run in fall months. According to information provided by Reclamation, the hydrology is too variable this time of year to provide for a meaningful 3-month release schedule. Instead, monthly consultations between NMFS and Reclamation are needed to ensure that operations are based on biological criteria and needs.

Action I.2.3.C. Drought Exception Procedures if Initial Forecast, Based on 90 Percent Hydrology, Shows that 55.0°F 7DADM at CCR or 1.9 MAF EOS Storage is Not Achievable

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Reclamation shall follow all procedures immediately above (Action I.2.3.B) and, in addition, shall:

1) By April 1, provide a contingency plan with a written justification that all actions within Reclamation's authorities and discretion are being taken to preserve cold water at Shasta Reservoir for the protection of winter-run.

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2) The contingency plan shall also, at a minimum, include the following assessments and actions:

    a) Relaxation of Wilkins Slough navigation criteria to at most 4,000 cfs.
    b) An assessment of any additional technological or operational measures that may be feasible and may increase the ability to manage the cold water pool.
    c) Notification to State Water Resources Control Board (SWRCB) that meeting the biological needs of winter-run and the needs of resident species in the Delta, delivery of water to nondiscretionary Sacramento Settlement Contractors, and Delta outflow

requirements per D-1641, may be in conflict in the coming season and requesting the Board's assistance in determining appropriate contingency measures, and exercising their authorities to put these measures in place.

3) If, during the temperature control season, temperature control on the Sacramento River cannot be maintained, then Reclamation shall bypass power at Shasta Dam if NMFS determines a bypass is necessary for preserving the cold water pool. This power bypass may be necessary to maintain temperature controls for winter-run, or later in the temperature season, for spring-run.

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Rationale: In these circumstances, there is a one-in-ten likelihood that minimal requirements for winter-run egg survival will not be achieved due to depletion of the cold water pool, resulting in temperature-related mortality of winter-run and, in addition, most likely contributing to temperature-related mortality of spring-run spawning in the fall. This is a conservative forecast, since there is a 90 percent probability that conditions will improve. However, the effects analysis in this Opinion concludes that these poor conditions could be catastrophic to the species, potentially leading to a significant reduction in the viability of winter-run. Delta objectives (salinity, X2, E/I ratio, OMR flow restrictions for both smelt and salmon) are also controlling at this time of year. There is potential for conflict between the need to maintain storage at Shasta and other legal and ecological requirements. Consequently, it is necessary to immediately limit releases from Shasta and develop a contingency plan.

Notification to the SWRCB is essential. Sacramento Settlement Contract withdrawal volumes from the Sacramento River can be quite substantial during these months. The court has recently concluded that Reclamation does not have discretion to curtail the Sacramento Settlement contractors to meet Federal ESA requirements. Therefore, NMFS is limited in developing an RPA that minimizes take to acceptable levels in these circumstances. Consequently, other actions are necessary to avoid jeopardy to the species, including fish passage at Shasta Dam in the long term.

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Separate from this consultation, NMFS will work with the SWRCB to determine whether contingency plans within the Board's authority are warranted, and to assist in developing such plans that will allow Reclamation to meet ESA requirements. The incidental take statement for this Opinion also provides limitations of ESA incidental take coverage for Settlement Contractors under the terms of this Opinion.

Action I.2.4 May 15[11] Through October 31 Keswick Release Schedule (Summer Action)

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Objective: To manage the cold water storage within Shasta Reservoir and make cold water releases from Shasta Reservoir to provide suitable spawning, egg incubation, and fry

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[11] This action will be initiated at the onset winter-run spawning, determined by CDFW aerial redd surveys and carcass surveys, and therefore, may be earlier or later than May 15.

emergence habitat temperatures for winter-run and spring-run in the Sacramento River while retaining sufficient storage to manage for next year's cohorts. To the extent feasible, manage for suitable temperatures for naturally spawning fall-run.

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Action: Reclamation shall develop and implement an annual Temperature Management Plan by May 15 to manage the cold water supply within Shasta Reservoir and make cold water releases from Shasta Reservoir and Spring Creek to provide suitable temperatures for listed species, and, when feasible, fall-run.

Reclamation shall manage operations in the Sacramento River as follows:

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1) Not exceed the temperature-dependent mortality objectives identified in Action I.2.1.
2) Not in excess of 56.0°F DAT at a compliance location between Balls Ferry and Bend Bridge from the start of winter-run spawning, based on CDFW aerial redd or carcass surveys, through 100 percent winter-run emergence for protection of winter-run, and not in excess of 56.0°F DAT at the same compliance location between Balls Ferry and Bend Bridge through October 31 for protection of mainstem spring run, whenever possible.
    a) Reclamation shall implement a pilot study for up to 3 years to meet the temperature target of 55.0°F 7DADM at CCR. A surrogate temperature target of 53.0°F DAT may be used in lieu of 55.0°F 7DADM. This pilot would focus temperature management at the downstream-most winter-run redd, based on water year type, as follows:
        i. Critically dry: < 56.0°F DAT[12]. In this case, temperature management shall be to CCR or the downstream-most winter-run redd, whichever location is further downstream
        ii. Dry: < 54.0°F DAT
        iii. Below Normal: < 53.0°F DAT
        iv. Above Normal: < 53.0°F DAT
        v. Wet: < 53.0°F DAT
        vi. Exception procedure: If a winter-run redd is detected considerably farther downstream than other winter-run redds, the SWIM Team shall convene pursuant to Action I.2.4(4), below, and determine if temperature management must be to that downstream most redd.
    b) If Reclamation determines at anytime that it is not feasible to meet the target in the pilot study without causing significant system-wide impacts, the environment, and/or impacts to other ESA-listed species, then Reclamation shall document this finding to NMFS, and request that the pilot study be suspended for the remainder of the water year. In this event, Reclamation shall:
        i. Submit an alternative plan for NMFS's concurrence that fully complies with all RPA requirements; and

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[12] This temperature was not achievable in 2014/2015. This temperature management target in critically dry years will require interactive decision making processes to determine the optimal management strategies during extreme conditions.

        ii. Submit additional modeling and analysis, with recommendations on how to further adjust the pilot study for the following year.
    c) During the course of the first year of the pilot study, Reclamation shall develop an analysis according to a workplan developed in conjunction with NMFS. The analysis will evaluate the impacts of the revised temperature management values, locations, and metrics.
        i. Should the analysis result in a finding that the revised temperature management compliance values, locations, and metrics would result in system-wide impacts to the environment, and/or impacts to other ESA listed species, Reclamation and NMFS will revise the pilot study, as appropriate, in light of these impacts, and also assess whether further adjustments to this RPA action are warranted. In addition, information from this pilot period will inform the larger reconsultation on CVP/SWP operations.

3) Reclamation shall operate to a final Temperature Management Plan starting May 15 and ending October 31.

4) Reclamation and NMFS shall convene a Shasta Water Interagency Management (SWIM) Team, comprised of representatives from Reclamation, NMFS, USFWS, CDFW, and the SWRCB, to track the implementation of the final Temperature Management Plan (including significant changes in treal-time operations). The SWIM Team will utilize information from its member agencies, as well as technical information from the SRTTG and other relevant stakeholders, to inform decisions and changes in operations.
    a) The SWIM Team will consider:
        i. data on winter-run redd construction and egg/alevin incubation timing, location, and distribution;
        ii. Shasta isothermalbaths;
        iii. temperature-dependent mortality modeling results;
        iv. actual vs. modeled Shasta cold water pool volume <49°F to ensure that actual cold water pool volume is:
            1. not less than 95% of modeled for wet and above normal water year types, and
            2. not less than 99% of modeled for critical, dry, and below normal water year types;
        v. projected temperature control device gate operations and configurations;
        vi. date of full side gate access, and adjust operations to ensure that full side gate access is no earlier than October 9; and
        vii. downstream diversions, flows, and Delta requirements.
    b) The SWIM Team will determine:
        i. the frequency of its meetings; and
        ii. if existing interagency teams, for example, WOMT, would satisfy the requirements and expectations, above.

5) As part of the adaptive management process, and in coordination with NMFS, by March 2010, Reclamation shall fund an independent modeler to review these procedures and the

recommendations of the Calfed Science Panel report on temperature management and recommend specific refinements to these procedures to achieve optimal temperature management, with due consideration of the Calfed Science panel's recommendations (Deas *et al*., 2009) regarding temperature management. Upon written concurrence of NMFS, refinements to the implementation procedures for this action suite, based on the independent contractor's report, may be adopted and implemented.

a) Reclamation, in coordination with NMFS and the Sacramento River Settlement Contractors, shall develop and implement a work plan for Shasta and Trinity divisions seasonal operational water temperature modeling. The resulting water temperature modeling shall support better initial forecasting and decision making, to include uncertainty estimates, joint probabilities of risk, and estimates of Shasta Reservoir stratification. Any temperature model developed through this effort shall utilize a platform so that it can be independently run.

Implementation Procedures: Reclamation shall take the following steps to develop an annual Temperature Management plan:

1) By April 25, Reclamation shall develop and submit to NMFS a draft Temperature Management Plan, to include:
    a) both 50 percent and 90 percent forecasts, including EOS storages, consistent with its draft plan of summer operations.
    b) outputs that demonstrate that the objectives in Action I.2.1 have a high probability of being met.
2) NMFS will provide comments within five business days to Reclamation, recommending that Reclamation either: (a) operate to one of the options; or (b) develop an alternative operations plan necessary to meet reasonably attainable preferred TCP and EOS storage.
3) Within five business days of receiving NMFS' recommendations, and based on NMFS's comments, Reclamation will develop an operations plan with specific monthly average Keswick releases to attain both TCP from May 15 through the EOS and EOS storage, and submit the plan to NMFS for concurrence.
4) By May 15, Reclamation and NMFS shall jointly submit a final Temperature Management Plan to meet the SWRCB 90-5 requirements using the SRTTG. From May 15 through October 31, the SWIM Team shall track implementation of this plan, and shall refine it based on real-time information, including run timing, location of redds, air and surface water temperature modeling, and projected versus actual extent of the cold water pool.
5) The temperature management plan shall also include the projected volume of cold water to be tracked, and triggers and corresponding actions if the volume is less than projected[13]

Rationale: Depending on hydrology and air temperature, from May through October, it is necessary to use the cold water pool in Shasta Reservoir to provide cold water releases to

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Deleted: Reclamation shall model two complete runs for each forecast, one with an upstream TCP and one with a downstream TCP. Together, Reclamation will present four risk-management options to NMFS for review. EOS Storage will be projected for each of the four runs. If it is very wet or very dry, there will be fewer options to present to NMFS.

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Deleted: Any disagreement at the work group level regarding how to implement or modify the plan will be elevated to NMFS and resolved through WOMT standard operating procedures.

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[13] This approach was piloted successfully in summer 2016.

maintain suitable water temperatures for listed anadromous fish below Shasta. Without access to the cold water pool, suitable temperatures for spawning, egg incubation, and fry emergence are not attainable. Preparation of an annual Temperature Management Plan allows Reclamation, in consultation with NMFS, to achieve optimal cold water management in a given year and conserving EOS storage. The storage level at the EOS is important to manage the risk of unsuitably warm water temperatures for winter-run in the following summer. Maintaining suitable temperatures in September and October is also important to minimize adverse effects of project operations to main stem Sacramento River spring-run. Fall-run, a non-listed species that is important as a prey base for Southern Resident killer whales, also benefits from suitable temperatures in the Fall.

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Development of 2 to 4 options for temperature management, prior to finalizing a plan allows for meaningful discussion of appropriate risk management strategies in a given year, based on timely hydrologic and biological considerations. Important factors differ from year to year, and need to be considered in operations planning. They include timing and location of spawning and redds based on aerial surveys; the extent of the cold water pool, given air temperatures; and operation of the Temperature Control Device to provide optimal use of the cold water pool. Preparation of a draft plan also allows for iterative planning and feedback. Operations can be tailored each year to achieve the optimal approach to temperature management to maintain viable populations of anadromous fish, based on the best available information.

Deleted: the projected size of the winter-run year class (and thus the extent of habitat needed);

The Calfed Science Program peer review report on temperature management emphasized the importance of refining temperature management practices in the long term and included recommendations for doing so. The requirement to hire an independent contractor to recommend specific refinements to the procedures in this RPA responds to these recommendations.

Rationale for 2017 Amendment:

- Best available science (*e.g.*, Martin *et al.* 2016[14]) and monitoring (*e.g.*, rotary screw trapping at Red Bluff Diversion Dam) since issuance of the 2009 CVP/SWP operations Opinion have indicated that 56°F DAT is not as protective as historically required for minimizing adverse temperature related effects on incubating eggs and alevin. Martin *et al.* (2016) predicted that the slower flowing water in the river would not supply the oxygen needed for egg viability in elevated temperature conditions, and that field studies found that the slower flow in the river equated to about a 3ºC difference in the temperature tolerance of eggs.
- EPA (2003) recommends 55°F 7DADM for incubating Chinook salmon eggs and alevin. Anderson *et al.* (2010, 2011) and EPA (2003) recommend temperature management to the downstream most redds.

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[14] Martin, B. T., A. Pike, S. N. John, N. Hamda, J. Roberts, S. T. Lindley, and E. M. Danner. 2016. Phenomenological vs. biophysical models of thermal stress in aquatic eggs. Ecology Letters (2016).

- A DAT (maintaining 56.0°F further downstream or 53°F at the downstream-most redd) is provided as a surrogate to 55.0°F 7DADM to provide operational flexibility and allow for a pilot study to be conducted.
- The SWIM Team was created in 2016 to monitor the implementation of the Sacramento River temperature management plan. The SWIM Team member agencies found the regular meetings helpful in both accountability to the temperature management plan, and also would provide the member agencies enough time in case operational adjustments are necessary.

Action I.2.4.1 Post Temperature Compliance Season Winter-Run Egg-to-Fry Survival Evaluation

Objective: To adaptively manage operations in subsequent years in order to minimize egg and fry mortality, as estimated using the temperature-dependent mortality model.

Action: Planned operations or other non-operational actions in subsequent years shall be adjusted in order to improve egg-to-fry survival, if necessary. Based on the 1996-2015 average egg-to-fry survival of 23.6% (27% prior to the drought), Reclamation shall achieve the following egg-to-fry survival metrics:

- Critically dry years: >15%
- Dry years: >20%
- Below Normal years: >25%
- Above Normal years: >25%
- Wet years: >25%

Rationale: Each year, the egg-to-fry survival to the Red Bluff Diversion Dam is calculated after the temperature management season. This measure is used to assess how well Reclamation did in operations to protect the early life stages of winter-run Chinook salmon. Annual hindcasts and associated reports are critical in understanding the effects of various operations of Shasta and Keswick dams and reservoirs.

Action I.2.5. Winter-Run Passage and Re-Introduction Program at Shasta Dam

See Fish Passage Program, Action V

Action I.2.6. Restore Battle Creek for Winter-Run, Spring-Run, and CV Steelhead

Objective: To partially compensate for unavoidable adverse effects of project operations by restoring winter-run and spring-run to the Battle Creek watershed. A second population of winter-run would reduce the risk of extinction of the species from lost resiliency and increased vulnerability to catastrophic events.

shall provide an annual report to NMFS on implementation and effectiveness of projects. Reclamation shall monitor and maintain these projects for five years.

Rationale: During interim operations, late arriving spring-run may be adversely affected by the dam after June 14. Construction and maintenance of the interim pumping facility also may have short-term adverse effects on spring-run.

The proposed passage restoration projects are likely to benefit the spring-run ESU as a whole by improving access to spawning habitat for some of the key populations within the ESU. Although the proposed improvements will not provide passage benefits to the small dependent populations that spawn upstream of RBDD, they will benefit the large independent populations that spawn in downstream tributaries. Passage improvements for the large independent population, in turn, will benefit the smaller populations throughout the Central Valley that depend on these larger populations to supplement their numbers and genetic diversity.

Action I.4. Wilkins Slough Operations

Objective: Enhance the ability to manage temperatures for anadromous fish below Shasta Dam by operating Wilkins Slough in the manner that best conserves the dam's cold water pool for summer releases.

Action: Reclamation shall convene the SRTTG to review past operational data, hydrology, and fisheries needs and recommend Wilkins Slough minimum flows for anadromous fish in critically dry years in lieu of the current 5,000 cfs navigation criterion.

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In years other than critically dry years**,** the need for a variance from the 5,000 cfs navigation criterion will be considered during the process of developing the Keswick release schedules (Action I.2.2-4).

Without SRTTG recommendations on Wilkins Slough minimum flows, Reclamation shall operate to Wilkins Slough flows less than 5,000 cfs, depending on Shasta storage, water year type, Delta requirements, and consultation with the fish agencies.

Rationale: In some circumstances, maintaining the Wilkins Slough navigation channel at 5,000 cfs may be a significant draw on Shasta reservoir levels and affect the summer cold water pool necessary to maintain suitable temperatures for winter-run spawning, egg incubation, and fry emergence. Reclamation has stated that it is no longer necessary to maintain 5,000 cfs for navigation (CVP/SWP operations BA, page 2-39), but may be critical to maintain other system-wide requirements. Operating to a minimal flow level based on fish needs, rather than on outdated navigational requirements, could enhance the ability to use cold-water releases to maintain cooler summer temperatures in the Sacramento River.

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Rationale for 2017 amendment: The deadline for the development of Wilkins Slough minimum flows was December 1, 2009, and NMFS is not aware of any current effort by Reclamation to develop those minimum flows. Water year 2014 was a critically dry water year type, and minimum flows at Wilkins Slough were reduced to 3,800 cfs at times. Reduced flows at Wilkins Slough will be made in lieu of Reclamation meeting the original RPA action.

Action I.5. Funding for CVPIA Anadromous Fish Screen Program (AFSP)

Objective: To reduce entrainment of juvenile anadromous fish from unscreened diversions.

Action: Reclamation shall screen priority diversions as identified in the CVPIA AFSP, consistent with previous funding levels for this program. In addition, Reclamation/CVPIA Program shall evaluate the potential to develop alternative screened intakes that allow diverters to withdraw water below surface levels required by the antiquated Wilkins Slough navigation requirement criterion of 5,000 cfs.

Rationale: Approximately ten percent of 129 CVP diversions listed in Appendix D-1 of the CVP/SWP operations BA are currently screened. Of these, most of the largest diversions (greater than 250 cfs) have already been screened; however, a large number of smaller diversions (less than 250 cfs) remain unscreened or do not meet NMFS fish screening criteria (NMFS 1997; *e.g.,* CVP and SWP Delta diversions, Rock Slough diversion). The AFSP has identified priorities for screening that is consistent with the needs of listed fish species. Screening will reduce the loss of listed fish in water diversion channels. In addition, if new fish screens can be extended to allow diversions below 5,000 cfs at Wilkins Slough, then cold water can be conserved during critically dry years at Shasta Reservoir for winter-run and spring-run life history needs.

Action Suite I.6: Sacramento River Basin Salmonid Rearing Habitat Improvements

Objective: To restore floodplain rearing habitat for juvenile winter-run, spring-run, and CV steelhead in the lower Sacramento River basin, to compensate for unavoidable adverse effects of project operations. This objective may be achieved at the Yolo Bypass, and/or through actions in other suitable areas of the lower Sacramento River.

The suite of actions includes near term and long-term actions. The near-term action (Action I.6.2) is ready to be implemented and can provide rearing benefits within two years of issuing this Opinion. The long-term actions (Actions I.6.1, I.6.3, and I.6.4) require additional planning and coordination over a five- to ten-year time frame.

These actions are consistent with Reclamation's broad authorities in CVPIA to develop and implement these types of restoration projects. When necessary to achieve the overall objectives of this action, Reclamation and DWR, in cooperation with other agencies and funding sources, Monitoring protocols shall follow established procedures utilized by the USFWS, CDFW, Reclamation, and DWR. Information collected from the monitoring programs will be used to make real-time decisions regarding DCC gate operation and export pumping.

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The DOSS group (Action IV.5) and WOMT will use information from monitoring to make decisions regarding DCC closures consistent with procedures below.

The DCC gate operations in the fall are initiated through a series of alerts. These alerts are signals that gate operations may need to be altered in the near future to avoid diversion of juvenile Chinook salmon migrating down the Sacramento River.

There are two initial alerts to warn of salmon presence in the system:

First Alert: There are two components to the first alert. Either condition, when met or identified, can trigger the alert. Tributary flow increases on Mill and Deer creeks are used to signal conditions conducive to emigration of yearling spring-run Chinook salmon. Starting in October, an daily average flow >95 cfs or an increase in the daily average tributary flow of more than 50 percent is used to indicate the appropriate cues for the initiation of salmon emigration[19].

Deleted: Capture of yearling-sized (> 70 mm) spring-run at the mouths of natal tributaries between October and April indicates that emigration from the tributaries has started or is occurring. As an environmental surrogate to the capture of the yearling-sized spring-run, which are difficult to capture in the rotary screw traps at the mouths of the natal tributary creeks, t

Deleted: over levels immediately preceding the flow spike

Second Alert: The second alert is based on two physical hydrologic criteria. When both criteria are met the second alert is triggered. The monitoring station used for these environmental measurements is Wilkins Slough, located near Knights Landing approximately 35 miles upstream of the Delta. When flows are greater than 7,500 cfs as measured at Wilkins Slough, and water temperatures are less than 13.5ºC (56.3ºF) as measured at Knights Landing, the second alert is triggered. Recoveries of emigrating Chinook salmon at the Knights Landing monitoring location have been associated with these two hydrologic conditions.

Rationale: Monitoring programs are necessary to track the movement of salmon within the Central Valley watersheds so that timely changes can be made when project actions are in conflict with the needs of listed fish. Evidence of initiation of juvenile Chinook salmon migration in the upper tributaries, or environmental conditions that would trigger such migration, is the basis for the alerts. The alerts are important to effective gate operation because the collection and dissemination of field data to the resource agencies, and coordination of responsive actions, may take several days to occur. The first two alerts warn NMFS and Reclamation that changes in DCC gate operations are likely to be necessary within a short time period.

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[19] The first significant flow in October is associated with the beginning of spring-run yearling emigration from natal tributaries - an indication that those fish are on their seaward migration and will soon be entering the Delta where they are susceptible to mortality factors associated with the Delta Cross Channel (DCC) and SWP/CVP export operations. This first tributary flow event, or “First Alert”, is the early warning criteria for closing the DCC.

Rationale for 2017 amendment: The first component of the first alert was modified to a flow criterion in lieu of operating the Mill and Deer creek rotary screw traps becaue utilizing a hydrologic criterion will increase the survival of juvenile spring-run Chinook salmon emigrating from Mill and Deer creeks by eliminating the mortality of juvenile spring-run as a result of the RST monitoring. Analysis of the data collected on Mill and Deer creeks indicates that only 1 percent of yearling spring-run Chinook salmon catch was observed to occur at flows less than 95 cfs, while approximately 15 percent of observed yearling spring-run Chinook salmon catch occurred at flows less than 110 cfs.

Action IV.1.2 DCC Gate Operation

Objective: Modify DCC gate operation to reduce direct and indirect mortality of emigrating juvenile salmonids and green sturgeon in November, December, and January.

Action: During the period between November 1 and June 15, DCC gate operations will be modified from the proposed action to reduce loss of emigrating salmonids and green sturgeon. The operating criteria provide for longer periods of gate closures during the emigration season to reduce direct and indirect mortality of yearling spring-run, winter-run, and CV steelhead. From December 1 to January 31, the gates will remain closed, except as operations are allowed using the implementation procedures/modified Salmon Decision Tree (below).

Implementation procedures: Monitoring data related to triggers in the decision tree will be reported on Daily Assessment Team calls and evaluated by DOSS (for formation of DOSS – see Action IV.5). Reclamation/DWR shall take actions within 24 hours of a triggered condition occurring. If the decision tree requires an evaluation of data or provides options, then DOSS shall convene within one day of the trigger being met. DOSS shall provide advice to NMFS, and the action shall be vetted through WOMT standard operating procedures.

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Rationale for 2011 amendment: "KK" was a typographical error in the 2009 RPA, intended to be a placeholder until the number for action that describes the formation of DOSS was identified.

October 1-November 30:

Date	VI. Action Triggers	Action Responses
October 1-November 30	Water quality criteria per D-1641 are met and either the Knights Landing Catch Index (KLCI) or the Sacramento Catch Index (SCI) are greater than 3 fish per day but less than or equal to 5 fish per day.	Within 24 hours of trigger, DCC gates are closed. Gates will remain closed for 3 days.

Enclosure 2

Clean Version of the 2011 Amended Reasonable and Prudent Alternative

Revised to Include the 2017 Amendments

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Table of Contents

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11.0 REASONABLE AND PRUDENT ALTERNATIVE

11.1 OVERVIEW

11.1.1 Approach to the RPA

If NMFS finds that a proposed action is likely to jeopardize a listed species or adversely modify its critical habitat, the ESA requires NMFS to suggest those reasonable and prudent alternatives that it believes would enable the project to go forward in compliance with the ESA. By regulation, a RPA is defined as "alternative actions identified during formal consultation that can be implemented in a manner consistent with the intended purpose of the action, that can be implemented consistent with the scope of the Federal agency's legal authority and jurisdiction, that is economically and technologically feasible, and that the [NMFS] Director believes would avoid the likelihood of jeopardizing the continued existence of listed species or resulting in the destruction or adverse modification of critical habitat" (50 CFR 402.02).

Regulations also require that NMFS discuss its findings and any RPAs with the action agency and utilize the action agency's expertise in formulating the RPA, if requested (50 CFR 402.14(g)(5)). This RPA was developed through a thoughtful and reasoned analysis of the key causes of the jeopardy and adverse modification findings, and a consideration of alternative actions within the legal authority of Reclamation and DWR to alleviate those stressors. NMFS has worked closely with Reclamation and DWR staff and greatly appreciates the expertise contributed by these agencies.

Because this complex action takes place in a highly altered landscape subject to many environmental stresses, it has been difficult to formulate an RPA that is likely to avoid jeopardy to all listed species and meets all regulatory requirements. As detailed in this Opinion, the current status of the affected species is precarious, and future activities and conditions not within the control of Reclamation or DWR are likely to place substantial stress on the species. NMFS initially attempted to devise an RPA for each species and its critical habitat solely by modifying project operations (*e.g.*, timing/magnitude of releases from dams, closure of operable gates and barriers, and reductions in negative flows). In some cases, however, simply altering project operations was not sufficient to ensure that the projects were likely to avoid jeopardizing the species or adversely modifying critical habitat.

Consequently, NMFS developed focused actions designed to compensate for a particular stressor, considering the full range of authorities that Reclamation and DWR may use to implement these actions. These authorities are substantial. The CVPIA, in particular, provides Reclamation with ample authority to provide benefits for fish and wildlife through measures such as purchasing water to augment in-stream flow, implementing habitat restoration projects, and taking other beneficial actions (Cummins *et al.,* 2008). Some RPA actions, therefore, call for restoring habitat or providing fish passage above dams, even though the water projects are not directly responsible for the impaired habitat or the blocked passage.

NMFS concentrated on actions that have the highest likelihood of alleviating the stressors with the most significant effects on the species, rather than attempting to address every project stressor for each species or every PCE for critical habitat. For example, water temperatures lethal to incubating eggs often occur when the air is warm and flows are low. Fish cannot reach spawning habitat with colder water at higher elevations if it is above currently impassable dams. Accordingly, NMFS' near-term measures provide suitable water temperatures below dams in a higher percentage of years, and long-term measures provide passage to cooler habitat above dams as soon as practicable. Reducing egg mortality from high water temperatures is a critical step in slowing or halting the decline of Central Valley salmonids.

The effects analysis in this Opinion explains that the adverse effects of the proposed action on listed anadromous fish and their critical habitats are both direct and indirect. The USFWS stated in its biological opinion on effects of the projects on Delta smelt that in addition to direct adverse effects such as entrainment at the pumps, the water projects have affected smelt "by creating an altered environment in the Delta that has fostered both the establishment of non-indigenous species and habitat conditions that exacerbate their adverse influence on delta smelt population dynamics." (USFWS 2008a, p. 189) Similarly, NMFS concludes that the water projects have both directly altered the hydrodynamics of the Sacramento-San Joaquin River basins and have interacted with other activities affecting the Delta to create an altered environment that adversely influences salmonid and green sturgeon population dynamics. The altered environment includes changes in habitat formation, species composition, and water quality, among others. Consequently, NMFS must take a broad view of the ways in which the project agencies can improve the ecosystem to ameliorate the effects of their actions.

There are several ways in which water operations adversely affect listed species that are addressed in this RPA. We summarize the most significant here:

1) Water operations result in elevated water temperatures that have lethal and sub-lethal effects on egg incubation and juvenile rearing in the upper Sacramento River. The immediate operational cause is lack of sufficient cold water in storage to allow for cold water releases to reduce downstream temperatures at critical times and meet other project demands. This elevated temperature effect is particularly pronounced in the Upper Sacramento for winter-run and mainstem spring-run, and in the American River for steelhead. The RPA includes a new year-round storage and temperature management program for Shasta Reservoir and the Upper Sacramento River, as well as long-term passage prescriptions at Shasta Dam and re-introduction of winter-run into its native habitat in the McCloud and/or Upper Sacramento rivers.

2) In Clear Creek, recent project operations have led to increased abundance of Clear Creek spring-run, which is an essential population for the short-term and long-term survival of the species. Nonetheless, in the proposed action, continuation of these operations is

uncertain. The RPA ensures that essential flows and temperatures for holding, egg incubation and juvenile survival will be maintained.

3) Red Bluff Diversion Dam (RBDD) on the Sacramento River impedes both upstream migration of adult fish to spawning habitat and downstream migration of juveniles. Effects are significant for winter-run and spring-run, but are particularly pronounced for green sturgeon and its proposed critical habitat in that a significant portion of the population is blocked from its spawning and holding habitat. The RPA mandates gate openings at critical times in the short term while an alternative pumping plant is built, and, by 2012, opening of the gates all year.

4) Both project and non-project effects have led to a significant reduction in necessary juvenile rearing habitat in the Sacramento River Basin and Delta. The project's flood control operations result in adverse effects through reduced frequency and magnitude of inundation of rearing habitat. To minimize these effects, the RPA contains both short-term and long-term actions for improving juvenile rearing habitat in the Lower Sacramento River and northern Delta.

5) Another major effect of water operations is diversion of out-migrating juveniles from the north Delta tributaries into the interior Delta through the open DCC gates. Instead of migrating directly to the outer estuary and then to sea, these juveniles are caught in the interior Delta and subjected to pollution, predators, and altered food webs that cause either direct mortality or impaired growth. The RPA mandates additional gate closures to minimize these adverse effects to winter-run, spring-run, and steelhead.

6) Similarly, water pumping causes reverse flows, leading to loss of juveniles migrating out from the Sacramento River system in the interior Delta and more juveniles being exposed to the State and Federal pumps, where they are salvaged at the facilities. The RPA prescribes Old and Middle River flow levels to reduce the number of juveniles exposed to the export facilities and prescribes additional measures at the facilities themselves to increase survival of fish.

7) The effects analysis shows that juvenile steelhead migrating out from the San Joaquin River Basin have a particularly high rate of loss due to both project and non-project related stressors. The RPA mandates additional measures to improve survival of San Joaquin steelhead smolts, including both increased San Joaquin River flows and export curtailments. Given the uncertainty of the relationship between flow and exports, the RPA also prescribes a significant new study of acoustic tagged fish in the San Joaquin Basin to evaluate the effectiveness of the RPA and refine it over the lifetime of the project.

8) On the American River, project-related effects on steelhead are pronounced due to the inability to consistently provide suitable temperatures for various life stages and flow-

related effects caused by operations. The RPA prescribes a flow management standard, a temperature management plan, additional technological fixes to temperature control structures, and, in the long term, a passage at Nimbus and Folsom Dams to restore steelhead to native habitat.

9) On the Stanislaus River, project operations have led to significant degradation of floodplain and rearing habitat for steelhead. Low flows also distort cues associated with out-migration. The RPA proposes a year-round flow regime necessary to minimize project effects to each life-stage of steelhead, including new spring flows that will support rearing habitat formation and inundation, and will create pulses that cue out-migration.

10) Nimbus Fish Hatchery steelhead program contribute to both loss of genetic diversity and mixing of wild and hatchery stocks of steelhead, which reduces the viability of wild stocks. The Nimbus and Trinity River Hatchery programs for non-listed fall-run also contribute to a loss of genetic diversity, and therefore, viability, for fall-run. The RPA requires development of Hatchery Genetics Management Plans to improve genetic diversity of both steelhead and fall-run, an essential prey base of Southern Resident.

This RPA is composed of numerous elements for each of the various project divisions and associated stressors and must be implemented in its entirety in order to avoid jeopardy and adverse modification. There are several actions that allow the project agencies options for alleviating a particular stressor. Reclamation and DWR may select the option they deem most practical — NMFS cares only that the stressor be sufficiently reduced. There are several actions in which NMFS expressly solicits additional research and suggestions from the project agencies for alternative actions to achieve needed results.

NMFS recognizes that the RPA must be an alternative that is likely to avoid jeopardizing listed species or adversely modifying their critical habitats, rather than a plan that will achieve recovery. Both the jeopardy and adverse modification standards, however, include consideration of effects on an action on listed species' chances of recovery. NMFS believes that the RPA does not reduce the likelihood of recovery for any of the listed species. The RPA cannot and does not, however, include all steps that would be necessary to achieve recovery. NMFS is mindful of potential social and economic consequences of reducing water deliveries and has carefully avoided prescribing measures that are not necessary to meet section 7 requirements.

An RPA must avoid jeopardy to listed species in the short term, as well as the long term. Essential short-term actions are presented for each division and are summarized for each species to ensure that the likelihood of survival and recovery is not appreciably reduced in the short term (*i.e.*, one to five years). In addition, because the proposed action is operation of the CVP/SWP until 2030, this consultation also includes long-term actions that are necessary to address project-related adverse effects on the likelihood of survival and recovery of the species over the next two decades.

Some of these long-term actions will require evaluation, planning, permitting, and funding. These include:

1) Providing fish passage at Shasta, Nimbus, and Folsom Dams, which ultimately is the only means of counteracting the loss of habitat needed for egg incubation and emergence, and steelhead over-summering habitat at lower elevations. This habitat loss has already occurred and will be exacerbated by climate change and increased water demands.

2) Providing adequate rearing habitat on the lower Sacramento River and Yolo Bypass through alteration of operations, weirs, and restoration projects.

3) Engineering projects to further reduce hydrologic effects and indirect loss of juveniles in the interior Delta.

4) Technological modifications to improve temperature management in Folsom Reservoir.

NMFS considered economic and technological feasibility in several ways when developing initial actions in this RPA. The RPA also allows for tailored implementation of many actions in consideration of economic and technological feasibility without compromising the RPA's effectiveness in avoiding jeopardy and adverse modification of critical habitat. Examples include:

1) Providing reasonable time to develop technologically feasible alternatives where none are "ready to go" – *e.g.*, the Delta engineering action (Action IV.1.3), and lower Sacramento River rearing habitat action (Action I.6.1).

2) Calling for a stepped approach to fish passage at dams, including studies and pilot projects, prior to a significant commitment of resources to build a ladder or invest in a permanent trap and haul program.

3) Providing a health and safety exception for export curtailments.

4) Using monitoring for species presence to initiate actions when most needed.

NMFS examined water supply costs of the RPA as one aspect of considering economic feasibility. While only costs to the action agency are considered in determining whether a RPA meets the regulatory requirement of economic feasibility, NMFS is mindful of potential social and economic costs to the people and communities that historically have depended on the Delta for their water supply. Any water supply impact is undesirable. NMFS made many attempts through the iterative consultation process to avoid developing RPA actions that would result in high water costs, while still providing for the survival and recovery of listed species.

NMFS estimates the water costs associated with the RPA to be 5-7% of average annual combined exports: 5% for CVP, or 130 thousand acre-feet (TAF)/year, and 7% for SWP, or 200 TAF/year[1]. The combined estimated annual average export curtailment is 330 TAF/year. These estimates are over and above export curtailments associated with the USFWS smelt Opinion. The OMR restrictions inn both Opinions tend to result in export curtailments of similar quantities at similar times of year. Therefore, in general, these 330 TAF export curtailments are associated with the NMFS San Joaquin River Ratio actions in the RPA. These water costs can be offset by application of b(2) water resources, water conservation, groundwater use, water recycling and toher processes currently underway.

The RPA includes collaborative research to enhance scientific understanding of the species and ecosystems, and to adapt actions to new scientific knowledge. This adaptive structure is important, given the long-term nature of the consultation and the scientific uncertainty inherent in a highly variable system. Monitoring and adaptive management are both built into many of the individual actions and are the subject of an annual program review. NMFS views both the CALFED Science Program and the NMFS Southwest Fisheries Science Center as essential partners in ensuring that the best scientific experts are brought together to assess the implementation and effectiveness of actions in this RPA. We will continue to pursue many of the long-term recommendations for improving science as recommended by the CALFED and CIE peer reviews, and we will seek to incorporate this new science as it becomes available through the adaptive management processes embedded in the RPA.

Finally, we note that the project agencies are currently developing and evaluating a plan to construct a diversion on the Sacramento River and a canal around the Delta, in the BDCP planning effort. Such a reconfiguration of the water conveyance system would take careful planning to avoid jeopardizing Sacramento River and north Delta species, as well as several years of environmental review and permitting, and would trigger a re-initiation of this Opinion. We expect that the collaborative research that is part of this RPA will inform this planning effort as it proceeds.

11.1.2 Organization of the RPA

The specific actions in the RPA are detailed in Section 11.2. That section begins with overarching actions that apply to operations in all geographic divisions of the project, including procedures for orderly functioning of the many technical teams that assist with decision making, research and adaptive management, and monitoring. These are followed by actions specific to each geographic division of the proposed action: Sacramento River, American River, East Side (Stanislaus River), and the Delta. There is a suite of actions for each geographic area. Section 11.2 concludes with subsections regarding fish passage at dams and modification of hatchery practices.

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[1] The proportion share between the CVP and SWP is attributable to CalLite programming and may not represent the true share of export reductions that would be allocated to each facility under actual conditions.

Section 11.3 is a species-by-species explanation of: (1) how each measure contributes to avoiding jeopardy or adverse modification for that species; and (2) the basis for NMFS' conclusion that the RPA measures as a whole are likely to avoid jeopardizing the species or adversely modifying its critical habitat. The information is presented in both narrative and table form. The narrative provides an overview, while the tables add detail. This section also address the other regulatory criteria necessary for a Reasonable and Prudent Criteria.

11.2 Reasonable and Prudent Alternative – Specific Actions

11.2.1. Decision-Making Procedures, Monitoring and Adaptive Management Protocols

11.2.1.1 Responsibilities and Procedures of Technical Teams

There are currently four Fisheries and Operations Technical Teams whose function is to make recommendations for adjusting operations to meet contractual obligations for water delivery and minimize adverse effects on listed anadromous fish species:

- Sacramento River Temperature Task Group (SRTTG)
- Clear Creek Technical Working Group (CCTWG)
- American River Group (ARG)
- San Joaquin River Technical Committee (SJRTC)

This RPA requires the creation of three additional technical teams:

- Delta Operations for Salmon and Sturgeon (DOSS) Group
- Stanislaus Operations Group (SOG)
- Interagency Fish Passage Steering Committee

Each group has responsibility to gather and analyze information, and make recommendations, regarding adjustments to water operations within the range of flexibility prescribed in the implementation procedures for a specific action in their particular geographic area. Under previous operations plans, recommendations for adjustments were made to the Water Operations Management Team (WOMT), a management-level group of representatives of Reclamation, DWR, CDFW, NMFS, and USFWS. The WOMT then made recommendations to state and regional directors for final action.

The Project Description for the proposed action (Appendix 1 to this Opinion), as revised by this RPA, establishes the responsibilities of each technical team. The RPA establishes the operations parameters that are necessary to avoid jeopardizing listed species or adversely modifying their critical habitat. Within those parameters, there is flexibility to adjust actions within a specified range based on current conditions. The allowed range of flexibility is prescribed in the "implementation procedures" portion of the RPA action. The technical teams and the WOMT will work within those implementation procedures to meet discretionary water contract obligations to the greatest extent consistent with survival and recovery of listed species. The teams also may recommend changes to the measures in this RPA, as detailed in the Research and Adaptive Management section of the RPA. Recommended changes outside the range of flexibility specified in the implementation procedures must receive written review and concurrence by NMFS and may trigger re-initiation.

This action prescribes standard operating procedures for decision-making that will apply to all teams.

1) Within 90 days of issuance of this Opinion, Reclamation shall send to the WOMT members a list of current members of each technical team. The WOMT representatives shall review the membership and make changes, if necessary. All groups shall include members with expertise in fish biology and hydrology. Each group shall designate a group leader to convene meetings and assure that necessary administrative steps are taken, such as recording and distributing meeting notes and recommendations.

2) Each group shall establish a regular meeting schedule at the beginning of each year, based on the anticipated need for adjustments to operations, and distribute the schedule to the members of the group. The group leader may reschedule a meeting, or call a special meeting, with three days notice at his or her discretion, or on request of NMFS or any two or more group members.

3) Brief notes of each meeting shall be recorded, including issues considered, recommendations made, and key information on which recommendations were based. Meeting notes shall be distributed to members within two days of the meeting.

4) Within one day after a technical team advises that an operational action should be initiated, changed, suspended, or terminated, consistent with the implementation procedures specified for actions in this RPA, the group leader shall provide to NMFS and Reclamation written advice and a biological rationale. The technical teams shall use the process described in the applicable RPA implementation procedures to provide a framework for their analysis. NMFS shall determine whether the proposed action is consistent with the implementation procedures in this RPA. If NMFS determines that the proposed action is consistent with the implementation procedures, then it avoids jeopardy to listed species or adverse modification of critical habitat. Both the technical team's advice and NMFS' recommendation shall be presented to the WOMT for discussion and concurrence. In the event that there is not consensus at the workgroup level, the workgroup leader shall convey the options and summary of the technical discussion to NMFS for consideration. NMFS will make a recommendation for action within the procedural guidelines of this RPA. NMFS will present its recommendations to the WOMT for discussion and concurrence (see #6 below).

5) If the recommended action will affect species within the jurisdiction of USFWS as well as NMFS, the technical team making the recommendation shall, to the extent that time allows, first coordinate with the Smelt Working Group (SWG). The technical team and the SWG, to the extent feasible, shall jointly make a recommendation to USFWS and NMFS (the Services), who will jointly determine whether the recommended action is consistent with the actions and implementation procedures of this RPA and is, therefore, necessary to avoid jeopardy to listed species and adverse modification of critical habitat. The Services shall then present their findings and recommendations to the WOMT.

6) The WOMT shall either concur with NMFS' (or the Services', as appropriate) recommendation or provide a written alternative to the recommendation, with biological justification, to NMFS (or the Services) within one calendar day. NMFS (or the Services) shall then make a determination as to whether the action proposed by the WOMT is consistent with this Opinion and ESA obligations.

7) Once NMFS (or the Services) makes a final determination that a proposed operational action is consistent with ESA obligations, Reclamation and DWR shall implement the operational action within two calendar days. Reclamation and DWR shall submit to NMFS (or the Services) data demonstrating the implementation of the action on a weekly basis, or post their operations on their website.

8) The action shall remain in effect until NMFS (or the Services), with advice from the appropriate technical team(s), determines that it should be modified or terminated as inconsistent with the implementation procedures for the RPA. The action shall be modified or terminated within two calendar days of such a determination.

9) These procedures may be modified for a particular team or working group by mutual agreement of NMFS and Reclamation. Modifications to the procedures shall be in writing, dated, and promptly distributed to all members of the group.

11.2.1.2. Research and Adaptive Management

Not later than November 30 of every year, in conjunction with the CALFED Science Program or other Science Peer Review process, Reclamation and NMFS shall host a workshop to review the prior water years' operations and to determine whether any measures prescribed in this RPA should be altered in light of information learned from prior years' operations or research. After completion of the annual review, NMFS may initiate a process to amend specific measures in this RPA to reflect new information, provided that the amendment is consistent with the Opinion's underlying analysis and conclusions and does not limit the effectiveness of the RPA in avoiding jeopardy to listed species or adverse modification of critical habitat. NMFS will ask the appropriate informational and technical teams to assess the need for a particular amendment and make recommendations to NMFS, according to the group processes for decision-making set forth in this RPA in action 11.2.1.1 above.

2011 Amendment: In the Fall of 2010, the Delta Stewardship Council convened an Independent Review Panel (IRP) to assist in the annual review required in this action[2]. On November 8-9, 2010, the Delta Science Program held a workshop to provide the IRP a forum for presentations and discussion of previously submitted technical reports. Following the workshop, the IRP produced a report that included recommendations for adjustments to the RPA, based on information presented in the review process. The IRP Report was finalized on December 9, 2010 (Anderson *et al*. 2010; http://www.deltacouncil.ca.gov/delta_science_program/events/workshop_OCAP_2010.html). NMFS has amended the RPA consistent with the IRP recommendations and this Opinion's underlying analysis and conclusions[3]. This amended RPA supersedes the 2009 RPA.

2017 Amendment: This amendment is based on the following considerations:

1) Operations of Shasta and Keswick reservoirs were the subject of multiple annual reviews. Shasta operations were one of the main focuses in the 2015 annual review.
2) On August 2, 2016, Reclamation requested reinitiation of the entire CVP/SWP operations consultation, citing new information related to multiple years of drought and recent data demonstrating extremely low population levels of endangered Sacramento River winter-run Chinook salmon[4]. In an August 17, 2016, response letter to Reclamation, NMFS agreed to reinitiate consultation[5].
3) New science and temperature survival models are available to describe conditions that may be necessary to provide suitable winter-run spawning, egg incubation, and fry emergence throughout the temperature management season.
4) Since the 2011 amendment, there have been clarifications and adaptive management changes made that are reflected in this 2017 amendment to update the RPA.

NMFS has amended the RPA to reflect new best available scientific and commercial information and based on observed Sacramento River conditions during the drought years 2014-2016. This amendment is consistent with the 2009 Opinion's underlying analysis and conclusions. Rationale provided for the specific changes within explains the need for the change and how it meets the objectives of the specific RPA actions. This amended RPA supersedes the 2009 RPA with 2011 amendments.

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[2] Under direction from the Secretaries of Commerce and Interior, the NMFS review was expanded to include a review of the implementation of the FWS' 2008 OCAP Opinion. The integrated review provided an opportunity to assure that the NMFS and FWS RPAs worked together in an ecosystem context.

[3] In addition, NMFS has taken this opportunity to correct some errors in the 2009 RPA. All changes are noted and explained in the "Rationale for 2011 amendment" sections accompanying the amendments.

[4] http://www.westcoast.fisheries.noaa.gov/publications/Central_Valley/Water%20Operations/bureau_of_reclamation_s_request_to_reinitiate_the_2009_cvpswp_operations_consultation_-_august_2__2016.pdf

[5] http://www.westcoast.fisheries.noaa.gov/publications/Central_Valley/Water%20Operations/nmfs_response_to_reclamation_s_request_to_reinitiate_the_2009_cvpswp_operations_consultation_-_august_17__2016.pdf

The purpose of the amendment is to set interim operational changes that are necessary at this time, based on aforementioned circumstances, to reflect new best available scientific and commercial information, and lessons learned from operations during the drought conditions throughout water years 2014-2016.

Amendments to the Shasta RPA actions will be issued in a phased approach. The majority of changes have associated monitoring and analytical requirements. These requirements, combined with ongoing collaborative science, and refinement of temperature forecasting models, will iteratively inform implementation of the amended actions in subsequent water years and overall success of meeting the biological objectives identified for the RPA actions, that may warrant a subsequent amendment. Changes made within the 2017 amendment, including new and refined tools and monitoring, will further be used to inform the larger reconsultation of CVP/SWP operations. Reconsultation will provide a comprehensive analysis of integrated operations.

NMFS and Reclamation will establish a research program in coordination with the Delta Science Program and other agencies to address key research and management questions arising from this Opinion. Prior to the beginning of a new calendar year, Reclamation shall submit to NMFS a research plan for the following year, developed in coordination with the above programs and agencies. Reclamation also shall provide NMFS access to all draft and final reports associated with this research. Specific research projects that have been identified as important to begin in the first year and complete as soon as possible are:

1) Cooperative development of a salmonid lifecycle model acceptable to NMFS, Reclamation, CDFW, and DWR

2) Temperature monitoring and modeling identified in RPA Action I.1.5

3) Green sturgeon research described in the RBDD actions

4) Rearing habitat evaluation metrics to guide rearing habitat Action 1.6

5) A 6-year acoustic-tagged study of juvenile salmonids out-migration in the San Joaquin River and through the southern Delta identified in Action IV.2.2.

11.2.1.3. Monitoring and Reporting

1) Reclamation and DWR shall participate in the design, implementation, and funding of the comprehensive CV steelhead monitoring program, under development through ERP, that includes adult and juvenile direct counts, redd surveys, and escapement estimates on CVP- and SWP-controlled streams. This program is necessary to develop better juvenile production estimates that form the basis of incidental take limits and will also provide necessary information to calculate triggers for operational actions.

2) Reclamation and DWR shall ensure that all monitoring programs regarding the effects of CVP and SWP operations and which result in the direct take of winter-run, spring-run, CV steelhead, or Southern DPS of green sturgeon, are conducted by a person or entity that has been authorized by NMFS. Reclamation and DWR shall establish a contact person to coordinate these activities with NMFS.

3) Reclamation and DWR shall submit weekly reports to the interagency Data Assessment Team (DAT) regarding the results of monitoring and incidental take of winter-run, spring-run, CV steelhead, and Southern DPS of green sturgeon associated with operations of project facilities.

4) Reclamation and DWR shall provide an annual written report to NMFS no later than October 1, following the salvage season of approximately October to May. This report shall provide the data gathered and summarize the results of winter-run, spring-run, CV steelhead, and Southern DPS of green sturgeon monitoring and incidental take associated with the operation of the Delta pumping plants (including the Rock Slough Pumping Plant). All juvenile mortality must be minimized and reported, including those from special studies conducted during salvage operations. This report should be sent to NMFS (West Coast Region, California Central Valley Office, 650 Capitol Mall, Suite 5-100, Sacramento, California 95814-4706).

5) Reclamation and DWR shall continue the real-time monitoring of winter-run, spring-run, CV steelhead, and Southern DPS of green sturgeon in the lower Sacramento River, the lower San Joaquin River, and the Delta to establish presence and timing to serve as a basis for the management of DCC gate operations and CVP and SWP Delta pumping operations consistent with actions in this RPA. Reclamation and DWR shall conduct continuous real-time monitoring between October 1 and June 30 of each year, commencing in 2009.

6) Reclamation and DWR shall submit weekly Data Assessment Team reports and an annual written report to NMFS describing the results of real-time monitoring of winter-run, spring-run, CV steelhead, and Southern DPS of green sturgeon associated with operations of the DCC and CVP and SWP Delta pumping facilities, and other Division level operations authorized through this RPA.

7) Reclamation shall coordinate with NMFS, the USFWS, and CDFW to continue implementation and funding of fisheries monitoring of spring-run and CV steelhead (including adult snorkel surveys, population estimates for steelhead, and rotary screw trapping) in Clear Creek to aide in determining the benefits and effects of flow and temperature management.

8) Monitoring Requirements: The following (A-E) are necessary to adaptively manage project operations and are either directly related to management of releases (*e.g.*,

temperature and flow), or are a necessary component of the Salmon Decision Process used to manage Delta operations (*e.g*., DCC gates and export pumping). Reclamation and DWR shall jointly fund these monitoring locations for the duration of the Opinion (through 2030) to ensure compliance with the RPA and assess the performance of the RPA actions. Most of these monitoring stations already exist and are currently being funded through a variety of sources (*i.e*., CDFW, USFWS, Reclamation, DWR, CALFED, and Interagency Ecological Program), however, CALFED funding for monitoring ends in 2009 and CDFW funding has been reduced due to budget cuts.

a) Upstream: Adult escapement and juvenile monitoring for spring-run, winter-run, and steelhead on the Sacramento River, American River, Feather River, Clear Creek, and Battle Creek. These may be performed through carcass surveys, redd surveys, weir counts, and rotary screw trapping. Unless prevented by circumstances beyond the control of Reclamation, aerial redd counts shall be conducted annually on the mainstem Sacramento River from Keswick Dam downstream to at least Tehama Bridge, from at least April through September. These surveys are necessary to determine the temporal and spatial distribution of winter-run and spring-run Chinook salmon. Exceptions to the annual aerial redd counts are allowed only when requested in writing (including the specific circumstance that may preclude the aerial redd surveys) and upon written concurrence by NMFS.

   Rationale for 2011 amendment: Aerial redd counts have been conducted annually at least since 2001. However, in water year 2010, they were conducted later in the winter-run Chinook salmon spawning season, and the SRTTG did not have the benefit of the temporal and spatial distribution data to inform its recommendation of a temperature compliance point. The IRP noted the confusion in the final establishment of the temperature compliance point: "It is not known why the compliance point was established downstream (Jelly's Ferry) when aerial redd surveys in 2010 indicated redds were upstream of Airport Road Bridge." (Anderson *et al*. 2010, page 12, note E).

b) RBDD: Adult counts using the three current fish ladders until the new pumping plant is operational. Rotary screw trapping to determine juvenile Chinook salmon passage or abundance year-round before and after pumping plant is operational. Green sturgeon monitoring, to include adult and juvenile estimates of passage, relative abundance, and run timing, in order to determine habitat use and population size with respect to management of Shasta Reservoir resources.
c) Sacramento River new juvenile monitoring station: The exact location to be determined, between RBDD and Knights Landing, in order to give early warning of fish movement and determine survival of listed fish species leaving spawning habitat in the upper Sacramento River.
d) Delta: Continuation of the following monitoring stations that are part of the IEP: Chipps Island Trawl, Sacramento Trawl, Knights Landings RST, and beach seining

program. Additionally, assist in funding new studies to determine green sturgeon relative abundance and habitat use in the Delta.

e) San Joaquin River monitoring shall include: Adult escapement and juvenile monitoring for steelhead on the Stanislaus River; Mossdale Kodiak Trawling to determine steelhead smolt passage; steelhead survival studies associated with VAMP; monitoring at HORB to determine steelhead movement in and around the barrier; predation studies in front of HORB and at the three agricultural barriers in the South Delta; and new studies to include the use of non-lethal fish guidance devices (*e.g.*, sound, light, or air bubbles) instead of rock barriers to keep juveniles out of the area influenced by export pumping.

11.2.2 Actions Listed by Division

I. SACRAMENTO RIVER DIVISION

<u>Introduction to the Sacramento River Division</u>: Project operations of the Sacramento River Division affect winter-run, spring-run, CV steelhead, the Southern DPS of green sturgeon. In addition, project operations affect fall-run, which are not listed. Fall-run salmon are considered in developing the actions as a prey base for Southern Residents. This Division section of the RPA includes actions related to minimizing adverse effects to spring-run and steelhead spawning and rearing in Clear Creek and all species in the main stem Sacramento River. Actions include those necessary to reduce the risk to temperature effects to egg incubation in the upper river, especially to winter-run and spring-run spawning below Shasta Dam. Also, the RPA contains actions for operation of RBDD – a major impediment to salmonid and green sturgeon migration. In addition, the RPA includes an action related to adjusting the antiquated Wilkins Slough navigation requirement, mandates the continuation of the fish screening program, and calls for restoration of essential rearing habitat in the lower river/northern Delta.

Operations of the Sacramento River Division are interconnected with those of the Trinity River Division. NMFS is in the process of conducting a separate consultation on the effects of the Trinity River Division operations on listed coho salmon in the Trinity River. NMFS is committed to ensuring appropriate coordination between the analysis and results of this Opinion and the forthcoming coho opinion. The Sacramento River Division RPA will be analyzed in that Opinion, and may be adjusted as necessary to avoid jeopardy to coho salmon and adverse modification of critical habitat.

<u>Action Suite I.1. Clear Creek</u>

Suite Objective: The proposed action includes a static flow regime (no greater than 200 cfs all year) and uncertainty as to the availability of b(2) water in the future pose significant risk to these species. The RPA actions described below were developed based on a careful review of past flow studies, current operations, and future climate change scenarios. Although not all of the flow studies have been completed, NMFS believes these actions are necessary to address adverse project effects on flow and water temperature that reduce the viability of spring-run and CV steelhead in Clear Creek.

Action I.1.1. Spring Attraction Flows

Objective: Encourage spring-run movement to upstream Clear Creek habitat for spawning.

Action: Reclamation shall annually conduct at least two pulse flows in Clear Creek in May and June of at least 600 cfs for at least three days for each pulse, to attract adult spring-run holding in the Sacramento River main stem. This may be done in conjunction with channel-maintenance flows (Action I.1.2).

Rationale: In order to prevent spring-run from hybridizing with fall-run in the Sacramento River, it is important to attract early spring-run adults as far upstream in Clear Creek as possible, where cooler water temperatures can be maintained over the summer holding period through releases from Whiskeytown Dam. This action will also prevent spring-run adults from spawning in the lower reaches of Clear Creek, where water temperatures are inadequate to support eggs and pre-emergent fry during September and October.

Action I.1.2. Channel Maintenance Flows

Objective: Minimize project effects by enhancing and maintain previously degraded spawning habitat for spring-run and CV steelhead

Action: Reclamation shall re-operate Whiskeytown Glory Hole spills during the winter and spring to produce channel maintenance flows of a minimum of 3,250 cfs mean daily spill from Whiskeytown for one day, to occur seven times in a ten-year period, unless flood control operations provide similar releases. Re-operation of Whiskeytown Dam should be implemented with other project facilities as described in the EWP Pilot Program (Reclamation 2008d).

Rationale: Channel maintenance flows are a necessary element of critical habitat (see PCEs) in order to restore proper functioning rivers. This modified operation allows higher flows necessary to move spawning gravels downstream from injection sites, which will increase the amount of spawning habitat available to spring-run and steelhead. Previous studies (McBain and Trush 1999) have shown that Clear Creek lacks sufficient gravel for spawning habitat. Both spring-run and steelhead need higher flows to provide the spawning and rearing habitat elements essential for survival and recovery.

Action I.1.3. Spawning Gravel Augmentation

Objective: Enhance and maintain previously degraded spawning habitat for spring-run and CV steelhead.

Action: Reclamation, in coordination with the Clear Creek Technical team, shall continue spawning gravel augmentation efforts. By December 31 each year, Reclamation shall provide a report to NMFS on implementation and effectiveness of the gravel augmentation program.

Rationale: Similar to above for Action I.1.2. Recent studies (USFWS 2007, 2008) have shown steelhead and spring-run utilize gravel injection sites for spawning. Gravel augmentation has increased the steelhead spawning habitat available in the lower reaches of Clear Creek and directly relates to higher abundance in recent years. The gravel augmentation program also benefits fall-run and late fall-run spawning. Including the gravel augmentation program in the RPA ensures that it is reasonably certain to occur in the future.

Action I.1.4. Spring Creek Temperature Control Curtain *(Note: This action benefits Sacramento River conditions, but is part of Clear Creek operations)*

Objective: Reduce adverse impacts of project operations on water temperature for listed salmonids in the Sacramento River.

Action: Reclamation shall replace the Spring Creek Temperature Control Curtain in Whiskeytown Lake by June 2011.

Rationale: The Spring Creek Tunnel releases provide cold water to Keswick Reservoir, which improves the ability to lower water temperatures during the summer for winter-run spawning and incubation. Recent underwater surveys concluded that the Whiskeytown Curtain is in poor condition and needs a major overhaul (Reclamation 2008b). Six rips in the fabric run the full depth of the curtain to 55 feet.

Action I.1.5. Thermal Stress Reduction

Objective: To reduce thermal stress to over-summering steelhead and spring-run during holding, spawning, and embryo incubation.

Action: Reclamation shall manage Whiskeytown releases to meet a daily average water temperature (DAT) of:

1) 60ºF at the Igo gage from June 1 through September 15; and

2) 56ºF at the Igo gage from September 15 to October 31.

Reclamation, in coordination with NMFS, will assess improvements to modeling water temperatures in Clear Creek and identify a schedule for making improvements.

Rationale: The water temperature criteria address the critical need for colder water that historically was available to salmonids above Whiskeytown Dam. If the criteria are not met, juvenile steelhead rearing habitat is limited, predation is higher, and disease is more prevalent. Spring-run adults need colder water to hold over during the summer until September. If water temperature is too warm, spring-run experience pre-spawn mortality and reduced production. The lower water temperature in September is necessary to reduce mortality of spring-run eggs and pre-emergent fry.

Action I.1.6. Adaptively Manage to Habitat Suitability/IFIM Study Results

Objective: Decrease risk to Clear Creek spring-run and CV steelhead population through improved flow management designed to implement state-of-the-art scientific analysis on habitat suitability.

Action: Reclamation shall operate Whiskeytown Reservoir as described in the Project Description with the modifications described in Action I.1 until September 30, 2012, or until 6 months after current Clear Creek salmonids habitat suitability (*e.g.*, IFIM) studies are completed, whichever occurs later.

When the salmonid habitat suitability studies are completed, Reclamation will, in conjunction with the CCTWG, assess whether Clear Creek flows shall be further adapted to reduce adverse impacts on spring-run and CV steelhead, and report their findings and proposed operational flows to NMFS within 6 months of completion of the studies. NMFS will review this report and determine whether the proposed operational flows are sufficient to avoid jeopardizing spring-run and CV steelhead or adversely modifying their critical habitat.

Reclamation shall implement the flows on receipt of NMFS' written concurrence. If NMFS does not concur, NMFS will provide notice of the insufficiencies and alternative flow recommendations. Within 30 days of receipt of non-concurrence by NMFS, Reclamation shall convene the CCTWG to address NMFS' concerns. Reclamation shall implement flows deemed sufficient by NMFS in the next calendar year.

Rationale: Past project operations have reduced spring-run and CV steelhead abundance in Clear Creek by creating passage barriers, raising water temperature, and reducing spawning gravels in key areas of critical habitat. Abundance has increased in recent years as a result of passage improvements, habitat restoration, and operational changes to improve temperature control. Persistence of the population and maintenance of its critical habitat will require continuation of flows adequate for migration and maintenance of spawning gravels and suitable water temperatures.

Action Suite I.2. Shasta Operations

Introduction to Shasta Operations: Maintaining suitable temperatures for spawning, egg incubation, fry emergence, and juvenile rearing in the Sacramento River is critically important for survival and recovery of the winter-run ESU. The winter-run ESU has been reduced to a single population, which has been blocked from its historical range above Shasta Dam. Consequently, suitable temperatures and habitat for this population must be maintained downstream of Shasta Dam through management of the cold water pool behind the dam in the summer. Maintaining optimum conditions for this species below Shasta is crucial until additional populations are established in other habitats or this population is restored to its historical range. Spring-run are also affected by temperature management actions from Shasta Reservoir.

The effects analysis in this Opinion highlights the very challenging nature of maintaining an adequate cold water pool in critically dry years, extended dry periods, and under future conditions, which will be affected by increased downstream water demands and climate change. This suite of actions is designed to ensure that Reclamation uses maximum discretion to reduce adverse impacts of the projects to winter-run and spring-run in the Sacramento River by maintaining sufficient carryover storage and optimizing use of the cold water pool. In most years, reservoir releases through the use of the TCD are a necessity in order to maintain the bare minimum population levels necessary for survival (Yates *et al.* 2008, Angilletta *et al.* 2008).

The effects analysis in this Opinion, and supplemental information provided by Reclamation, make it clear that despite Reclamation's best efforts, severe temperature-related effects cannot be avoided in some years. The RPA includes exception procedures to deal with this reality. Due to these unavoidable adverse effects, the RPA also specifies other actions that Reclamation must take, within its existing authority and discretion, to compensate for these periods of unavoidably high temperatures. These actions include restoration of habitat at Battle Creek that may be support a second population of winter-run, and a fish passage program at Keswick and Shasta dams to partially restore winter-run to their historical cold water habitat.

Objectives: The following objectives must be achieved to address the avoidable and unavoidable adverse effects of Shasta operations on winter-run and spring-run:

1) Ensure a sufficient cold water pool to provide suitable temperatures for winter-run spawning, egg incubation, and fry emergence in most years, without sacrificing the potential for cold water management in a subsequent year. Additional actions to those in the 2004 CVP/SWP operations Opinion are needed, due to increased vulnerability of the population to temperature effects attributable to changes in Trinity River ROD operations, projected climate change hydrology, and increased water demands in the Sacramento River system.

2) Ensure suitable temperature regimes for spring-run spawning, egg incubation, and fry emergence, especially in September and October. Suitable spring-run temperatures will also partially minimize temperature effects to naturally-spawning, non-listed Sacramento River fall-run, an important prey base for endangered Southern Resident killer whales.

3) Establish a second population of winter-run in Battle Creek as soon as possible, to partially compensate for unavoidable project-related effects on the one remaining population.

4) Restore passage at Shasta Reservoir with experimental reintroductions of winter-run to the upper Sacramento and/or McCloud rivers, to partially compensate for unavoidable project-related effects on the remaining population.

2017 amendment: Appendix 2-A of the CVP/SWP operations Opinion is the "Decision Criteria and Processes for Sacramento River Water Temperature Management." NMFS searched the RPA for Appendix 2-A and did not find any references to it. It appears to be a stand alone document that includes information and requirements that may be inconsistent or confusing in consideration of this RPA, and especially the 2017 amendments to RPA Action Suite I.2. To that end, and through this 2017 amendment, NMFS is rescinding Appendix 2-A from the CVP/SWP operations Opinion, and any compliance requirements within Appendix 2-A are not valid.

Action I.2.1 Objective-Based Management.

Objective: The following conceptual objectives were adapted from the multi-year drought sequence experienced in Victoria, Australia (Mount *et al*. 2016[6]), and applied to the following RPA Actions based on water year type. This transition from using performance measures to an objective-based management approach is intended to ensure operations are managed to criteria that are more biologically meaningful.

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[6] 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. June 2016.

	Critically Dry	Dry	Below Normal	Above Normal & Wet
Objectives	PROTECT - Avoid critical loss of population - Avoid catastrophic changes to habitat	MAINTAIN - Maintain river function with reduced reproductive capacity - Manage within dry-spell tolerance	RECOVER - Improve ecological health and resilience - Improve recruitment opportunities	ENHANCE - Maximize species recruitment opportunities - Restore key floodplain linkages - Restore key ecological flows
Priorities	- Undertake emergency flows to avoid catastrophic changes - Carry-over water for critical environments in the following year	- Provide priority flow components - Carry-over water for critical environmental components in the following year	- Provide all in-bank flow components - Provide out-of-bank flows if reach dry-spell tolerance - Carry-over water for large watering events	- Provide all ecological functioning flow components

Based on the above conceptual objectives, NMFS and Reclamation will work together to establish temperature-dependent mortality objectives by water year type, and manage to these objectives, in order to minimize temperature effects associated with operations of the CVP. This 2017 amendment contains an initial set of objectives that may be adjusted in subsequent amendments or the reconsultation of CVP/SWP operations.

To facilitate management to the temperature-dependent mortality objectives and in order to meet the temperature requirements set forth in subsequent actions, NMFS and Reclamation will establish storage targets for minimum peak storage in April/May and at the End-of-September (EOS). Storage targets will help to ensure that the beneficial variability of the system from changes in hydrology will be measured and maintained.

Action: Reclamation shall use the following mortaility objectives for forecasting, temperature planning and implementation and shall report on them annually to NMFS. If there is significant deviation from these objectives, then Reclamation shall reinitiate consultation with NMFS.

These objectives are interim in the context of the 2017 amendment and will be reviewed and further assessed within the scope of the workplan for 2017 and the larger reconsultation[7].

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[7] An additional science and modeling workplan is being prepared to support additional analyses of effectiveness of these objectives in achieving biological objectives, and to evaluate possible system-wide re-operational impacts of these objectives.

Temperature-dependent mortality to winter-run Chinook shall not exceed the following:

- Critically dry: <30% mortality
- Dry: <8% mortality
- Below Normal: <3% mortality
- Above Normal: <3% mortality
- Wet: <3% mortality

In order to meet the above temperature-dependent mortality objectives and the requirements set forth in RPA Action I.2.4, Reclamation will target:

- Mimimum storage between April 1 and May 31, based on water year type, in order to meet the temperature-dependent mortality objectives and the requirements set forth in RPA Action I.2.4, below, no less than:
    - Critically dry: 3.5 million acre-feet (MAF)
    - Dry: 3.9 MAF
    - Below Normal: 4.2 MAF
    - Above Normal: 4.2 MAF
    - Wet: 4.2 MAF

- EOS storage, at Shasta Reservoir, based on water year type, no less than:
    - Critically dry: 1.9 MAF
    - Dry: 2.2 MAF
    - Below Normal: 2.8 MAF
    - Above Normal: 3.2 MAF
    - Wet: 3.2 MAF

Should the storage targets above not be met, Reclamation shall provide written documention to NMFS to describe the reasons behind the inability to achieve these storage targets.

Further, should Reclamation be unable meet 1.9 MAF EOS storage, Reclamation shall meet with NMFS to confer and determine additional actions that are needed to protect winter-run Chinook salmon (Action I.2.3.C).

Additional examination of minimum peak April/May and EOS storage in order to meet the temperature-dependent mortality objectives and the requirements set forth in RPA Action I.2.4 will occur in larger reconsultation. The reconsultation will also include analysis and assessment of the impacts of combinations of different, successive water year types on winter-run Chinook salmon survival and mortality.

Rationale for 2017 amendment:

- This 2017 amendment deletes the previous performance measures that were based on temperature compliance locations to be met with prescribed frequency.

- The temperature-dependent mortality objectives take advantage of new scientific models (*e.g.*, Martin *et al*. 2016), and are intended to create the most flexible and effective operations by directly managing to a biologically meaningful objective. The variability in objectives by water year type is based on the variable goals that can realistically be achieved given drier years (when effects will be greater) versus wetter years (when species recovery is possible).
- The minimum peak April/May and EOS storage objectives targets consider hydrology (*i.e.*, water year type), and are provided in order to meet the temperature requirements set forth in the subsequent actions in preserving key aspects of life history and run time diversity. The volumes are taken from those presented in the CVP/SWP operations BA, effects analysis in the Opinion, and NMFS technical memo on historic Shasta operations, and a 2017 Reclamation analysis of the relationships between storage and cold water pool volumes.
- There is an explicit commitment to conduct additional science and modelling and further refine these objectives.

Action I.2.2. November through February Keswick Release Schedule (Fall Actions)

Objective: Minimize impacts to listed species and naturally spawning non-listed fall-run from high water temperatures by implementing standard procedures for release of cold water from Shasta Reservoir.

Action: Depending on EOS storage and hydrology, Reclamation shall develop and implement a Keswick release schedule, and reduce deliveries and exports as detailed below.

Action I.2.2.A Implementation Procedures for EOS Storage at 2.8 MAF and Above

If the EOS storage is at 2.8 MAF or above, by October 15, Reclamation shall convene the SRTTG to consider a range of fall actions. A written monthly average Keswick release schedule shall be developed and submitted to NMFS by November 1 of each year, based on the criteria below. The monthly release schedule shall be tracked through the work group. If there is any disagreement in the group, including NMFS technical staff, the issue/action shall be elevated to the Shasta Water Interagency Management (SWIM) Team [see Action I.2.4(4), below] for resolution.

The workgroup shall consider and the following criteria in developing a Keswick release schedule:

1) Need for flood control space: A maximum 3.25 MAF end-of-November storage is necessary to maintain space in Shasta Reservoir for flood control.

2) Need for stable Sacramento River level/stage to increase habitat for optimal spring-run and fall-run redds/egg incubation and minimization of redd dewatering and juvenile stranding.

3) Need/recommendation to implement USFWS' Delta smelt Fall X2 action as determined by the Habitat Study Group (HSG) formed in accordance with the 2008 Delta smelt Opinion. NMFS will continue to participate in the HSG chartered through the 2008 Delta smelt biological opinion. If, through the HSG, a fall flow action is recommended that draws down fall storage significantly from historical patterns, then NMFS and USFWS will confer and recommend to Reclamation an optimal storage and fall flow pattern to address multiple species' needs.

If there is a disagreement at the workgroup level, actions may be elevated to the NMFS California Central Valley Office Assistant Regional Administrator and resolved through the WOMT's standard operating procedures.

Rationale: 2.8 MAF EOS storage is linked to the potential to provide sufficient cold water to minimize temperature-dependent mortality in the following year. Therefore, in these circumstances, actions should target the fall life history stages of the species covered by this Opinion *(i.e.*, spring-run spawning, winter-run emigration). The development of a Keswick release schedule is a direct method for controlling storage maintained in Shasta Reservoir. It allows Reclamation to operate in a predictable way, while meeting the biological requirements of the species. The B2IT workgroup, or similar interagency work group, has been used in the past to target actions to benefit fall-run during this time of year using b(2) resources, and, because of its expertise, may also be used by Reclamation to develop this flow schedule. In the past, the B2IT group has used the CVPIA AFRP guidelines to target reservoir releases. Over time, it may be possible to develop a generic release schedule for these months, based on the experience of the work group.

Action I.2.2.B Implementation Procedures for EOS Storage Above 1.9 MAF and Below 2.8 MAF

If EOS storage is between 1.9 and 2.8 MAF, then Reclamation shall convene the SRTTG to consider a range of fall actions. Reclamation shall provide NMFS and the work group with storage projections based on 50 percent, 70 percent, and 90 percent hydrology through February, and develop a monthly average Keswick release schedule based on the criteria below. The monthly release schedule shall be submitted to NMFS by November 1.

Criteria for the release schedule shall include:

1) Maintain Keswick releases between 7,000 cfs and 3,250 cfs to reduce adverse effects on mainstem spring-run and conserve storage for next year's cold water pool.

2) Consider fall-run needs per CVPIA AFRP guidelines, through January, including stabilizing flows to keep redds from de-watering.

3) Be more conservative in Keswick releases throughout fall and early winter if hydrology is dry, and release more water for other purposes if hydrology becomes wet. For example, release no more than 4,000 cfs if hydrology remains dry.

The Keswick release schedule shall follow this or a similar format, to be refined by the workgroup:

	October forecast based on EOS storage	50% hydrology		70% hydrology		90% hydrology	
		Projected storage MAF	Planned release CFS	Projected storage MAF	Planned release CFS	Projected storage MAF	Planned release CFS
Monthly average Keswick release	November						
	December						
	January						
	February						

Reclamation, in coordination with the work group, shall review updated hydrology and choose a monthly average release for every month (November, December, January, February), based on the release schedule. In the event that the updated hydrology indicates a very dry pattern and consequent likely reduction in storage, the work group may advise Reclamation to take additional actions, including export curtailments, if necessary to conserve storage.

If there is a disagreement at the work group level, actions may be elevated to NMFS and resolved through the SWIM Team.

Rationale: It is necessary to be reasonably conservative with fall releases to increase the likelihood of adequate storage in the following year to provide cold water releases for winter-run. This action is intended to reduce adverse effects on each species without compromising the ability to reduce adverse effects on another species. A work group with biologists from multiple agencies will refine the flow schedule, providing operational certainty while allowing for real-time operational changes based on updated hydrology. Over time, it may be possible to develop a generic release schedule for these months, based on the experience of the work group.

Action I.2.2.C. Implementation and Exception Procedures for EOS Storage of 1.9 MAF or Below

If the EOS storage is at or below 1.9 MAF, then Reclamation shall:

1) In early October, reduce Keswick releases to 3,250 cfs as soon as possible, unless higher releases are necessary to meet temperature compliance points (see action I.2.3).

2) Starting in early October, if cool weather prevails and temperature control does not mandate higher flows, curtail discretionary water deliveries (including, but not limited to agricultural rice decomposition deliveries) to the extent that these do not coincide with temperature management for the species. It is important to maintain suitable temperatures targeted to each life stage. Depending on air and water temperatures, delivery of water for rice decomposition, and any other discretionary purposes at this time of year, may coincide with the temperature management regime for spring-run and fall-run. This action shall be closely coordinated with NMFS, USFWS, and CDFW.

3) By November 1, submit to NMFS storage projections based on 50 percent, 70 percent, and 90 percent hydrology through February. In coordination with NMFS, Reclamation shall: (1) develop a monthly average Keswick release schedule similar in format to that in Action I.2.2.B, based on the criteria below and including actions specified below; and (2) review updated hydrology and choose a monthly average release for every month, based on the release schedule. November releases shall be based on a 90 percent hydrology estimate.

Criteria and actions:

1) Keswick releases shall be managed to improve storage and maintained at 3,250 cfs unless hydrology improves.

2) November monthly releases will be based on 90 percent hydrology.

3) Consider fall-run needs through January as per CVPIA AFRP guidelines, including stabilizing flows to keep redds from dewatering.

4) Continue to curtail discretionary agricultural rice decomposition deliveries to the extent that these do not coincide with temperature management for the species, or impact other ESA-listed species. It is important to maintain suitable temperatures targeted to each life stage. Depending on air and water temperatures, delivery of water for rice decomposition may coincide with the temperature management regime for spring-run and fall-run. This action shall be closely coordinated with NMFS. USFWS, and CDFW.

5) If operational changes are necessary to meet Delta outflow, X2, or other legal requirements during this time, then:

   a) CVP/SWP Delta combined exports shall be curtailed to 2,000 cfs if necessary to meet legal requirements while maintaining a 3,250 cfs Keswick release (or other planned

   release based on biological needs of species); and
   b) if it is necessary to curtail combined exports to values more restrictive than 2,000 cfs in order to meet Delta outflow, X2, or other legal requirements, then Reclamation and DWR shall, as an overall strategy, first, increase releases from Oroville or Folsom; and
   c) in general, Reclamation shall increase releases from Keswick as a last resort.
   d) Based on updated monthly hydrology, this restriction may be relaxed, with NMFS' concurrence.

6) If the hydrology and storage have not improved by January, additional restrictions apply – see Action I.2.4.

Rationale: Per action I.2.1, Reclamation shall target a minimum of 1.9 MAF EOS. However, during a severe or extended drought, 1.9 EOS storage may not be achievable. In this circumstance, Reclamation should take additional steps in the fall and winter months to conserve Shasta storage to the maximum extent possible, in order to increase the probability of maintaining cold water supplies necessary for spawning, egg incubation, and fry emergence for the following summer's cohort of winter-run.

Assessment of the hydrologic record and CALSIM modeling shows that operational actions taken during the first year of a drought sequence are very important to providing adequate storage and operations in subsequent drought years. The biological effects of an extended drought are particularly severe for winter-run. Extended drought conditions are predicted to increase in the future in response to climate change. While it is not possible to predict the onset of a drought sequence, in order to ensure that project operations avoid jeopardizing listed species, Reclamation should operate in any year in which storage falls below 1.9 MAF EOS storage as potentially the first year of a drought sequence. The CVP storage system is likely to recover more quickly in the winter and spring months if additional storage conservation measures are taken in the fall and winter.

The curtailments to discretionary rice decomposition deliveries and combined export curtailment of 2,000 cfs are necessary to conserve storage when EOS storage is low. These actions were developed through an exchange of information and expertise with Reclamation operators.

This action is consistent with comments from the Calfed Science Peer Review panel. That panel recommended that Shasta be operated on a two-year (as opposed to single year) hydrologic planning cycle and that Reclamation take additional steps to incorporate planning for potential drought and extended drought into its operations.

Action I.2.3. Initial Forecast; March – May 14[8] Keswick Release Schedule (Spring Actions)

Objective: To conserve water in Shasta Reservoir in the spring in order to provide sufficient water to reduce adverse effects of high water temperature in the summer months for winter-run, without sacrificing carryover storage in the fall.

Actions:

1) Prior to an initial water allocation, Reclamation shall make its initial forecast of deliverable water, shall identify if the objectives in RPA Action I.2.1 can be attained, including minimum peak April/May and EOS storage targets, and analyze the effects of that forecast on the ability to meet the April/May storage targets below. Acknowledging considerable uncertainty in this long-range forecast, the goal is to forecast operations that provide sufficient cold water to meet the objectives 90 percent of the time. Keeping this 90 percent objective in mind, the model shall contain conservative meteorological inputs for hydrology, including, but not limited to precipitation, runoff and snowpack, ambient summer air temperatures, and assumptions or projections of Shasta Reservoir stratification. In the other 10 percent of the time, it may be necessary to revise allocations in the May period, associated with the final temperature plan. Storage targets for forecasting purposes between April 1 and May 31, based on water year type, are to be no less than:
    - Critically Dry: 3.5 MAF
    - Dry: 3.9 MAF
    - Below Normal: 4.2 MAF
    - Above Normal: 4.2 MAF
    - Wet: 4.2 MAF

    a) The draft initial forecast shall include:
        i. Projected Shasta cold water pool volume based on a stratification model or hindcasting comparable Shasta volumes; and
        ii. Management plans for Keswick releases August through October in order to minimize the potential for winter-run redd dewatering[9].
    b) NMFS shall be provided at least 3 business days to review the draft forecast.
    c) NMFS shall review the draft initial forecast to determine whether the ESA requirements for temperature and flow management, as necessary, would be met while implementing the forecasted delivery schedule.

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[8] Or until the start of winter-run spawning as determined by CDFW aerial redd surveys and carcass surveys, which may be earlier or later than May 14.

[9] The extent of allowable winter-run redd dewatering depends on many factors, including Shasta storage, water year type, strength of the run (which unfortunately is not known until after the season), and CDFW monitoring of the redds most vulnerable to dewatering. Therefore, the extent of dewatering will be based on real-time assessments of the above factors and monitoring.

   d) NMFS shall provide a written evaluation to Reclamation prior to Reclamation making the first allocation announcements and for each subsequent month for discretionary contract deliveries.
   e) Reclamation will provide to NMFS an initial forecast no later than March 31.

3) Reclamation shall make releases to maintain a temperature compliance point not in excess of 61.0°F 7DADM at Jellys Ferry from March 1 through May 15.
   a) Reclamation will implement a pilot study for up to 3 years using a surrogate temperature target of 58.0°F DAT at Jellys Ferry in lieu of 61.0°F 7DADM and shall implement the same requirements as those contained in the pilot study in Action I.2.4(2)(b-c).

Rationale for 2017 amendment: The initial forecast was required as part of Reclamation's initial allocations planning in order to determine the impact of Shasta management. Additional initial forecast requirements/expectations are based on observed river conditions during drought operations over the last few years, and what may be necessary to provide for suitable winter-run egg and alevin incubation throughout the temperature management season. Additional requirements, which were not included previously, are now included to address the potential for winter-run redd dewatering.

The minimum peak April/May and EOS storage targets consider hydrology (*i.e.*, water year type), and are provided in order to meet the temperature requirements set forth in the subsequent actions in preserving key aspects of life history and run time diversity. The volumes are taken from those presented in the CVP/SWP operations BA, effects analysis in the Opinion, NMFS technical memo on historic Shasta operations, and a 2017 Reclamation analysis of the relationships between storage and cold water pool volumes.

Action I.2.3.A Implementation Procedures if Initial Forecast, Based on 90 Percent Hydrology, Shows Biological Objectives, Storage Targets, and Temperature Management are Achievable

If all of the following metrics are met, based on the initial forecast, then Reclamation shall announce allocations and operate Keswick releases in March, April, and May consistent with its standard plan of operation. Preparation of a separate Keswick release schedule is not necessary in these circumstances.

1) End of April storage ≥ 4.2 MAF
2) End of September storage ≥ 3.2 MAF
3) 51.5°F Keswick release temperature from May 15 through October 31 [this would be used as a surrogate for 55.0°F 7-day average of the daily maximum temperatures (7DADM) at the CCR California Data Exchange Center gaging station upstream of the confluence of Clear Creek on the Sacramento River]; and
4) Full side gate water releases from the Shasta Dam temperature control device no earlier than October 9

Rationale: The 90 percent forecast is a conservative approach for assessing the potential to manage water temperatures and meet EOS targets. If both of these performance metrics are projected to be met at the time of the initial forecast, then no restrictions on allocations due to this suite of actions are necessary.

Action I.2.3.B Implementation Procedures if Initial Forecast, Based on 90 Percent Hydrology, Shows that Not All of the Metrics in Action I.2.3.A Are Achievable

1) If the initial forecast, based on 90 percent hydrology, shows that not all of the metrics in Action I.2.3.A, above, are achievable, then Reclamation shall implement the following monthly Keswick release schedule, based on water year type, until the Sacramento River temperature management plan pursuant to RPA Action I.2.4 is finalized[10]:

Water Year Type	Monthly Keswick Releases (cfs)	
	April	May
Critically Dry	4,000	7,500
Dry	6,000	8,000
Below Normal	6,000	9,000
Above Normal	6,500	11,000
Wet	8,000	12,000

2) The Keswick release schedule shall include the following criteria and actions:
   a) Maintain minimum monthly average flows necessary to meet nondiscretionary delivery obligations and legal requirements.
   b) Provide for flow-related biological needs of spring life stages of all species covered by this Opinion in the Sacramento River and Delta, to the greatest extent possible.
   c) If operational changes are necessary to meet Delta outflow, X2, or other legal requirements during this time, then:

      - CVP/SWP Delta combined exports shall be curtailed to 2,000 cfs if necessary to meet legal requirements while maintaining a 3,250 cfs Keswick Dam release (or other planned release based on biological needs of species); and
      - if it is necessary to curtail combined exports to values more restrictive than 2000 cfs in order to meet Delta outflow, X2, or other legal requirements, then Reclamation and DWR shall, as an overall strategy, first, increase releases from Oroville or Folsom Dam; and
      - in general, Reclamation shall increase releases from Keswick Dam as a last resort.

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[10] If flood control rules require releases above these monthly average flows, then Reclamation shall inform NMFS of this conflict and discuss it on a Shasta Water Interagency Management Team call to further coordinate releases, as appropriate.

- Based on improvements in updated monthly hydrology, this restriction may be relaxed, with NMFS' concurrence.

3) In addition to Reclamation's forecasted plan of operations, the initial forecast shall include a model run with the following Keswick release schedule based on water year type, in order to assess the comparative performance of alternative plans in their ability to meet temperature criteria:

Water Year Type	**Monthly Keswick release schedule (cfs)**						
	Apr	May	Jun	Jul	Aug	Sep	Oct
Critically Dry	4,000	7,500	7,500	7,500	7,500	7,000	5,000
Dry	6,000	8,000	10,000	10,000	10,000	7,500	6,000
Below Normal	6,000	9,000	12,000	12,000	12,000	7,500	6,500
Above Normal	6,500	11,000	12,500	14,500	12,000	9,000	7,000
Wet	8,000	12,000	13,500	14,500	12,000	10,000	7,000

Rationale: It is necessary to manage storage for potential dry years, to reduce adverse effects on winter-run egg incubation in summer months, and on spring-run in fall months. According to information provided by Reclamation, the hydrology is too variable this time of year to provide for a meaningful 3-month release schedule. Instead, monthly consultations between NMFS and Reclamation are needed to ensure that operations are based on biological criteria and needs.

Action I.2.3.C. Drought Exception Procedures if Initial Forecast, Based on 90 Percent Hydrology, Shows that 55.0°F 7DADM at CCR or 1.9 MAF EOS Storage is Not Achievable

Reclamation shall follow all procedures immediately above (Action I.2.3.B) and, in addition, shall:

1) By April 1, provide a contingency plan with a written justification that all actions within Reclamation's authorities and discretion are being taken to preserve cold water at Shasta Reservoir for the protection of winter-run.

2) The contingency plan shall also, at a minimum, include the following assessments and actions:

   a) Relaxation of Wilkins Slough navigation criteria to at most 4,000 cfs.
   b) An assessment of any additional technological or operational measures that may be feasible and may increase the ability to manage the cold water pool.
   c) Notification to State Water Resources Control Board (SWRCB) that meeting the biological needs of winter-run and the needs of resident species in the Delta, delivery of water to nondiscretionary Sacramento Settlement Contractors, and Delta outflow

requirements per D-1641, may be in conflict in the coming season and requesting the Board's assistance in determining appropriate contingency measures, and exercising their authorities to put these measures in place.

3) If, during the temperature control season, temperature control on the Sacramento River cannot be maintained, then Reclamation shall bypass power at Shasta Dam if NMFS determines a bypass is necessary for preserving the cold water pool. This power bypass may be necessary to maintain temperature controls for winter-run, or later in the temperature season, for spring-run.

Rationale: In these circumstances, there is a one-in-ten likelihood that minimal requirements for winter-run egg survival will not be achieved due to depletion of the cold water pool, resulting in temperature-related mortality of winter-run and, in addition, most likely contributing to temperature-related mortality of spring-run spawning in the fall. This is a conservative forecast, since there is a 90 percent probability that conditions will improve. However, the effects analysis in this Opinion concludes that these poor conditions could be catastrophic to the species, potentially leading to a significant reduction in the viability of winter-run. Delta objectives (salinity, X2, E/I ratio, OMR flow restrictions for both smelt and salmon) are also controlling at this time of year. There is potential for conflict between the need to maintain storage at Shasta and other legal and ecological requirements. Consequently, it is necessary to immediately limit releases from Shasta and develop a contingency plan.

Notification to the SWRCB is essential. Sacramento Settlement Contract withdrawal volumes from the Sacramento River can be quite substantial during these months. The court has recently concluded that Reclamation does not have discretion to curtail the Sacramento Settlement contractors to meet Federal ESA requirements. Therefore, NMFS is limited in developing an RPA that minimizes take to acceptable levels in these circumstances. Consequently, other actions are necessary to avoid jeopardy to the species, including fish passage at Shasta Dam in the long term.

Separate from this consultation, NMFS will work with the SWRCB to determine whether contingency plans within the Board's authority are warranted, and to assist in developing such plans that will allow Reclamation to meet ESA requirements. The incidental take statement for this Opinion also provides limitations of ESA incidental take coverage for Settlement Contractors under the terms of this Opinion.

Action I.2.4 May 15[11] Through October 31 Keswick Release Schedule (Summer Action)

Objective: To manage the cold water storage within Shasta Reservoir and make cold water releases from Shasta Reservoir to provide suitable spawning, egg incubation, and fry

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[11] This action will be initiated at the onset winter-run spawning, determined by CDFW aerial redd surveys and carcass surveys, and therefore, may be earlier or later than May 15.

emergence habitat temperatures for winter-run and spring-run in the Sacramento River while retaining sufficient storage to manage for next year's cohorts. To the extent feasible, manage for suitable temperatures for naturally spawning fall-run.

Action: Reclamation shall develop and implement an annual Temperature Management Plan by May 15 to manage the cold water supply within Shasta Reservoir and make cold water releases from Shasta Reservoir and Spring Creek to provide suitable temperatures for listed species, and, when feasible, fall-run.

Reclamation shall manage operations in the Sacramento River as follows:

1) Not exceed the temperature-dependent mortality objectives identified in Action I.2.1.
2) Not in excess of 56.0°F DAT at a compliance location between Balls Ferry and Bend Bridge from the start of winter-run spawning, based on CDFW aerial redd or carcass surveys, through 100 percent winter-run emergence for protection of winter-run, and not in excess of 56.0°F DAT at the same compliance location between Balls Ferry and Bend Bridge through October 31 for protection of mainstem spring run, whenever possible.
    a) Reclamation shall implement a pilot study for up to 3 years to meet the temperature target of 55.0°F 7DADM at CCR. A surrogate temperature target of 53.0°F DAT may be used in lieu of 55.0°F 7DADM. This pilot would focus temperature management at the downstream-most winter-run redd, based on water year type, as follows:
        i. Critically dry: < 56.0°F DAT[12]. In this case, temperature management shall be to CCR or the downstream-most winter-run redd, whichever location is further downstream
        ii. Dry: < 54.0°F DAT
        iii. Below Normal: < 53.0°F DAT
        iv. Above Normal: < 53.0°F DAT
        v. Wet: < 53.0°F DAT
        vi. Exception procedure: If a winter-run redd is detected considerably farther downstream than other winter-run redds, the SWIM Team shall convene pursuant to Action I.2.4(4), below, and determine if temperature management must be to that downstream most redd.
    b) If Reclamation determines at anytime that it is not feasible to meet the target in the pilot study without causing significant system-wide impacts, the environment, and/or impacts to other ESA-listed species, then Reclamation shall document this finding to NMFS, and request that the pilot study be suspended for the remainder of the water year. In this event, Reclamation shall:
        i. Submit an alternative plan for NMFS's concurrence that fully complies with all RPA requirements; and

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[12] This temperature was not achievable in 2014/2015. This temperature management target in critically dry years will require interactive decision making processes to determine the optimal management strategies during extreme conditions.

        ii. Submit additional modeling and analysis, with recommendations on how to further adjust the pilot study for the following year.
    c) During the course of the first year of the pilot study, Reclamation shall develop an analysis according to a workplan developed in conjunction with NMFS. The analysis will evaluate the impacts of the revised temperature management values, locations, and metrics.
        i. Should the analysis result in a finding that the revised temperature management compliance values, locations, and metrics would result in system-wide impacts to the environment, and/or impacts to other ESA listed species, Reclamation and NMFS will revise the pilot study, as appropriate, in light of these impacts, and also assess whether further adjustments to this RPA action are warranted. In addition, information from this pilot period will inform the larger reconsultation on CVP/SWP operations.

3) Reclamation shall operate to a final Temperature Management Plan starting May 15 and ending October 31.
4) Reclamation and NMFS shall convene a Shasta Water Interagency Management (SWIM) Team, comprised of representatives from Reclamation, NMFS, USFWS, CDFW, and the SWRCB, to track the implementation of the final Temperature Management Plan (including significant changes in treal-time operations). The SWIM Team will utilize information from its member agencies, as well as technical information from the SRTTG and other relevant stakeholders, to inform decisions and changes in operations.
    a) The SWIM Team will consider:
        i. data on winter-run redd construction and egg/alevin incubation timing, location, and distribution;
        ii. Shasta isothermalbaths;
        iii. temperature-dependent mortality modeling results;
        iv. actual vs. modeled Shasta cold water pool volume <49°F to ensure that actual cold water pool volume is:
            1. not less than 95% of modeled for wet and above normal water year types, and
            2. not less than 99% of modeled for critical, dry, and below normal water year types;
        v. projected temperature control device gate operations and configurations;
        vi. date of full side gate access, and adjust operations to ensure that full side gate access is no earlier than October 9; and
        vii. downstream diversions, flows, and Delta requirements.
    b) The SWIM Team will determine:
        i. the frequency of its meetings; and
        ii. if existing interagency teams, for example, WOMT, would satisfy the requirements and expectations, above.
5) As part of the adaptive management process, and in coordination with NMFS, by March 2010, Reclamation shall fund an independent modeler to review these procedures and the

recommendations of the Calfed Science Panel report on temperature management and recommend specific refinements to these procedures to achieve optimal temperature management, with due consideration of the Calfed Science panel's recommendations (Deas *et al*., 2009) regarding temperature management. Upon written concurrence of NMFS, refinements to the implementation procedures for this action suite, based on the independent contractor's report, may be adopted and implemented.

  a) Reclamation, in coordination with NMFS and the Sacramento River Settlement Contractors, shall develop and implement a work plan for Shasta and Trinity divisions seasonal operational water temperature modeling. The resulting water temperature modeling shall support better initial forecasting and decision making, to include uncertainty estimates, joint probabilities of risk, and estimates of Shasta Reservoir stratification. Any temperature model developed through this effort shall utilize a platform so that it can be independently run.

Implementation Procedures: Reclamation shall take the following steps to develop an annual Temperature Management plan:

1) By April 25, Reclamation shall develop and submit to NMFS a draft Temperature Management Plan, to include:
    a) both 50 percent and 90 percent forecasts, including EOS storages, consistent with its draft plan of summer operations.
    b) outputs that demonstrate that the objectives in Action I.2.1 have a high probability of being met.
2) NMFS will provide comments within five business days to Reclamation, recommending that Reclamation either: (a) operate to one of the options; or (b) develop an alternative operations plan necessary to meet reasonably attainable preferred TCP and EOS storage.
3) Within five business days of receiving NMFS' recommendations, and based on NMFS's comments, Reclamation will develop an operations plan with specific monthly average Keswick releases to attain both TCP from May 15 through the EOS and EOS storage, and submit the plan to NMFS for concurrence.
4) By May 15, Reclamation and NMFS shall jointly submit a final Temperature Management Plan to meet the SWRCB 90-5 requirements using the SRTTG. From May 15 through October 31, the SWIM Team shall track implementation of this plan, and shall refine it based on real-time information, including run timing, location of redds, air and surface water temperature modeling, and projected versus actual extent of the cold water pool.
5) The temperature management plan shall also include the projected volume of cold water to be tracked, and triggers and corresponding actions if the volume is less than projected[13].

Rationale: Depending on hydrology and air temperature, from May through October, it is necessary to use the cold water pool in Shasta Reservoir to provide cold water releases to

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[13] This approach was piloted successfully in summer 2016.

maintain suitable water temperatures for listed anadromous fish below Shasta. Without access to the cold water pool, suitable temperatures for spawning, egg incubation, and fry emergence are not attainable. Preparation of an annual Temperature Management Plan allows Reclamation, in consultation with NMFS, to achieve optimal cold water management in a given year and conserving EOS storage. The storage level at the EOS is important to manage the risk of unsuitably warm water temperatures for winter-run in the following summer. Maintaining suitable temperatures in September and October is also important to minimize adverse effects of project operations to main stem Sacramento River spring-run. Fall-run, a non-listed species that is important as a prey base for Southern Resident killer whales, also benefits from suitable temperatures in the Fall.

Development of 2 to 4 options for temperature management, prior to finalizing a plan allows for meaningful discussion of appropriate risk management strategies in a given year, based on timely hydrologic and biological considerations. Important factors differ from year to year, and need to be considered in operations planning. They include timing and location of spawning and redds based on aerial surveys; the extent of the cold water pool, given air temperatures; and operation of the Temperature Control Device to provide optimal use of the cold water pool. Preparation of a draft plan also allows for iterative planning and feedback. Operations can be tailored each year to achieve the optimal approach to temperature management to maintain viable populations of anadromous fish, based on the best available information.

The Calfed Science Program peer review report on temperature management emphasized the importance of refining temperature management practices in the long term and included recommendations for doing so. The requirement to hire an independent contractor to recommend specific refinements to the procedures in this RPA responds to these recommendations.

Rationale for 2017 Amendment:

- Best available science (*e.g.*, Martin *et al*. 2016[14]) and monitoring (*e.g.*, rotary screw trapping at Red Bluff Diversion Dam) since issuance of the 2009 CVP/SWP operations Opinion have indicated that 56°F DAT is not as protective as historically required for minimizing adverse temperature related effects on incubating eggs and alevin. Martin *et al*. (2016) predicted that the slower flowing water in the river would not supply the oxygen needed for egg viability in elevated temperature conditions, and that field studies found that the slower flow in the river equated to about a 3ºC difference in the temperature tolerance of eggs.
- EPA (2003) recommends 55°F 7DADM for incubating Chinook salmon eggs and alevin. Anderson *et al*. (2010, 2011) and EPA (2003) recommend temperature management to the downstream most redds.

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[14] Martin, B. T., A. Pike, S. N. John, N. Hamda, J. Roberts, S. T. Lindley, and E. M. Danner. 2016. Phenomenological vs. biophysical models of thermal stress in aquatic eggs. Ecology Letters (2016).

- A DAT (maintaining 56.0°F further downstream or 53°F at the downstream-most redd) is provided as a surrogate to 55.0°F 7DADM to provide operational flexibility and allow for a pilot study to be conducted.
- The SWIM Team was created in 2016 to monitor the implementation of the Sacramento River temperature management plan. The SWIM Team member agencies found the regular meetings helpful in both accountability to the temperature management plan, and also would provide the member agencies enough time in case operational adjustments are necessary.

Action I.2.4.1 Post Temperature Compliance Season Winter-Run Egg-to-Fry Survival Evaluation

Objective: To adaptively manage operations in subsequent years in order to minimize egg and fry mortality, as estimated using the temperature-dependent mortality model.

Action: Planned operations or other non-operational actions in subsequent years shall be adjusted in order to improve egg-to-fry survival, if necessary. Based on the 1996-2015 average egg-to-fry survival of 23.6% (27% prior to the drought), Reclamation shall achieve the following egg-to-fry survival metrics:

- Critically dry years: >15%
- Dry years: >20%
- Below Normal years: >25%
- Above Normal years: >25%
- Wet years: >25%

Rationale: Each year, the egg-to-fry survival to the Red Bluff Diversion Dam is calculated after the temperature management season. This measure is used to assess how well Reclamation did in operations to protect the early life stages of winter-run Chinook salmon. Annual hindcasts and associated reports are critical in understanding the effects of various operations of Shasta and Keswick dams and reservoirs.

Action I.2.5. Winter-Run Passage and Re-Introduction Program at Shasta Dam

See Fish Passage Program, Action V

Action I.2.6. Restore Battle Creek for Winter-Run, Spring-Run, and CV Steelhead

Objective: To partially compensate for unavoidable adverse effects of project operations by restoring winter-run and spring-run to the Battle Creek watershed. A second population of winter-run would reduce the risk of extinction of the species from lost resiliency and increased vulnerability to catastrophic events.

Description of Action: Reclamation shall direct discretionary funds to implement the Battle Creek Salmon and Steelhead Restoration Project. Phase 1A funding is currently allocated through various partners and scheduled to commence in Summer 2009 (Reclamation 2008c). DWR shall direct discretionary funds for Phase 1B and Phase 2, consistent with the proposed amended Delta Fish Agreement. By December 31 of each year, Reclamation and DWR will submit a written report to NMFS on the status of the project, including phases completed, funds expended, effectiveness of project actions, additional actions planned (including a schedule for further actions), and additional funds needed. The Battle Creek Salmon and Steelhead Restoration Project shall be completed no later than 2019.

Rationale: Modeling projections in the BA show that adverse effects of ongoing project operations cannot be fully minimized. Severe temperature-related effects due to project operations will occur in some years. This RPA includes an exception procedure in anticipation of these occurrences (see Action I.2.2). Establishing additional populations of winter-run is critical to stabilize the high risk of extinction resulting from the proposed action on the only existing population of this species. $26 million has been identified for this project in the American Recovery and Reinvestment Act of 2009.

Action Suite I.3. Red Bluff Diversion Dam (RBDD) Operations

Objectives: Reduce mortality and delay of adult and juvenile migration of winter-run, spring-run, CV steelhead, and Southern DPS of green sturgeon caused by the presence of the diversion dam and the configuration of the operable gates. Reduce adverse modification of the passage element of critical habitat for these species. Provide unimpeded upstream and downstream fish passage in the long term by raising the gates year-round, and minimize adverse effects of continuing dam operations, while pumps are constructed replace the loss of the diversion structure.

Action I.3.1. Operations after May 14, 2012: Operate RBDD with Gates Out

Action: No later than May 15, 2012, Reclamation shall operate RBDD with gates out all year to allow unimpeded passage for listed anadromous fish. If the Red Bluff Alternative Intake Structure is not anticipated to be operational by May 15, 2012, Reclamation may submit a request to NMFS, no later than January 31, 2012, to close the gates from June 15 to September 1, 2012. This request must document that all milestones for construction of the alternative pumping plant have been met and that all other conservation measures (see below) have been implemented.

Rationale: RBDD impedes and delays upstream migration of adult winter-run, spring-run, CV steelhead, and Southern DPS of green sturgeon. It also impedes and delays downstream passage of juveniles of the same species. It adversely modifies critical habitat for these species by impairing important mainstem passage. Pumps can be used to deliver water currently made available by placing gates in the river, and $109 million has been identified in the recent American Recovery and Reinvestment Act of 2009 for the Red Bluff Pumping Plant.

Action I.3.2. Interim Operations

Action: Until May 14, 2012, Reclamation shall operate RBDD according to the following schedule:

- September 1 - June 14: Gates open. No emergency closures of gates are allowed.
- June 15 - August 31: Gates may be closed at Reclamation's discretion, if necessary to deliver water to TCCA.

Rationale: Having gates out until June 15 is necessary for winter-run, spring-run and green sturgeon adult passage to spawning habitat. TCCA can withdraw 465 cfs without the gates in the river. Their water demand typically reaches 800 cfs by June 15, therefore, TCCA will need supplemental pumping capacity to meet water demand until June 15. NMFS has consulted with Reclamation separately on the effects of an interim pumping operation. Implementation of these improvements to passage conditions at RBDD, in conjunction with several other conservation and research measures proposed by TCCA (Appendix 2-B), is expected to reduce the effects of continuing (for the next three years) the (modified) operations of RBDD to a level that will not reduce the likelihood of survival and recovery of these ESUs and DPSs.

Action I.3.3. Interim Operation for Green Sturgeon

Objective: Allow passage of green sturgeon during interim operations.

Action: When gates are in, Reclamation shall retain a minimum 18-inch opening under the gates that are open, to allow safe downstream passage of adult green sturgeon. The 18-inch opening may be modified to 12 inches by the RBDD technical team if necessary to maintain the structural integrity of the dam and/or adequate attraction flows for salmonids at the fish ladders, or in consideration of other real-time fish migratory issues.

Rationale: Twelve to 18 inches is the estimated minimum gate opening that would allow adult green sturgeon to pass downstream underneath the RBDD gates uninjured.

Action I.3.4: Measures to Compensate for Adverse Effects of Interim Operations on Green Sturgeon

Objective: Offset short-term effects to green sturgeon due to interim gate operations by investing in geographically specific research needed to determine green sturgeon life history and recovery needs.

Action: Reclamation shall continue ongoing funded research to characterize green sturgeon populations in the upper Sacramento River Basin, their movements, and habitat usage, as planned through fiscal year 2009. In addition, Reclamation (or TCCA) shall convene a technical team, including representatives from NMFS, CDFW, USFWS, Corps, the University of California at Davis (UCD), and other cooperators, to review studies and results and coordinate research needs for green sturgeon. Reclamation and/or TCCA shall provide the necessary funding to insure that research will continue to be conducted in a coordinated and cooperative manner with the express intent of fully implementing the research projects described in the UCD proposal in Appendix 2-B to this Opinion.

Rationale: The exact timing of spawning migration for green sturgeon is not known, and during interim operations the potential remains for late arriving green sturgeon to be blocked by the dam after June 14. There is also a potential for post-spawn adult migrants and post-hatch juvenile migrants to be adversely affected, since they must pass downstream through the narrow clearance and high turbulence caused by the closed dam gates between June 14 and August 31.

Although the proposed studies will not directly benefit the green sturgeon that will be impacted by the dam during the interim period before the gates are permanently lifted, these studies will greatly benefit the Southern DPS of green sturgeon as a whole by revealing important information that will improve their likelihood of survival and recovery over the long term. The studies will provide vital information on the life history and biological requirements of green sturgeon, which will allow NMFS to develop and implement a comprehensive and effective recovery plan for the DPS. By combining these long-term benefits to the survival and recovery of the Southern DPS of green sturgeon with the other significant improvements to habitat conditions required within this RPA (reduced gates-in periods, increased minimum gate openings, improved water temperature conditions for spawning and rearing, improved migration and rearing conditions in the lower river and Delta), the full implementation of this RPA is expected to offset the effects of continuing (for the next three years) the (modified) operations of RBDD to a level that will not reduce the likelihood of survival and recovery of the green sturgeon DPSs.

Action I.3.5. Measures to Compensate for Adverse Effects of Interim Operations on Spring-Run

Objective: Offset unavoidable short-term effects to spring-run from passage impediments of RBDD by restoring spring-run passage elsewhere in the Sacramento River system.

Action: Reclamation shall provide $500,000 for implementation of spring- run passage improvement projects in the Sacramento River. Appendix 2-B describes specific projects that may be implemented. By December 15, 2009, Reclamation shall provide NMFS with a prioritized list of projects from Appendix 2-B and an implementation schedule. Reclamation shall provide an annual report to NMFS on implementation and effectiveness of projects. Reclamation shall monitor and maintain these projects for five years.

Rationale: During interim operations, late arriving spring-run may be adversely affected by the dam after June 14. Construction and maintenance of the interim pumping facility also may have short-term adverse effects on spring-run.

The proposed passage restoration projects are likely to benefit the spring-run ESU as a whole by improving access to spawning habitat for some of the key populations within the ESU. Although the proposed improvements will not provide passage benefits to the small dependent populations that spawn upstream of RBDD, they will benefit the large independent populations that spawn in downstream tributaries. Passage improvements for the large independent population, in turn, will benefit the smaller populations throughout the Central Valley that depend on these larger populations to supplement their numbers and genetic diversity.

Action I.4. Wilkins Slough Operations

Objective: Enhance the ability to manage temperatures for anadromous fish below Shasta Dam by operating Wilkins Slough in the manner that best conserves the dam's cold water pool for summer releases.

Action: Reclamation shall convene the SRTTG to review past operational data, hydrology, and fisheries needs and recommend Wilkins Slough minimum flows for anadromous fish in critically dry years in lieu of the current 5,000 cfs navigation criterion.

In years other than critically dry years, the need for a variance from the 5,000 cfs navigation criterion will be considered during the process of developing the Keswick release schedules (Action I.2.2-4).

Without SRTTG recommendations on Wilkins Slough minimum flows, Reclamation shall operate to Wilkins Slough flows less than 5,000 cfs, depending on Shasta storage, water year type, Delta requirements, and consultation with the fish agencies.

Rationale: In some circumstances, maintaining the Wilkins Slough navigation channel at 5,000 cfs may be a significant draw on Shasta reservoir levels and affect the summer cold water pool necessary to maintain suitable temperatures for winter-run spawning, egg incubation, and fry emergence. Reclamation has stated that it is no longer necessary to maintain 5,000 cfs for navigation (CVP/SWP operations BA, page 2-39), but may be critical to maintain other system-wide requirements. Operating to a minimal flow level based on fish needs, rather than on outdated navigational requirements, could enhance the ability to use cold-water releases to maintain cooler summer temperatures in the Sacramento River.

Rationale for 2017 amendment: The deadline for the development of Wilkins Slough minimum flows was December 1, 2009, and NMFS is not aware of any current effort by Reclamation to develop those minimum flows. Water year 2014 was a critically dry water year type, and minimum flows at Wilkins Slough were reduced to 3,800 cfs at times. Reduced flows at Wilkins Slough will be made in lieu of Reclamation meeting the original RPA action.

Action I.5. Funding for CVPIA Anadromous Fish Screen Program (AFSP)

Objective: To reduce entrainment of juvenile anadromous fish from unscreened diversions.

Action: Reclamation shall screen priority diversions as identified in the CVPIA AFSP, consistent with previous funding levels for this program. In addition, Reclamation/CVPIA Program shall evaluate the potential to develop alternative screened intakes that allow diverters to withdraw water below surface levels required by the antiquated Wilkins Slough navigation requirement criterion of 5,000 cfs.

Rationale: Approximately ten percent of 129 CVP diversions listed in Appendix D-1 of the CVP/SWP operations BA are currently screened. Of these, most of the largest diversions (greater than 250 cfs) have already been screened; however, a large number of smaller diversions (less than 250 cfs) remain unscreened or do not meet NMFS fish screening criteria (NMFS 1997; *e.g.,* CVP and SWP Delta diversions, Rock Slough diversion). The AFSP has identified priorities for screening that is consistent with the needs of listed fish species. Screening will reduce the loss of listed fish in water diversion channels. In addition, if new fish screens can be extended to allow diversions below 5,000 cfs at Wilkins Slough, then cold water can be conserved during critically dry years at Shasta Reservoir for winter-run and spring-run life history needs.

Action Suite I.6: Sacramento River Basin Salmonid Rearing Habitat Improvements

Objective: To restore floodplain rearing habitat for juvenile winter-run, spring-run, and CV steelhead in the lower Sacramento River basin, to compensate for unavoidable adverse effects of project operations. This objective may be achieved at the Yolo Bypass, and/or through actions in other suitable areas of the lower Sacramento River.

The suite of actions includes near term and long-term actions. The near-term action (Action I.6.2) is ready to be implemented and can provide rearing benefits within two years of issuing this Opinion. The long-term actions (Actions I.6.1, I.6.3, and I.6.4) require additional planning and coordination over a five- to ten-year time frame.

These actions are consistent with Reclamation's broad authorities in CVPIA to develop and implement these types of restoration projects. When necessary to achieve the overall objectives of this action, Reclamation and DWR, in cooperation with other agencies and funding sources, including the Delta Fish Agreement and any amendments, shall: (1) apply for necessary permits; (2) seek to purchase land, easements, and/or water rights from willing sellers; (3) seek additional authority and/or funding from Congress or the California State Legislature, respectively; and (4) pursue a Memorandum of Agreement with the Corps.

Similar actions addressing rearing and fish passage are under consideration in the BDCP development process and may ultimately satisfy the requirements in Actions I.6 and I.7. BDCP is scheduled to be completed by December 31, 2010.

Action I.6.1. Restoration of Floodplain Rearing Habitat

Objective: To restore floodplain rearing habitat for juvenile winter-run, spring-run, and CV steelhead in the lower Sacramento River basin. This objective may be achieved at the Yolo Bypass, and/or through actions in other suitable areas of the lower Sacramento River.

Action: In cooperation with CDFW, USFWS, NMFS, and the Corps, Reclamation and DWR shall, to the maximum extent of their authorities (excluding condemnation authority), provide significantly increased acreage of seasonal floodplain rearing habitat, with biologically appropriate durations and magnitudes, from December through April, in the lower Sacramento River basin, on a return rate of approximately one to three years, depending on water year type. In the event that this action conflicts with Shasta Operations Actions I.2.1 to I.2.3, the Shasta Operations Actions shall prevail.

Implementation procedures: By December 31, 2011, Reclamation and DWR shall submit to NMFS a plan to implement this action. This plan should include an evaluation of options to: (1) restore juvenile rearing areas that provide seasonal inundation at appropriate intervals, such as areas identified in Appendix 2-C or by using the Sacramento River Ecological Flow Tool (ESSA/The Nature Conservancy 2009) or other habitat modeling tools; (2) increase inundation of publicly and privately owned suitable acreage within the Yolo Bypass; (3) modify operations of the Sacramento Weir (which is owned and operated by the Department of Water Resources) or Fremont Weir to increase rearing habitat; and (4) achieve the restoration objective through other operational or engineering solutions. An initial performance measure shall be 17,000-20,000 acres (excluding tidally-influenced areas), with appropriate frequency and duration. This measure is based on the work by Sommer *et al*. (2001, 2004) at Yolo Bypass and on recent analyses conducted for the BDCP process of inundation levels at various river stages (BDCP Integration Team 2009).[15] The plan may include a proposal to modify this performance measure, based on best available science or on a scientifically based adaptive management process patterned after Walters (1997).

This plan also shall include: (1) specific biological objectives, restoration actions, and locations; (2) specific operational criteria; (3) a timeline with key milestones, including

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[15] The analyses assumed a notch in the Fremont Weir.

restoration of significant acreage by December 31, 2013; (4) performance goals and associated monitoring, including habitat attributes, juvenile and adult metrics, and inundation depth and duration criteria; (5) specific actions to minimize stranding or migration barriers for juvenile salmon; and (6) identification of regulatory and legal constraints that may delay implementation, and a strategy to address those constraints. Reclamation and DWR shall, to the maximum extent of their authorities and in cooperation with other agencies and funding sources, implement the plan upon completion, and shall provide annual progress reports to NMFS. In the event that less than one half of the total acreage identified in the plan's performance goal is implemented by 2016, then Reclamation and DWR shall re-initiate consultation.

The USFWS' Delta smelt biological opinion includes an action to restore 8,000 acres of tidal habitat for the benefit of Delta smelt. If these 8,000 acres also provide suitable rearing habitat for salmonids, they may be used in partial satisfaction of the objective of this action.

This action is not intended to conflict with or replace habitat restoration planning in the BDCP process.

Rationale: Rearing and migration habitats for all anadromous fish species in the Sacramento basin are in short supply. Project operations limit the availability of such habitats by reducing the frequency and duration of seasonal over-bank flows as a result of flood management and storage operational criteria. Recent evaluations on the Yolo Bypass and Cosumnes River have shown that juvenile Chinook salmon grow faster when seasonal floodplain habitats are available (Sommer *et al*. 2001, 2005; Jeffres *et al.* 2008). Sommer *et al.* (2005) suggest these floodplain benefits are reflected in adult return rates. This action is intended to offset unavoidable adverse effects to rearing habitat and juvenile productivity of winter-run, spring-run, and CV steelhead in the Sacramento River basin, by increasing available habitat that is inundated with the frequency and duration of suitable floodplain rearing habitats during December through April.

In high flow years (*e.g.*, similar to 1998), this action can be achieved solely by inundation of the Yolo Bypass. In other years, this action may be accomplished by a combination of actions such as increasing the year-to-year inundation frequency of existing floodplains such as portions of the Yolo Bypass, by restoring rearing habitat attributes to suitable areas, through restoration or enhancement of intertidal areas such as Liberty Island, creation or re-establishment of side channels, and re-created floodplain terrace areas.

Action I.6.2. Near-Term Actions at Liberty Island/Lower Cache Slough and Lower Yolo Bypass

Description of Action: By September 30, 2010, Reclamation and/or DWR shall take all necessary steps to ensure that an enhancement plan is completed and implemented for Liberty Island/Lower Cache Slough, as described in Appendix 2-C. This action shall be monitored for the subsequent five years, at a minimum, to evaluate the use of the area by juvenile salmonids and to measure changes in growth rates. Interim monitoring reports shall be submitted to NMFS annually, by September 30 each year, and a final monitoring report shall be submitted on September 30, 2015, or in the fifth year following implementation of enhancement actions. NMFS will determine at that time whether modification of the action or additional monitoring is necessary to achieve or confirm the desired results. This action shall be designed to avoid stranding or migration barriers for juvenile salmon.

Action I.6.3. Lower Putah Creek Enhancements

Description of Action: By December 31, 2015, Reclamation and/or DWR shall develop and implement Lower Putah Creek enhancements as described in Appendix Y of Reclamation's final BA, including stream realignment and floodplain restoration for fish passage improvement and multi-species habitat development on existing public lands. By September 1 of each year, Reclamation and/or DWR shall submit to NMFS a progress report towards the successful implementation of this action. This action shall not result in stranding or migration barriers for juvenile salmon.

Action I.6.4. Improvements to Lisbon Weir

Action: By December 31, 2015, Reclamation and/or DWR shall, to the maximum extent of their authorities, assure that improvements to the Lisbon Weir are made that are likely to achieve the fish and wildlife benefits described in Appendix 2-C. Improvements will include modification or replacement of Lisbon Weir, if necessary to achieve the desired benefits for fish. If neither Reclamation nor DWR has authority to make structural or operational modifications to the weir, they shall work with the owners and operators of the weir to make the desired improvements, including providing funding and technical assistance. By September 1 of each year, Reclamation and/or DWR shall submit to NMFS a report on progress toward the successful implementation of this action. Reclamation and DWR must assure that this action does not result in migration barriers or stranding of juvenile salmon.

Rationale for Actions I.6.2 to I.6.4: These actions have been fully vetted by CDFW and found to be necessary initial steps in improving rearing habitat for listed species in the lower Sacramento River basin. These improvements are necessary to off-set ongoing adverse effects of project operations, primary due to flood control operations. Additional descriptions of these actions are contained in the draft amendment to the Delta Fish Agreement (CVP/SWP operations BA appendix Y).

Action I.7. Reduce Migratory Delays and Loss of Salmon, Steelhead, and Sturgeon at Fremont Weir and Other Structures in the Yolo Bypass

Objective: Reduce migratory delays and loss of adult and juvenile winter-run, spring-run, CV steelhead and Southern DPS of green sturgeon at Fremont Weir and other structures in the Yolo Bypass.

Description of Action: By December 31, 2011, as part of the plan described in Action I.6.1, Reclamation and/or DWR shall submit a plan to NMFS to provide for high quality, reliable migratory passage for Sacramento Basin adult and juvenile anadromous fishes through the Yolo Bypass. By June 30, 2012, Reclamation and/or DWR shall obtain NMFS concurrence and, to the maximum extent of their authorities, and in cooperation with other agencies and funding sources, begin implementation of the plan, including any physical modifications. By September 30, 2009, Reclamation shall request in writing that the Corps take necessary steps to alter Fremont Weir and/or any other facilities or operations requirements of the Sacramento River Flood Control Project or Yolo Bypass facility in order to provide fish passage and shall offer to enter into a Memorandum of Understanding, interagency agreement, or other similar mechanism, to provide technical assistance and funding for the necessary work. By June 30, 2010, Reclamation shall provide a written report to NMFS on the status of its efforts to complete this action, in cooperation with the Corps, including milestones and timelines to complete passage improvements.

Reclamation and/or DWR shall assess the performance of improved passage and flows through the bypass, to include an adult component for salmonids and sturgeon (*i.e.,* at a minimum, acoustic receivers placed at the head and tail of the bypass to detect use by adults).

Rationale: The Yolo Bypass and Fremont Weir has been a documented source of migratory delay to, and loss of, adult winter-run, spring-run, CV steelhead and Southern DPS of green sturgeon. The existing fish passage structure is inadequate to allow normal passage at most operational levels of the Sacramento River. The project agencies must work with the Corps, which owns and operates Fremont Weir, to achieve improvements for fish. Other structures within the Yolo Bypass, such as the toe drain, Lisbon Weir, and irrigation dams in the northern end of the Tule Canal, also can impede migration of adult anadromous fish. Additionally, stranding of juvenile salmonids and sturgeon has been reported in the Yolo Bypass in scoured areas behind the weir and in other areas. This action offsets unavoidable project effects on adult migration and minimizes the direct losses from flood management activities associated with operations.

Rationale for 2011 amendment: The date "June 30, 2011" in the 2009 RPA was a typographical error, and corrected to "June 30, 2012." The action refers back to Action I.6.1, which has a requirement for a plan to be submitted to NMFS by December 31, 2011. NMFS concurrence on the plan cannot precede the date that the plan is due.

II. AMERICAN RIVER DIVISION

<u>Introduction to American River Actions</u>: The CV steelhead DPS is the only species addressed in this Opinion with a spawning population in the American River. The DPS includes naturally spawned steelhead in the American River (and other Central Valley stocks) and excludes steelhead spawned and reared at Nimbus Fish Hatchery. The in-river population is small, with observations of a few hundred adults returning to spawn in the American River each year. Limited observations made in 2003, 2004, 2005, and 2007 of whether in-river spawners were adipose fin-clipped or not indicate that some in-river spawners are of wild origin (Hannon and Deason 2008). This suggests that the listed stock has some ability to survive habitat conditions in the American River, Delta, and Ocean, even in their degraded state as described in preceding sections of this Opinion.

The in-river population is likely entirely made up of Nimbus Fish Hatchery steelhead or their descendents. Early Nimbus Fish Hatchery broodstock included naturally produced fish from the American River and stocks from the Washougal (Washington), Siletz (Oregon), Mad, Eel, Sacramento and Russian rivers, with the Eel River stock being the most heavily used (Staley 1976, McEwan and Jackson 1996).

Even though the American River steelhead population is small and is entirely influenced by hatchery fish with out-of-basin genetics, NMFS views the population as being important to the survival and recovery of the species. CV TRT shares this view by recommending that, "*every extant population be viewed as necessary for the recovery of the ESU"* (Lindley *et al.* 2007). In addition, the steelhead population has presumably become somewhat locally adapted to the American River, and it has potential to substantially contribute to the viability of the DPS if water, habitat, and hatchery management efforts are coordinated and directed at achieving such a goal.

Key proposed project-related stressors include: (1) the provision of water temperatures warmer than steelhead life stage-specific requirements; (2) flow fluctuations that dewater redds, strand fry, and isolate fry and juveniles in off-channel pools where they are vulnerable to both predation and exposure to lethal and sub-lethal water temperatures; and (3) low flows limiting the availability of quality rearing habitat including predator refuge habitat.

The most influential baseline stressor to steelhead within the American River Division is the presence of Nimbus and Folsom dams, which block steelhead from all of their historic spawning and rearing habitat. This Opinion concludes that both increased water demands and effects of climate change will lead to further deterioration of suitable habitat conditions, including increased temperatures and decreased flows. Therefore, a passage program to expand the range of the American River steelhead population above Folsom Dam is necessary. If feasible, American River steelhead should be provided access to their full historic range. Given the long-term duration associated with the fish passage actions (see Fish Passage Program below, in Action V), it is necessary to plan and implement actions targeted at improving steelhead habitat below Nimbus Dam. NMFS concludes that coordinated management in four realms - water operations and associated structures, American River habitat, Nimbus Fish Hatchery operations, and in-river harvest – will substantially lower the extinction risk of American River steelhead

Action II.1. Lower American River Flow Management

Objective: To provide minimum flows for all steelhead life stages.

Action: Implement the flow schedule specified in the Water Forum's[16] Flow Management Standard (FMS), which is summarized in Appendix 2-D of this Opinion. The FMS flow schedule has been developed by the Water Forum, Reclamation, USFWS, NMFS, and CDFW in order to establish required minimum flows for anadromous salmonids in the lower American River. The flow schedule specifies minimum flows and does not preclude Reclamation from making higher releases at Nimbus Dam.

Reclamation shall ensure that flow, water temperature, steelhead spawning, and steelhead rearing monitoring is conducted annually in order to help inform the ARG process and to evaluate take associated with flow fluctuations and warm water temperatures. Steelhead monitoring surveys should follow the objectives and protocols specified in the FMS Monitoring and Evaluation Program relating to steelhead spawning and rearing.

Implementation procedures: Reclamation shall convene the American River Group (ARG), comprised of representatives from Reclamation, NMFS, USFWS, CDFW and the Water Forum, to make recommendations for management within the constraints of the FMS. If there is a lack of consensus, ARG shall advise NMFS, and NMFS will make a recommendation to the WOMT for a decision.

Rationale: Reclamation operates Folsom Dam and Reservoir to provide water for irrigation, municipal and industrial uses, hydroelectric power, recreation, water quality, flood control, and fish protection. Reclamation operates Folsom Dam and Reservoir under a state water right permit and fish protection requirements that were adopted in 1958 as SWRCB Decision 893 (D-893). This decision allows flows at the mouth of the American River to fall as low as 250 cfs from January through mid-September, with a minimum of 500 cfs required between September 15 and December 31.

Biological, socioeconomic, legal, and institutional conditions have changed substantially since the SWRCB adopted D-893 in 1958. For example, D-893 does not address requirements of the CVPIA, the 1995 Bay Delta Plan, or previous Opinions to protect Central Valley anadromous salmonids. The SWRCB, Reclamation and many diverse stakeholders (*e.g.*, Water Forum) involved in various American River actions have agreed that the

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[16] In September 1993, the Water Forum, a diverse group of business and agricultural leaders, citizens groups, environmentalists, water managers, and local governments in the Sacramento Region, was formed to evaluate water resources and future water supply needs of the Sacramento metropolitan region.

conditions specified in D-893 are not sufficiently protective of the fishery resources within the lower American River.

The flow schedule specified in Appendix 2-D was developed to require more protective minimum flows in the lower American River in consideration of the river's aquatic resources, particularly steelhead and fall-run.

The monitoring called for in this RPA action including flow, water temperature, steelhead spawning, and steelhead rearing monitoring is necessary for the ARG to responsibly carry out this mission. In addition, this monitoring is necessary to evaluate take associated with American River Division operations.

Action II.2. Lower American River Temperature Management

Objective: Maintain suitable temperatures to support over-summer rearing of juvenile steelhead in the lower American River.

Action: Each year, Reclamation shall prepare a draft Operations Forecast and Temperature Management Plan based on forecasted conditions and submit the draft Plan to NMFS for review by May 1 of each year. The information provided in the Operations Forecast will be used in the development of the Temperature Plan. The draft plan shall contain: (1) forecasts of hydrology and storage; (2) a modeling run or runs, using these forecasts, demonstrating that the temperature compliance point can be attained (see Coldwater Management Pool Model approach in Appendix 2-D); (3) a plan of operation based on this modeling run that demonstrates that all other non-discretionary requirements are met; and (4) allocations for discretionary deliveries that conform to the plan of operation. Reclamation shall use an iterative approach, varying proposed operations, with the objective to attain the temperature compliance point at Watt Avenue Bridge. Within ten calendar days of receiving the draft Temperature Plan, NMFS will provide a written review of this plan for the purpose of determining whether requirements in this Opinion are likely to be met. Reclamation shall produce a final plan prior to May 15 deliveries and implement the plan upon finalization. Reclamation may update the plan every month based on hydrology and must seek NMFS' concurrence on proposed deviations from the plan that may reduce the likelihood that the temperature objective will be met.

Temperature Requirement: Reclamation shall manage the Folsom/Nimbus Dam complex and the water temperature control shutters at Folsom Dam to maintain a daily average water temperature of 65°F or lower at Watt Avenue Bridge from May 15 through October 31, to provide suitable conditions for juvenile steelhead rearing in the lower American River. If this temperature is exceeded for three consecutive days, or is exceeded by more than 3°F for a single day, Reclamation shall notify NMFS in writing and will convene the ARG to make recommendations regarding potential cold water management alternatives to improve water temperature conditions for fish, including potential power bypasses. If there is a lack of consensus on actions to be taken, the ARG shall advise NMFS and be elevated through the WOMT standard operating procedures.

Exception: When preparing the Operations Forecast and Temperature Management Plan, Reclamation may submit to NMFS a written determination that, after taking all actions within its authorities, it is unlikely to meet the above temperature requirement. This determination must be supported by specific iterative modeling techniques that vary allocations and delivery schedules such as application of the Coldwater Management Pool model (see Appendix 2-D). In the event that Reclamation determines that other nondiscretionary requirements (*e.g*., D-1641 or requirements of the USFWS' Delta smelt biological opinion) conflict with attainment of the temperature requirement, Reclamation will convene the ARG to obtain recommendations. If consensus cannot be achieved within the ARG, the ARG shall advise NMFS, and NMFS will make a recommendation to the WOMT, per standard operating procedures.

During the May 15 to October 31 period, when the 65°F temperature requirement cannot be met because of limited cold water availability in Folsom Reservoir, then the target daily average water temperature at Watt Avenue may be increased incrementally (*i.e*., no more than one degree Fahrenheit every 12 hours) to as high as 68°F.

The priority for use of the lowest water temperature control shutters at Folsom Dam shall be to achieve the water temperature requirement for steelhead, and thereafter may also be used to provide cold water for fall-run spawning.

Rationale: As demonstrated in section 6.4 of this Opinion, steelhead are frequently exposed to water temperatures warmer than required for juvenile rearing, resulting in reduced fitness as is evident through the expression of visible thermal stress symptoms (*i.e*., bacterial inflammations). This thermal stress decreases steelhead immune system function and increases steelhead vulnerability to other sources of sub-lethal and lethal effects such as disease and predation. Monitoring of juvenile steelhead conducted by CDFW showed that bacterial inflammation was prevalent in steelhead throughout the river and the frequency of its occurrence increased as the duration of exposure to water temperatures over 65°F increased. The 65°F or lower daily average water temperature target was identified based on CDFW's monitoring as well as published scientific literature. Based on past convention of the ARG, the temperature compliance point is maintained at Watt Avenue Bridge, even though suitable rearing habitat is between Watt Avenue and Nimbus Dam.

Action II.3. Structural Improvements

Objective: Improve the ability to manage the cold water pool to provide suitable temperatures for listed fish through physical and structural improvements at the dams.

Action: Reclamation shall evaluate physical and structural modifications that may improve temperature management capability, as detailed below. Upon completion of the evaluation, Reclamation shall select the most promising projects and shall submit, by June 30th 2010, a proposed plan to NMFS to implement selected projects. Reclamation shall seek NMFS' concurrence that the proposed projects are likely to be effective in reducing adverse effects of warm water temperatures on listed fish. With NMFS' concurrence, Reclamation shall implement selected projects by December 15, 2012.

Modifying the following structures may substantially improve the ability to manage temperature in the Lower American River to reduce adverse effects of unsuitably warm water on listed species. The comparative benefits and costs of alternative modifications that will achieve objectives have not been fully analyzed. Reclamation shall analyze alternatives for each of the objectives listed below and shall implement the most effective alternative(s) for each objective:

1) **Folsom Dam temperature control device.** The objective of this action is to improve access to and management of Folsom Reservoir's cold water pool. Alternatives include enhancement of the existing shutters, replacement of the shutter system, and construction of a device to access cold water below the penstocks. If neither Reclamation nor DWR has authority to make structural or operational modifications to the control device, they shall seek to enter into an MOU with the Army Corps of Engineers to utilize their existing authorities.

2) **Cold water transport through Lake Natoma.** The objective of this action is to transfer cold water from Folsom Dam to Nimbus Dam with minimal increase in temperature. Alternatives include dredging, construction of temperature curtains or pipelines, and changes in Lake Natoma water surface elevation.

3) **El Dorado Irrigation District Temperature Control Device (EID TCD).** The objective of this action is to conserve cold water in Folsom Lake. Alternative intake structures have been analyzed by EID. The most effective device for conserving cold water should be constructed. If neither Reclamation nor DWR has authority to make structural or operational modifications to the EID TCD, they shall work with the owners and operators of the TCD to make the desired improvements, including providing funding and technical assistance

4) **Temperature Management Decision-Support Tools.** The objective of this action is to provide effective tools to make transparent temperature management decisions. Alternatives include decision impact analyses, regular analysis of a broad array of operational scenarios, improved operations group processes, and monitoring.

Rationale: Maintaining suitable water temperatures for all life history stages of steelhead in the American River is a chronic issue because of operational (*e.g.*, Folsom Reservoir operations to meet Delta water quality objectives and demands and deliveries to M&I users in Sacramento County) and structural (*e.g*., limited reservoir water storage and coldwater pool) factors. Increased water demand and climate change will lead to further deterioration of suitable habitat conditions, including increased temperatures. Action II.2 provides for a temperature management plan to minimize operational effects to steelhead using current technology. However, the current technology is out-dated resulting in less than optimal ability to access and fully utilize cold water in any given hydrology or ambient temperature regime. Alternative technologies have been studied previously, but not funded or implemented. Because of the significant temperature related effects that will persist despite implementation of Action II.2, all feasible technological options should be pursued. These technological actions will increase the likelihood that temperate control points will be attained, as prescribed in Action II-2, and therefore American River water temperatures will be suitable for steelhead more frequently.

Action II.4. Minimize Flow Fluctuation Effects

Objective: Reduce stranding and isolation of juvenile steelhead through ramping protocols.

Action: The following flow fluctuation objectives shall be followed:

1) From January 1 through May 30, at flow levels <5,000 cfs, flow reductions shall not exceed more than 500 cfs/day and not more than 100 cfs per hour.

2) From January 1 through May 30, Reclamation shall coordinate with NMFS, CDFW, and USFWS to fund and implement monitoring in order to estimate the incidental take of salmonids associated with reductions in Nimbus Dam releases.

3) Minimize the occurrence of flows exceeding 4,000 cfs throughout the year, except as may be necessary for flood control or in response to natural high precipitation events.

Rationale: Flow fluctuations in the lower American River have been documented to result in steelhead redd dewatering and isolation (Hannon *et al.,* 2003, Hannon and Deason 2008), fry stranding, and fry and juvenile isolation (Water Forum 2005a). By limiting the rate of flow reductions, the risk of stranding and isolating steelhead is reduced. Two lower American River habitat evaluations indicate that releases above 4,000 cfs inundate several pools along the river that are isolated at flows below this threshold [California Department of Fish and Game (CDFG) 2001, Hall and Healey 2006]. Thus, by maintaining releases below 4,000 cfs the risk of isolating juvenile steelhead is reduced.

Action II.5. Fish Passage at Nimbus and Folsom Dams

Objective: Provide access for steelhead to historic cold water habitat above Nimbus and Folsom dams.

Action: See Fish Passage Program, Action V.

Rationale: The effects analysis in this Opinion leads to the conclusion that steelhead will continue to be vulnerable to serious effects of elevated temperatures in most years and particularly in dry and critically dry years, even if actions are taken to improve temperature management. The frequency of these occurrences is expected to increase with climate change and increased water demands. Therefore, it is essential to evaluate options for providing steelhead to access their historic cold water habitat above Nimbus and Folsom dams and to provide access if feasible.

Action Suite II.6. Implement the Following Actions to Reduce Genetic Effects of Nimbus and Trinity River Fish Hatchery Operations

Objective of Actions II.6.1-3: The following actions are identified to offset project effects related to Nimbus Fish Hatchery by reducing introgression of out-of-basin hatchery stock with wild steelhead populations in the Central Valley, including the American River population and other populations in the Sacramento River system (Garza and Pearse 2008). In addition, actions are necessary at both Nimbus and Trinity River fish hatcheries to increase diversity of fall-run production, in order to increase the likelihood of prey availability for Southern Residents and reduce adverse effects of hatchery fall-run straying on genetic diversity of natural fall-run and spring-run.

Action II.6.1. Preparation of Hatchery Genetic Management Plan (HGMP) for Steelhead

Action: Reclamation shall fund CDFW to prepare a complete draft HGMP for steelhead production at Nimbus Fish Hatchery, in accordance with current NMFS guidelines, and submit that draft for NMFS review by June 2011. Specific actions shall include:

1) Reclamation shall fund genetic screening at Nimbus Fish Hatchery for steelhead to determine most appropriate brood stock source. This action shall be completed by March 31, 2012.

2) Reclamation shall fund a study examining the potential to replace the Nimbus Fish Hatchery steelhead broodstock, with genetically more appropriate sources. This action shall be completed by March 31, 2012.

Action II.6.2. Interim Actions Prior to Submittal of Draft HGMP for Steelhead

Action: Reclamation shall use its authorities to ensure that, prior to completion of the draft HGMP, the hatchery is operated according to the following protocols:

1) Release all hatchery-produced steelhead juveniles in the American River at Nimbus Fish Hatchery or at a location in the American River as close to Nimbus Fish Hatchery as is feasible to reduce straying. This action shall be implemented within 30 days of issuance of this Opinion.

2) Release all unclipped steelhead adults returning to Nimbus Fish Hatchery back into the lower American River so they can spawn naturally. This action shall be implemented within 30 days of issuance of this Opinion.

3) Stop inter-basin transfers of steelhead eggs or juveniles to other hatcheries, except upon specific written concurrence of NMFS. This action shall be implemented within 30 days of issuance of this Opinion.

Action II.6.3: Develop and Implement Fall-run Chinook Salmon Hatchery Management Plans for Nimbus and Trinity River Fish Hatcheries

Action: By June 2014, develop and begin implementation of Hatchery Management Plans for fall-run production at Nimbus Fish Hatchery and spring-run and fall-run at Trinity River Fish Hatchery. Reclamation shall fund CDFW to develop and submit draft plans for NMFS review by June 2013. The goal of the plans shall be to reduce impacts of hatchery Chinook salmon on natural fall-run and spring-run, and increase the genetic diversity and diversity of run-timing for these stocks.

Rationale for actions II.6.1-3: Hatcheries have been established on CVP and SWP rivers to offset effects of dams and project operations. Since these hatcheries were initially put into operation, additional knowledge has been developed that has advanced NMFS understanding of how hatchery operations can affect listed and non-listed salmonids. The operations of Nimbus Fish Hatchery and the spring- and fall-run operations of Trinity River Fish Hatchery are interrelated and interdependent to the proposed action.

Nimbus Fish Hatchery steelhead broodstock is predominantly Eel River stock. Maintaining this genetic broodstock has adverse effects on listed steelhead in the CV steelhead DPS (Garza and Pearse 2008). Based on genetics information presented in Garza and Pearse (2008), *O. mykiss* from the American River above Folsom Dam retain ancestral CV steelhead genetics and potentially could provide a broodstock source to replace the current Nimbus Fish Hatchery steelhead broodstock. This would eliminate the spread of Eel River genetics to CV steelhead. An HGMP is necessary to minimize effects of ongoing steelhead hatchery program on steelhead contained within the DPS.

Southern Residents depend on Chinook salmon as prey. Preparation of hatchery management plans for fall-run at Nimbus Fish Hatchery and spring-run and fall-run at Trinity River Fish Hatchery is necessary to reduce operational effects on Southern Residents prey over the long term. Improving the genetic diversity and diversity of run timing of Central Valley fall-run will decrease the potential for localized prey depletions and increase the likelihood that fall-run can withstand stochastic events, such as poor ocean conditions (Lindley *et al.,* 2009), and thereby provide a consistent food source in years with overall poor productivity. .

III. EAST SIDE DIVISION

Introduction to Stanislaus River/Eastside Division Actions: The steelhead population on the Stanislaus River is precariously small and limited to habitat areas below the dams that historically were unsuitable owing to high summer temperatures. All of the four steelhead populations in the Southern Sierra Nevada Diversity Group of the CV steelhead DPS are in similar condition and are not presently considered viable. Using the framework in this Opinion for jeopardy analysis, the DPS is not viable if one of the Diversity Groups is not viable. The overall poor status of the Diversity Group increases the importance of minimizing the effects of project operations on the Stanislaus River population.

Modeled operations suggest that it is possible to operate dams of the Eastside Division in a manner that avoids jeopardy to steelhead; however, if future climate conditions are warmer, drier, or both, summertime temperatures will restrict the extent of suitable habitat for steelhead.

The fundamental operational criteria are sufficiently ill-defined in the CVP/SWP operations BA as to provide limited guidance to the Action Agency on how to operate. This suite of actions provides sufficiently specific operational criteria so that operations will avoid jeopardizing steelhead and will not adversely modify their critical habitat. Operational actions to remove adverse modification of critical habitat include a new flow schedule to minimize effects of flood control operations on functionality of geomorphic flows and access of juvenile steelhead to important rearing areas.

Overall Objectives: (1) Provide sufficient definition of operational criteria for Eastside Division to ensure viability of the steelhead population on the Stanislaus River, including freshwater migration routes to and from the Delta; and (2) halt or reverse adverse modification of steelhead critical habitat.

Overall Rationale: Sufficient uncertainty exists as to whether VAMP pulse flows and b(2) allocations are reasonably likely to occur in the future. VAMP, as defined by the SJRA, is due to expire in 2011. The BA commits to subsequent flows similar to VAMP ("Vamp-like flows"), but this is a very vague commitment. The project description does not define the particular contribution, timing, duration, or magnitude of these flows from the tributaries that contribute to VAMP, including the Stanislaus River. In addition, the BA specifies the amount of water designated to offset VAMP export curtailments as 48 TAF; but the need, based on past performance, has varied from approximately 45 to 150 TAF. Additional demands for smelt protection and future drainage settlement terms are being placed on b(2) water, and it is uncertain that b(2) water will be available consistently in each year in the quantity, duration, and timing needed for CV steelhead in the Stanislaus River. The annual water contract allocation process from New Melones is inadequately defined in the project description to assure the proposed action will not prevent the establishment of a viable population of steelhead.

Action III.1.1. Establish Stanislaus Operations Group for Real-Time Operational Decision-Making as Described in These Actions and Implementation Procedures

Action: Reclamation shall create a SOG to provide a forum for real-time operational flexibility implementation of the alternative actions defined in this RPA and for clarification of decision-making processes regarding other allocations of the NMTP. This group shall include Reclamation, NMFS, USFWS, DWR, CDFW, SWRCB, and outside expertise at the discretion of NMFS and Reclamation. This group shall provide direction and oversight to ensure that the East Side Division actions are implemented, monitored for effectiveness and evaluated. Reclamation, in coordination with SOG, shall submit an annual summary of the status of these actions. See introduction to RPA for further information on group procedures.

Action III.1.2. Provide Cold Water Releases to Maintain Suitable Steelhead Temperatures

Action: Reclamation shall manage the cold water supply within New Melones Reservoir and make cold water releases from New Melones Reservoir to provide suitable temperatures for CV steelhead rearing, spawning, egg incubation smoltification, and adult migration in the Stanislaus River downstream of Goodwin Dam in order to maintain the following temperature compliance schedule:

Criterion and Temperature Compliance Location	Duration	Steelhead Life Stage Benefit
Temperature below 56°F at Orange Blossom Bridge (OBB)	Oct 1*-Dec 31	Adult migration
Temperature below 52 °F at Knights Ferry and 57°F at OBB	Jan 1-May 31	Smoltification
Temperature Below 55°F at OBB	Jan 1-May 31	Spawning and incubation
Temperature below 65°F at OBB	June 1-Sept 30	Juvenile rearing

***This criterion shall apply as of October 1 or as of initiation date of fall pulse flow as agreed to by NMFS**.

Temperature compliance shall be measured based on a seven-day average daily maximum temperature.

Exception: If any of these criteria is or is expected to be exceeded based on a three-day average daily maximum temperature, Reclamation shall immediately notify NMFS of this condition and shall submit to NMFS a written determination that, after taking all actions within its authorities, it is unlikely to meet the above temperature requirement and the extent and duration of the expected exceedance. This determination must be supported by specific iterative modeling techniques that vary allocations and delivery schedules. In the event that

Reclamation determines that other nondiscretionary requirements (*e.g.*, D-1641 or requirements of the USFWS' Delta smelt biological opinion) conflict with attainment of the temperature requirement, Reclamation will convene SOG to obtain recommendations. If consensus cannot be achieved within SOG, then SOG shall advise NMFS, and NMFS will make a recommendation to WOMT per standard operating procedures.

Rationale: CV steelhead are dependent on East Side Division operations to maintain suitable in-stream temperatures. Operational criteria are not clearly described in the CVP/SWP Operations BA to ensure that appropriate temperatures are met for CV steelhead adult migration, spawning, egg incubation, juvenile rearing, and smoltification. The temperature compliance schedule above provides an operational framework to minimize temperature-related effects of proposed operations in the reaches of the river most used by CV steelhead on a year-round basis. Temperature criteria for adult CV steelhead migration in the lower Stanislaus River are included, as we expect that fall attraction flows will improve downstream temperature conditions for adult migration.

Observations at the fish counting weir on the Stanislaus River indicate that apparent CV steelhead enter the river in October, usually coincident with the release of fall attraction flows that provide cooler water and flow cues for fall-run.

The literature regarding appropriate criteria for smoltification suggests optimal temperatures of less than 52°F (Adams *et al*., 1975, Myrick and Cech 2001) or 57°F (EPA 2001). In order to provide optimal temperatures for smoltification within a feasible operational scenario, the smoltification temperature criteria are lower for Knights Ferry at 52°F and 57°F for Orange Blossom Bridge.

No steelhead spawning surveys have been conducted on the Stanislaus River, but fall-run surveys indicate that spawning may occur from Goodwin Dam (RM 59) almost to the City of Oakdale (RM 40), with the highest use occurring above Knights Ferry (RM 55). Based on observations of trout fry, most spawning occurs upstream of OBB (Kennedy and Cannon 2002). Consequently, specific temperature criteria of 55ºF or less at Riverbank should be met from December through May to ensure that temperatures are suitable for all available spawning habitat, however, modeled results and CDEC data (figure 6-35) indicates that temperatures at Riverbank are likely to exceed this level. Based on observations of trout fry, most spawning occurs upstream of OBB (Kennedy and Cannon 2002). Suitable spawning temperatures are likely to be met at OBB, except in May in critically dry years, and exception procedures will be implemented.

Action III.1.3. Operate the East Side Division Dams to Meet the Minimum Flows, as Measured at Goodwin Dam, Characterized in Figure 11-1, and as Specified in Appendix 2-E

Objective: To maintain minimum base flows to optimize CV steelhead habitat for all life history stages and to incorporate habitat maintaining geomorphic flows in a flow pattern that will provide migratory cues to smolts and facilitate out-migrant smolt movement on declining limb of pulse.

Action: Reclamation shall operate releases from the East Side Division reservoirs to achieve a minimum flow schedule as described in Appendix 2-E and Figure 11-1, below. This flow schedule specifies minimum flows and does not preclude Reclamation from making higher releases for fishery benefits or other operational criteria. When operating at higher flows than specified, Reclamation shall implement ramping rates for flow changes that will avoid stranding and other adverse effects on CV steelhead. In particular, flows that exceed 800 cfs will inundate known side channels that provide habitat, but that also pose stranding risks. When spring pulses greater than 800 cfs are identified in Figure 11-1, the declining limb is not reduced below 800 cfs until after the last pulse.

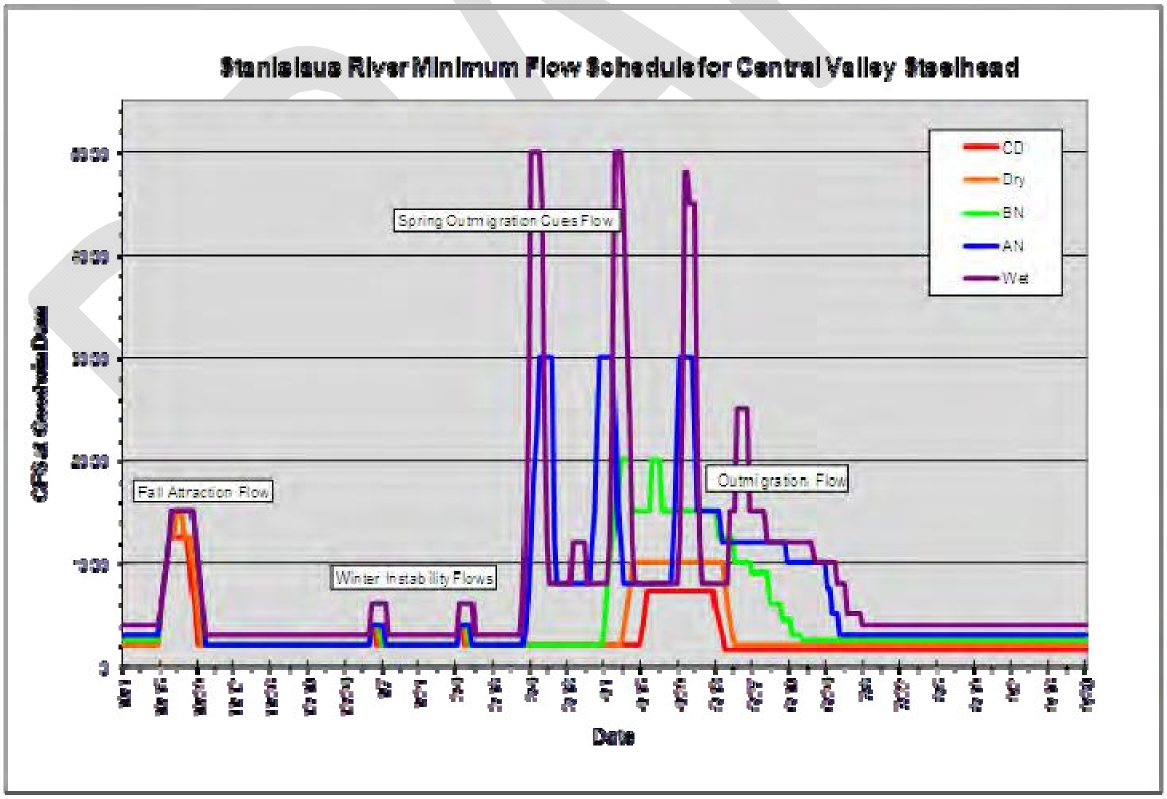

Figure 11-1. Minimum Stanislaus River in-stream flow schedule for CV steelhead as measured at Goodwin Dam

Implementation procedures: Reclamation shall convene the SOG to adaptively manage flows according to this schedule. The timing, magnitude, and duration of the flows in Appendix 2-E are intended to provide certain hydrologic features at certain times of year to benefit CV steelhead, as explained in the Rationale. Based upon the advice of SOG and the concurrence by NMFS[17], the flows may be implemented with minor modifications to the timing, magnitude, and/or duration, as long as NMFS concurs that the rationale for the shift in timing, magnitude, and/or duration is deemed by NMFS to be consistent with the intent of the action. For example, Reclamation may execute shorter duration pulses more frequently (*e.g.*, 2 - 4 times) during the longer pulse period. Implementation of this action should be coordinated with allocation of water resources dedicated for fish, such as the 98.3 TAF to CDFW and b(2) or b(3), if applied. The SOG shall follow standard operating procedures resolving any conflict through the WOMT process. The team shall also advise Reclamation on operations needed to minimize the adverse effects of flow fluctuations associated with New Melones Reservoir and Goodwin Dam operations on CV steelhead spawning, egg incubation, and fry and juvenile rearing within the Stanislaus River. If new information is developed, such as an update of Stanislaus River CV steelhead in-stream flow needs, more specific geomorphic analyses regarding channel forming flows, or real-time recommendations from the SOG, Reclamation may submit to NMFS a revised annual minimum flow schedule that may be implemented if NMFS concurs that it is consistent with ESA obligations. These revisions may trigger re-initiation and re-consultation.

Rationale: This flow schedule includes the following components:

1) Minimum base flows based on IFIM (Aceituno 1993) to optimize available CV steelhead habitat for adult migration, spawning, and juvenile rearing. These base flows are scaled to water year type as defined by the New Melones water supply parameter[18], with lowest flows in critically dry years and highest flows in wet years.

2) Fall pulse flow to improve in-stream conditions sufficiently to attract CV steelhead to the Stanislaus River.

3) Winter instability flows to simulate natural variability in the winter hydrograph and to enhance access to varied rearing habitats.

4) Channel forming and maintenance flows in the 3,000 to 5,000 cfs range in above normal and wet years to maintain spawning and rearing habitat quality. These flows are scheduled to occur after March 1 to protect incubating eggs and are intended to work synergistically with providing outmigration flow cues and late spring flows, described

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[17] Concurrence by NMFS is necessary only for pulse flows that are timed or shaped differently than the pulse descriptions I Appendix 2-E.

[18] The New Melones water supply parameter is calculated as the sum of end of February New Melones Reservoir storage and cumulative inflow to New Melones Reservoir from March through September.

next. These flows are high intensity, but limited duration to avoid potential seepage issues that have been alleged under extended periods of flow greater than 1,500 cfs.

5) Outmigration flow cues to enhance likelihood of anadromy.

6) Late spring flows for conveyance and maintenance of downstream migratory habitat quality in the lowest reaches and into the Delta.

An analysis of Stanislaus River rotary screw trap captures of smolted CV steelhead conducted by Reclamation in April 2009 (Hannon 2009b) identified that the median date for smolt CV steelhead out migration is March 1 (Figure RR- Julian Day 60), ranging from January through June. Juveniles are generally captured in trawls at Mossdale in smolted condition in late May (Julian Day 151 and Figure 4-4). CV steelhead are larger than fall-run smolts and may be less dependent on pulse flows to convey them out of the Stanislaus River, but the variability of pulses provides migratory cues to smolted CV steelhead. Capture information suggests that it is important to maintain suitable migratory conditions from the Stanislaus River to the Delta into the month of June. This action will allow more smolted fish to migrate out of system by extending the declining limb of the outmigration pulse and increasing migratory cues.

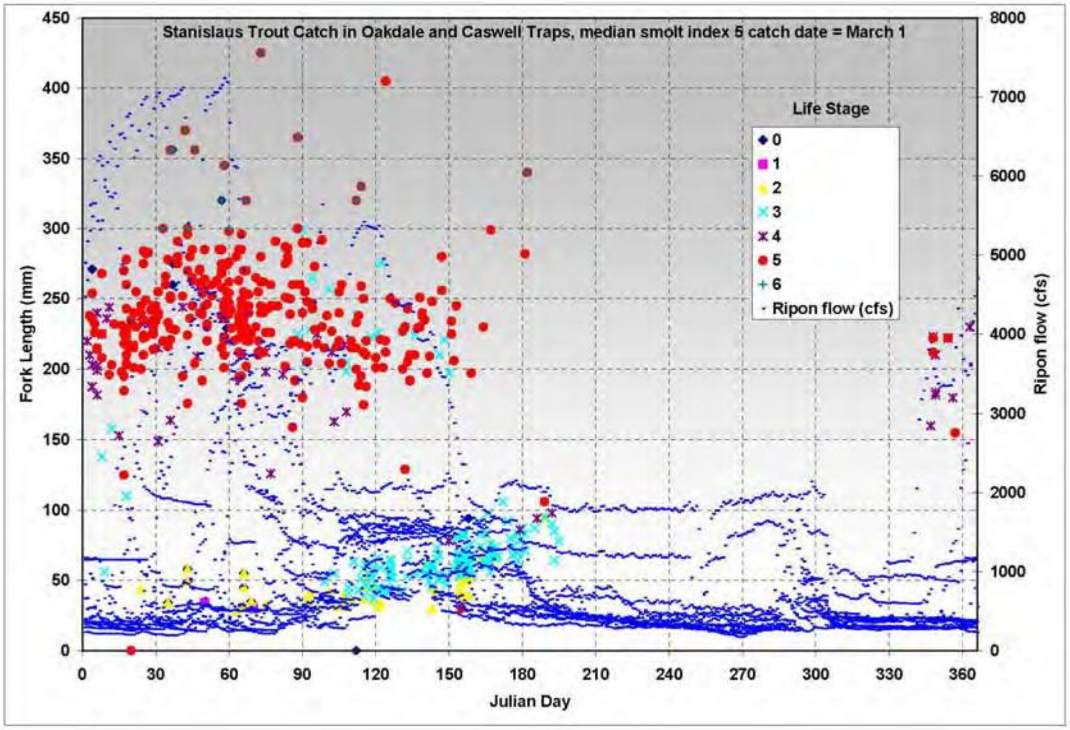

Figure 11-2. Smolt stage *O.mykiss* captured in Stanislaus River Rotary Screw Traps

The fall pulse flow was originally instituted to provide attraction flows for fall-run. Monitoring of adult salmonids at the Stanislaus River counting weir indicates that the fall pulse flow attracts both fall-run and CV steelhead into the Stanislaus River, making freshwater riverine habitat available. These riverine conditions have better temperature and water quality than conditions in the Delta during this period. The purpose of the fall pulse flow is to provide flow cues downstream for incoming adults, as well as providing some remedial effect on the low dissolved oxygen conditions that develop in the Stockton Deep Water Ship Channel. In addition to steelhead, this action also produces ancillary benefits to fall-run EFH.

Modeling conducted in the preparation of this action indicate that the temperature criteria of Action III.1.2 can generally be met under this alternative minimum flow schedule and are often improved, but that exceedances may occur in certain months (*e.g.*, May and early fall) during dry year types. Based on SALMOD analyses, temperature related mortality may be about 2 percent higher in critically dry years, but is reduced by about 1 percent in all other year types under the proposed alternative (Figure 11-3).

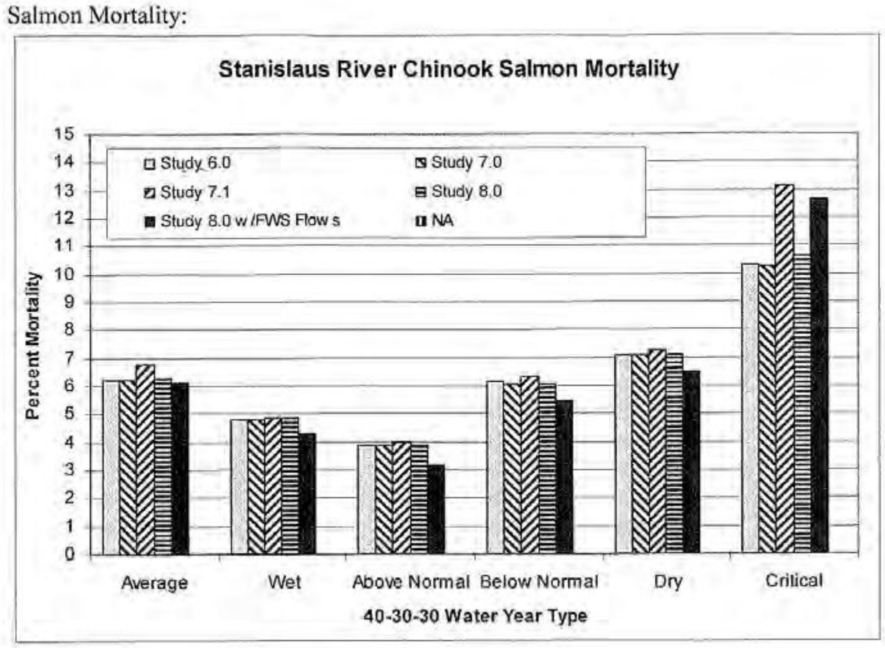

Figure 11-3. Modeled temperature effects of alternative Stanislaus River flows, draft provided by Reclamation on May 5, 2009.

Rationale for 2011 amendments:

5) Figure 11-1: Figure 11-1, as provided in the 2009 RPA, showed draft flows that varied slightly from the final flow schedule in Appendix 2-E. Figure 11-1 is now fully consistent with the flow schedule in Appendix 2-E.
6) Flexibility in implementing flow schedules: The minimum flow schedules provided in Appendix 2-E remain the same. The amendments to Action III.1.3 and its implementation procedures are intended to provide the SOG with more flexibility to

adjust the timing, magnitude, and duration of the pulse flows (*not* the minimum flows in between pulses) described in Figure 11-1 and Appendix 2-E based on considerations such as:

a) optimizing intended benefits to CV steelhead (*e.g*., based on observed fish distribution or run timing and observed flow and temperature conditions and the intent of the pulse flow as described in the "Rationale," above);
b) coordinating Stanislaus River flows for CV steelhead with flows on other San Joaquin River tributaries (*e.g*., during the fall attraction flow or during the VAMP period); or
c) coordinating operational objectives to use Goodwin Dam releases to achieve multiple benefits (*e.g*., during April and May when Stanislaus River flows may be contributing to multiple regulatory requirements at the same time).

Any change in the timing, magnitude, and/or duration of the pulse flows must provide protection to CV steelhead and critical habitat that is equal to or greater than the protection provided by the pulse flows as described in Appendix 2-E. This clarified flexibility can also result in improved water supply when multiple operational objectives can be satisfied with a single strategic release. These amendments were supported by the ISP.

Action Suite III.2. Stanislaus River CV Steelhead Habitat Restoration

Overall objective: Dam operations have and will continue to suppress channel-forming flows that replenish spawning beds. The physical presence of the dams impedes normal sediment transportation processes. This action is necessary to partially alleviate adverse modification of steelhead critical habitat from operations.

Action III.2.1. Increase and Improve Quality of Spawning Habitat with Addition of 50,000 Cubic Yards of Gravel by 2014 and with a Minimum Addition of 8,000 Cubic Yards per Year for the Duration of the Project Actions

Action: Reclamation shall minimize effects of their operations through improving spawning habitat with addition of 50,000 cubic yards of gravel by 2014. Reclamation shall submit a plan, including monitoring, and schedule to NMFS for gravel augmentation by June 2010. Reclamation shall begin gravel augmentations no later than summer 2011. Reclamation shall submit to NMFS a report on implementation and effectiveness of action by 2015. Spawning gravel replenishment sites shall be monitored for geomorphic processes, material movement, and salmonid spawning use for a minimum of three years following each addition of sediment at any given site.

Rationale: Kondolf (*et al.,*) 2001 identified levels of sediment depletion at 20,000 cubic yards per year owing to a variety of factors including mining and geomorphic processes associated with dam operations, past and ongoing. Kondolf (*et al*.,) 2001 and other reports cited in that work, identify a loss of over 60 percent of spawning area for salmonids since 1966. This level of replenishment will restore adversely affected spawning habitat to relieve adverse habitat conditions and provide sediment to partially offset ongoing loss rates. Sediment addition may also be conducted in a manner to remediate sediment related loss of geomorphic function, such as channel incision, to and allow for inundation of floodplain rearing habitat.

Rationale for 2011 Amendment: Use of "tons" in the 2009 RPA was a typographical error. The change from "tons" to "cubic yards" was made to be consistent with the intent of the action. This change does not result in any change in implementation.

Action III.2.2. Conduct Floodplain Restoration and Inundation Flows in Winter or Spring to Inundate Steelhead Juvenile Rearing Habitat on One- to Three-Year Schedule.

Action: Reclamation shall seek advice from SOG to develop an operational strategy to achieve floodplain inundation flows that inundate CV steelhead juvenile rearing habitat on a one- to three-year return schedule. Reclamation shall submit a proposed plan of operations to achieve this flow regime by June 2011. This plan shall include the minimum flow schedule identified in Action III.1.2, or shall provide justification for any proposed modification of the minimum flow schedule. NMFS will review and, if satisfactory, approve the operational strategy. Reclamation will implement strategy starting in 2012.

Rationale: Kondolf *et al*., (2001) identified that floodplain terraces and point bars inundated before operation of New Melones Dan have become fossilized with fine material and thick riparian vegetation that is never rejuvenated by scouring. Channel forming flows in the 8,000 cfs range have occurred only twice since New Melones Dam began operation 28 years ago. Lack of channel forming flows and lack of sediment input blocked by the dams has resulted in channel incision of one to three feet over 13 years. Floodplain juvenile rearing habitat and connectivity will continue to be degraded by New Melones operations, as proposed.

Action III.2.3. Restore Freshwater Migratory Habitat for Juvenile Steelhead by Implementing Projects to Increase Floodplain Connectivity and to Reduce Predation Risk During Migration

Objective: This action is necessary to compensate for continued operational effects on rearing and freshwater migratory habitat due to flood control operations. The goal of this action is to improve habitat quality of freshwater migratory habitat for juvenile steelhead.

Action: By June 2010, in cooperation with the SOG, Reclamation shall develop a list of projects to improve the habitat values of freshwater migratory habitat in the Stanislaus River, and associated monitoring, for implementation and submit the list to NMFS for review. Reclamation shall begin implementation of NMFS-approved projects by June 2011. Reclamation shall submit a report of project implementation and effectiveness by June 2016.

These projects may include actions that reduce exposure to predation directly, or projects that may offset predation effects by improving rearing habitat values to allow juveniles to grow larger before outmigration. These projects may include both flow- and non-flow-related actions. Flow-related actions shall be coordinated with operational flows as defined in Action III.2.2 and Action III.1.2. These projects may also include, but shall not be limited to, evaluations to identify locations or sources of higher juvenile mortality in order to identify and implement projects with the highest likelihood to prevent CV steelhead mortality.

Rationale: Predation studies on the Tuolumne River have shown losses of up to 60 percent of outmigrating salmon smolts in run-of-river gravel mining ponds and dredged areas. Losses on the Stanislaus River have not been similarly quantified, but predation on fall run smolts and *O. mykiss* by striped bass and large mouth bass have been documented. These run-of-river ponds also reduce flow velocities as compared to incoming river channels, requiring outmigrating salmonids to expend more energy to traverse these sections. Operational releases provide flows lower than typical unimpaired flows, which exacerbates the effect of this stressor on outmigrating juveniles and degrades the habitat value of necessary freshwater migratory corridors. Additional flows or flow pulses could alleviate this added energy demand and improve survival through these problem areas. Channel modifications in these problem areas can improve migration success. Improvements in floodplain habitat quality can improve juvenile growth and larger juveniles are more likely to avoid predation mortality.

Action III.2.4. Evaluate Fish Passage at New Melones, Tulloch, and Goodwin Dams

Objective: Evaluate access for steelhead to historic cold water habitat above New Melones, Tulloch, and Goodwin dams.

Action: See Fish Passage Program, Action V.

Rationale: The effects analysis in this Opinion leads to the conclusion that steelhead will continue to be vulnerable to serious effects of elevated temperatures in dry and critically dry years, even if actions are taken to improve temperature management. The frequency of these occurrences is expected to increase with climate change and increased water demands. Therefore, it is essential to evaluate options for providing steelhead to access their historic cold water habitat above New Melones, Tulloch, and Goodwin dams and to provide access if feasible..

IV. DELTA DIVISION

Introduction: An important life history phase for all anadromous fish is their movement through an estuary as adults moving upstream to spawning grounds, and as juveniles moving downstream to the ocean. For some fish, the estuary also serves as a staging area and, for some juveniles, a rearing area prior to their entering the ocean. Within the Central Valley, all anadromous fish, including listed winter-run, spring-run, CV steelhead, and Southern DPS of green sturgeon, depend on the Sacramento-San Joaquin Delta environment during these life phases. This dependence was an important factor in designation of critical habitat in the Delta for these species. A properly functioning Delta is critical to migration pathways and rearing habitat, both of which are primary constituent elements of critical habitat for these fish.

Currently, the fish are exposed to a multitude of stressors in the Delta during passage and rearing. The Delta has been severely degraded over the past 150 years, primarily due to anthropogenic actions within its boundaries and in its surrounding watersheds. Nearly 90 percent of its fringing marshes have been lost and replaced with raised levees armored with rock riprap. The channelization of the Delta waterways through the construction of raised levees for flood control has isolated the Delta from its surrounding floodplains. These seasonally inundated floodplains served as important rearing habitats for many of the native fish species occurring in the Delta, including salmonids, and juvenile green sturgeon.

The structure of the Delta, particularly in the central and southern Delta, has been significantly altered by construction of manmade channels and dredging, for shipping traffic and water conveyance. Intentional and unintentional introductions of non-native plant and animal species have greatly altered the Delta ecosystem. Large predatory fish such as striped bass and largemouth bass have increased the vulnerability of emigrating juveniles and smolts to predation, while infestations of aquatic weeds such as *Egeria densa* have diminished the useable near-shore, shallow water habitat needed by emigrating salmonids for rearing.

The use of Delta islands for intensive agriculture has increased demand for irrigation water from the Delta, as well as increased the discharge of agricultural runoff into Delta waterways surrounding these farmed islands. These discharges carry chemicals such as fertilizers, pesticides, herbicides, and excessive nutrients, leading to degradation of water quality parameters such as DO content and suspended sediment, and increasing exposure to toxic compounds. Likewise, increasing urbanization in the areas surrounding the Delta increases the load of contaminants associated with stormwater runoff, discharges from wastewater sanitation plants, and industrial activities. Overall, conditions in the Delta make emigrating anadromous fish highly vulnerable to any added stressors and substantially reduce their chances for survival.

The proposed actions for the CVP and SWP include continued diversion of water from the Delta at the project's export facilities, with increased export levels. These actions will increase the level of stressors in the Delta beyond those previously described and exacerbate many of those already present. NMFS has identified several factors associated with operation of the CVP and SWP that affect the long-term viability and resiliency of winter-run, spring-run, CV steelhead, and the Southern DPS of green sturgeon in the Central Valley. In addition to these specific factors, the operations of the CVP and SWP alter Delta hydrodynamics and interact with other stressors to enhance the vulnerability of listed fish to morbidity and mortality during their time in the Delta.

The adverse effects of the proposed action identified in this Opinion include:

1) Diversion from the North Delta into the Delta interior of early emigrating winter-run juveniles, yearling spring-run, and CV steelhead, through the operation of the DCC gates in late fall and early winter.

2) Enhanced vulnerability of juvenile salmonids to entrainment and indirect mortality, through alteration of the hydrodynamics of the interior and south Delta waterways, due to the influence of export pumping actions in winter and spring.

3) Enhanced vulnerability of CV steelhead from the San Joaquin River basin to exports and export-related changes in hydrodynamics.

4) Direct mortality from entrainment of juvenile salmonids and green sturgeon at the CVP and SWP export facilities.

The actions prescribed below will minimize or avoid the proposed action's adverse effects on hydraulic patterns in the Delta that affect listed salmonids and green sturgeon. They will modify the interactions that listed fish have with other stressors in the Delta and thereby avoid appreciably reducing the likelihood of survival and recovery of listed fish.

The current metric for monitoring direct take and mortality of listed fish by the CVP and SWP actions is the level of salvage and calculated loss at fish collection facilities. This metric is a reflection of export levels and the diversion of large volumes of water through the facilities. Counting fish at the salvage facilities alone, however, does not account for fish that have been lost prior to the point of collection, and thus is an inaccurate measure of adverse export influence. It does not account for fish that have been drawn into the waters of the central Delta through the DCC gates or Georgiana Slough and lost to predation, toxics, or other factors before reaching the south Delta, nor does it account for fish that make it to the south Delta, where they are further influenced by the reverse flows moving toward the pumps and are delayed in their migration; which increases their vulnerability to predation, toxics, or other forms of loss, such as stranding in agricultural diversions.

Overall Objectives: The juveniles of all four listed species migrating downstream in the Sacramento River have a much greater chance of survival when they migrate directly to the estuary within the Sacramento River than when they are diverted by water operations into the southern or central Delta, where they are exposed to increased risks of predation, exposure to toxic pollutants, and entrainment into water diversions. The Delta Division measures will reduce the likelihood of diversion of emigrating juveniles into the southern or central Delta, and will reduce mortality of emigrating juveniles that have been entrained at the fish collection facilities and entered the salvage process.

There are six actions to be taken in the Delta:

- Action IV.1: Modify DCC gate operations and evaluate methods to control access to Georgiana Slough and the Interior Delta to reduce diversion of listed fish from the Sacramento River into the southern or central Delta.
- Action IV.2: Control the net negative flows toward the export pumps in Old and Middle rivers to reduce the likelihood that fish will be diverted from the San Joaquin or Sacramento River into the southern or central Delta.
- Action IV.3: Curtail exports when protected fish are observed near the export facilities to reduce mortality from entrainment and salvage.
- Action IV.4: Improve fish screening and salvage operations to reduce mortality from entrainment and salvage.
- Action IV.5: Establish a technical group to assist in determining real-time operational measures, evaluating the effectiveness of the actions, and modifying them if necessary.
- Action IV.6: Do not implement the South Delta Barriers Improvement Program.

A summary of Actions IV.1 and IV.2 and their timeframes is provided below in Figure 11-4.

Action Suite IV.1 Delta Cross Channel (DCC) Gate Operation, and Engineering Studies of Methods to Reduce Loss of Salmonids in Georgiana Slough and Interior Delta

Objective: Reduce the proportion of emigrating listed salmonids and green sturgeon that enter the interior delta through either the open DCC gates or Georgiana Slough.

Rationale: Salmon migration studies show losses of approximately 65 percent of groups of outmigrating fish that are diverted from the mainstem Sacramento River into the waterways of the central and southern Delta (Brandes and McLain 2001; Vogel 2004, 2008; Perry and Skalski 2008). Diversion into the internal Delta also increases the likelihood of entrainment and mortality associated with the pumping facilities. These effects are inferred from both particle tracking models, which derive the fate of particles over time, and direct study of acoustically tagged and CWT salmonids (Vogel 2004, SJRGA 2007).

On average, up to 25 percent of Sacramento River flows are diverted into the channels of the DCC when the gates are open, with a maximum of 35 to 40 percent. Approximately 20 percent, on average, of the Sacramento River flow is diverted into Georgiana Slough. During November and December, approximately 25 percent of the Sacramento River flow is diverted into the interior Delta through these two channels. Recent studies by Perry and Skalski (2008) indicate that by closing the DCC gates when fish are present, total through-Delta survival of marked fish to Chipps Island increases by nearly 50 percent for fish moving downstream in the Sacramento River system. Closing the DCC gates appears to redirect the migratory path of emigrating fish into Sutter and Steamboat Sloughs and away from Georgiana Slough, resulting in higher survival rates. Similar benefits have been described in previous studies (Newman 2008, Brandes and McLain 2001) with CWT fish.

Based on data from monitoring studies in the lower Sacramento River, approximately 45 percent of the annual winter-run emigration from the Sacramento River enters the Delta between November and January. During the same period, about eight percent of the annual CV steelhead emigration from the Sacramento River Basin occurs. Yearling spring-run pass into the Delta in January, but these fish account for only three percent of the total annual population of spring-run emigrants entering the Delta.

	Action IV. 1.2 - Operation of DCC to enhance protection of emigrating salmonids/green sturgeon	**Action IV. 2.1** - Maintain San Joaquin River Inflow/Export ratio		**Action IV. 2.2** - Acoustic Tag Experiment	**Action IV. 2.3** - Reduced exports to limit negative flows in OMR depending on presence of salmonids
		2009 - 2011 Interim Operations	**2012 + Long term Operations**		
Oct.	**Oct. 1 - Nov. 30** - Gates closed if fish are present				
Nov.					
Dec.	**Dec. 1 - 14** - Gates closed except for experiments/water quality **Dec. 15 - Jan. 31** Gates Closed				
Jan.					**Jan 1 - June 15** - OMR (-5000 to -2500 cfs) until after June 1 water temperature at Mossdale ≥72° F for 7 days
Feb.	[redacted]				
Mar.	[redacted]			**March 1 - June 15**	
Apr.	[redacted]	**April 1 - May 31** - Maintain Vernalis Inflow/Export ratio dependingon IOP water supply parameters	**April 1 - May 31** - Maintain Vernalis Inflow/Export Ratios depending on water year type		
May	[redacted]				
Jun.	[redacted]				

Figure 11-4. A summary of Actions IV.1 and IV.2 and their timeframes.

Actions taken during the early emigration period (November through January) to reduce diversion of listed salmonids can affect a significant proportion of the populations of listed fish. As discussed earlier in the effects section, these early migrants represent life history strategies that spread the risk of mortality over a greater temporal span, increasing diversity and resiliency of the populations.

Percent of Juvenile Chinook salmon and steelhead production entering the Delta from the Sacramento River by month.

Month	Sacramento River Total[1,2]	Fall-Run[3]	Spring-Run[3]	Winter-Run[3]	Sacramento Steelhead[4]
January	12	14	3	17	5
February	9	13	0	19	32
March	26	23	53	37	60
April	9	6	43	1	0
May	12	26	1	0	0
June	0	0	0	0	0
July	0	0	0	0	0
August	4	1	0	0	0
September	4	0	0	0	1
October	6	9	0	0	0
November	9	8	0	03	1
December	11	0	0	24	1
Total	100	100	100	100	100

Notes:
[1] Mid Water trawl data
[2] All runs combined
[3] Runs from Sacramento River basin only
[4] Rotary screw trap data from Knights Landing
Source: SDIP Draft EIR/EIS 2005 Tables J-23 and J-24, Appendix J.

Action IV.1.1 Monitoring and Alerts to Trigger Changes in DCC Operations

Objective: To provide timely information for DCC gate operation that will reduce loss of emigrating winter-run, spring-run, CV steelhead, and green sturgeon.

Action: Monitoring of Chinook salmon migration in the Sacramento River Basin and the Delta currently occurs at the RBDD, in spring-run tributaries to the Sacramento River, on the Sacramento River at Knights Landing and Sacramento, and sites within the Delta. Reclamation and DWR shall continue to fund these ongoing monitoring programs, as well as the monitoring of salvage and loss of Chinook salmon juveniles at the Delta fish collection facilities operated by the CVP and SWP. Funding shall continue for the duration of the proposed action (2030). Reclamation and DWR may use their own fishery biologists to conduct these monitoring programs, or they may provide funds to other agencies to do the required monitoring.

Monitoring protocols shall follow established procedures utilized by the USFWS, CDFW, Reclamation, and DWR. Information collected from the monitoring programs will be used to make real-time decisions regarding DCC gate operation and export pumping.

The DOSS group (Action IV.5) and WOMT will use information from monitoring to make decisions regarding DCC closures consistent with procedures below.

The DCC gate operations in the fall are initiated through a series of alerts. These alerts are signals that gate operations may need to be altered in the near future to avoid diversion of juvenile Chinook salmon migrating down the Sacramento River.

There are two initial alerts to warn of salmon presence in the system:

First Alert: There are two components to the first alert. Either condition, when met or identified, can trigger the alert. Tributary flow increases on Mill and Deer creeks are used to signal conditions conducive to emigration of yearling spring-run Chinook salmon. Starting in October, an daily average flow >95 cfs or an increase in the daily average tributary flow of more than 50 percent is used to indicate the appropriate cues for the initiation of salmon emigration[19].

Second Alert: The second alert is based on two physical hydrologic criteria. When both criteria are met the second alert is triggered. The monitoring station used for these environmental measurements is Wilkins Slough, located near Knights Landing approximately 35 miles upstream of the Delta. When flows are greater than 7,500 cfs as measured at Wilkins Slough, and water temperatures are less than 13.5ºC (56.3ºF) as measured at Knights Landing, the second alert is triggered. Recoveries of emigrating Chinook salmon at the Knights Landing monitoring location have been associated with these two hydrologic conditions.

Rationale: Monitoring programs are necessary to track the movement of salmon within the Central Valley watersheds so that timely changes can be made when project actions are in conflict with the needs of listed fish. Evidence of initiation of juvenile Chinook salmon migration in the upper tributaries, or environmental conditions that would trigger such migration, is the basis for the alerts. The alerts are important to effective gate operation because the collection and dissemination of field data to the resource agencies, and coordination of responsive actions, may take several days to occur. The first two alerts warn NMFS and Reclamation that changes in DCC gate operations are likely to be necessary within a short time period.

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[19] The first significant flow in October is associated with the beginning of spring-run yearling emigration from natal tributaries - an indication that those fish are on their seaward migration and will soon be entering the Delta where they are susceptible to mortality factors associated with the Delta Cross Channel (DCC) and SWP/CVP export operations. This first tributary flow event, or “First Alert”, is the early warning criteria for closing the DCC.

Rationale for 2017 amendment: The first component of the first alert was modified to a flow criterion in lieu of operating the Mill and Deer creek rotary screw traps becaue utilizing a hydrologic criterion will increase the survival of juvenile spring-run Chinook salmon emigrating from Mill and Deer creeks by eliminating the mortality of juvenile spring-run as a result of the RST monitoring. Analysis of the data collected on Mill and Deer creeks indicates that only 1 percent of yearling spring-run Chinook salmon catch was observed to occur at flows less than 95 cfs, while approximately 15 percent of observed yearling spring-run Chinook salmon catch occurred at flows less than 110 cfs.

Action IV.1.2 DCC Gate Operation

Objective: Modify DCC gate operation to reduce direct and indirect mortality of emigrating juvenile salmonids and green sturgeon in November, December, and January.

Action: During the period between November 1 and June 15, DCC gate operations will be modified from the proposed action to reduce loss of emigrating salmonids and green sturgeon. The operating criteria provide for longer periods of gate closures during the emigration season to reduce direct and indirect mortality of yearling spring-run, winter-run, and CV steelhead. From December 1 to January 31, the gates will remain closed, except as operations are allowed using the implementation procedures/modified Salmon Decision Tree (below).

Implementation procedures: Monitoring data related to triggers in the decision tree will be reported on Daily Assessment Team calls and evaluated by DOSS (for formation of DOSS – see Action IV.5). Reclamation/DWR shall take actions within 24 hours of a triggered condition occurring. If the decision tree requires an evaluation of data or provides options, then DOSS shall convene within one day of the trigger being met. DOSS shall provide advice to NMFS, and the action shall be vetted through WOMT standard operating procedures.

Rationale for 2011 amendment: "KK" was a typographical error in the 2009 RPA, intended to be a placeholder until the number for action that describes the formation of DOSS was identified.

October 1-November 30:

Date	**VI. Action Triggers**	Action Responses
October 1-November 30	Water quality criteria per D-1641 are met and either the Knights Landing Catch Index (KLCI) or the Sacramento Catch Index (SCI) are greater than 3 fish per day but less than or equal to 5 fish per day.	Within 24 hours of trigger, DCC gates are closed. Gates will remain closed for 3 days.

	Water quality criteria per D-1641 are met and either the KLCI or SCI is greater than 5 fish per day	Within 24 hours, close the DCC gates and keep closed until the catch index is less than 3 fish per day at both the Knights Landing and Sacramento monitoring sites.
	The KLCI or SCI triggers are met but water quality criteria are not met per D-1641 criteria.	DOSS reviews monitoring data and makes recommendation to NMFS and WOMT per procedures in Action IV.5.

Rationale: Depending on the catch magnitude, there are several options for closing the DCC gates, ranging from not closing them and monitoring catch at Knights Landing and the Sacramento monitoring sites, to closing the DCC gates until the catch index decreases to fewer than three fish per day at the Knights Landing and Sacramento monitoring sites. Fish and water quality needs (*i.e.,* salinity levels) are frequently mutually exclusive, with respect to the DCC position, from November through January.

December 1-14:

Date	Action Triggers	Action Responses
December 1 - December 14	Water quality criteria are met per D-1641.	DCC gates are closed. If Chinook salmon migration experiments are conducted during this time period (*e.g.,* Delta Action 8 or similar studies), the DCC gates may be opened according to the experimental design, with NMFS' prior approval of the study.
	Water quality criteria are not met but both the KLCI and SCI are less than 3 fish per day.	DCC gates may be opened until the water quality criteria are met. Once water quality criteria are met, the DCC gates will be closed within 24 hours of compliance.
	Water quality criteria are not met but either of the KLCI or SCI is greater than 3 fish per day.	DOSS reviews monitoring data and makes recommendation to NMFS and WOMT per procedures in Action IV.5

Rationale: The Spring-run Protection Plan (1998 *op. cit*. CVP/SWP operations BA Appendix B) provides that Reclamation will close the DCC gates on December 1 for the protection of spring-run yearlings unless there is a water quality issue. The DOSS can recommend opening the DCC gates for water quality purposes during this period. In addition, CDFW analysis indicates that there is a significant relationship between DCC gate operations and subsequent loss of winter-run at the Delta Fish Facilities. Closing the DCC gates between December 15 and January 15 reduces the total loss of winter-run at the Delta Fish Facilities. The report is posted at: http://www.science.calwater.ca.gov/pdf/ewa/EWA_delta_cross_channel_closures_06_111406.pdf.

The USFWS conducts a juvenile Chinook salmon Delta survival experiment each year in December and January. This is usually conducted in the first two weeks of December and may include experimental openings of the DCC gates. http://www.delta.dfg.ca.gov/jfmp/PatFiles/Delta_Action_8_Workshop.doc. These studies may be implemented if NMFS concurs that the study plan has been adapted to sufficiently reduce loss of salmonids.

December 15 – January 31:

Date	Action Triggers	Action Responses
December 15 – January 31	December 15-January 31	DCC Gates Closed.
	NMFS-approved experiments are being conducted.	Agency sponsoring the experiment may request gate opening for up to five days; NMFS will determine whether opening is consistent with ESA obligations.
	One-time event between December 15 to January 5, when necessary to maintain Delta water quality in response to the astronomical high tide, coupled with low inflow conditions.	Upon concurrence of NMFS, DCC Gates may be opened one hour after sunrise to one hour before sunset, for up to 3 days, then return to full closure. Reclamation and DWR will also reduce Delta exports down to a health and safety level during the period of this action.

Rationale: CDFW analysis indicates that there is a significant relationship between DCC gate operations and subsequent loss of winter-run at the Delta Fish Facilities. Closing the DCC gates between December 15 and January 15 reduces the total loss of winter-run at the Delta Fish Facilities. The report is posted at: http://www.science.calwater.ca.gov/pdf/ewa/EWA_delta_cross_channel_closures_06_111406.pdf

If the KLCI or SCI is less than three, and the water temperature and flow criteria are indicative of low risk to listed salmonids, then experiments on fall- and late-fall-run may be permissible; however, in a low production year, trap efficiencies and detection rates may result in under-representation of the number of fish passing these locations. Under such conditions the DOSS group shall act conservatively in this decision process even when no fish have been detected at Knights Landing or Sacramento rotary screw traps. If conditions change, indicating that risks to listed salmonids are elevated, experiments will be suspended and the DCC gates closed if NMFS determines that closure is necessary to reduce the risk to emigrating salmonids.

February 1 – June 15:

Date	Action Trigger	Action Response
February 1 – May 20	D-1641 mandatory gate closure.[9]	Gates closed, per WQCP criteria

Date	Action Trigger	Action Response
May 21 – June 15	D-1641 gate operations criteria	DCC gates closed for 14 days during this period, per 2006 WQCP, if NMFS determines it is necessary.

Overall Rationale for Action IV.1.2: Emigrating salmonids are vulnerable to diversion into the DCC when the gates are open. Fish traveling downstream in the Sacramento River move past the mouth of the DCC on the outside bend of the river. A series of studies conducted by Reclamation and USGS (Horn and Blake 2004) used acoustic tracking of released juvenile Chinook salmon to follow their movements in the vicinity of the DCC under different flows and tidal conditions. The study results indicate that the behavior of the Chinook salmon juveniles increased their exposure to entrainment through both the DCC and Georgiana Slough. Horizontal positioning along the east bank of the river during both the flood and ebb tidal conditions enhanced the probability of entrainment into the two channels. Upstream movement of fish with the flood tide demonstrated that fish could pass the channel mouths on an ebb tide and still be entrained on the subsequent flood tide cycle. In addition, diel movement of fish vertically in the water column exposed more fish at night to entrainment into the DCC than during the day, due to their higher position in the water column and the depth of the lip to the DCC channel mouth (-2.4 meters). Additional studies have shown that the mortality rate of the fish diverted into the DCC and subsequently into the Mokelumne river system is quite high (Perry and Skalski 2008; Vogel 2004, 2008). Closure of the DCC gates during periods of salmon emigration eliminates the potential for entrainment into the DCC and the Mokelumne River system with its high loss rates. In addition, closure of the gates appears to redirect the migratory paths of emigrating fish into channels with relatively less mortality (*e.g.,* Sutter and Steamboat Sloughs), due to a redistribution of river flows among the channels. The overall effect is an increase in the apparent survival rate of these salmon populations as they move through the Delta.

The closure of the DCC gates will increase the survival of salmonid emigrants through the Delta, and the early closures reduce loss of fish with unique and valuable life history strategies in the spring-run and CV steelhead populations. Spring-run emigrating through the Delta during November and December are yearling fish. These fish are larger and have a higher rate of success in surviving their entrance into the ocean environment. In addition, variation in the timing of ocean entry distributes the risk of survival over a broader temporal period. This alternative life history strategy reduces the probability that poor ocean conditions in spring and summer will affect the entire population of spring-run. Since yearling fish enter the marine environment in late fall and winter, they avoid the conditions that young-of-the-year fish encounter in spring and summer, thus increasing the likelihood that at least a portion of the population will benefit from suitable ocean conditions during their recruitment to the ocean phase of their life cycle. For the same reasons, CV steelhead benefit from having their ocean entry spread out over several months.

Rationale for 2011 amendments:

1) **Change in dates**: The change in dates from "February 1 – May 15" to "February 1 – May 20" and from "May 16 – June 15" to "May 21 – June 15" are minor amendments to be consistent and in compliance with State law (Water Rights Decision D-1641, December 29, 1999, page 184, http://www.waterboards.ca.gov/waterrights/board_decisions/adopted_orders/decisions/d1600_d1649/wrd1641.pdf).
2) **Change in action response**: The change in action response for May 21-June 15 from "DCC gates may be closed for up to 14 days during this period" to "DCC gates closed for 14 days during this period," is an amendment to be consistent and in compliance with State law (Water Quality Control Plan, December 13, 2006, page 17, footnote 24, http://www.waterboards.ca.gov/waterrights/water_issues/programs/bay_delta/wq_control_plans/2006wqcp/docs/2006_plan_final.pdf).

Action IV.1.3 Consider Engineering Solutions to Further Reduce Diversion of Emigrating Juvenile Salmonids to the Interior and Southern Delta, and Reduce Exposure to CVP and SWP Export Facilities

Objectives: Prevent emigrating salmonids from entering the Georgiana Slough channel from the Sacramento River during their downstream migration through the Delta. Prevent emigrating salmonids from entering channels in the south Delta (*e.g.*, Old River, Turner Cut) that increase entrainment risk to CV steelhead migrating from the San Joaquin River through the Delta.

Action: Reclamation and/or DWR shall convene a working group to consider engineering solutions to further reduce diversion of emigrating juvenile salmonids to the interior Delta and consequent exposure to CVP and SWP export facilities. The working group, comprised of representatives from Reclamation, DWR, NMFS, USFWS, and CDFW, shall develop and evaluate proposed designs for their effectiveness. in reducing adverse impacts on listed fish and their critical habitat. Reclamation or DWR shall subject any proposed engineering solutions to external independent peer review and report the initial findings to NMFS by March 30, 2012. Reclamation or DWR shall provide a final report on recommended approaches by March 30, 2015. If NMFS approves an approach in the report, Reclamation or DWR shall implement it. To avoid duplication of efforts or conflicting solutions, this action should be coordinated with USFWS' Delta smelt biological opinion and BDCP's consideration of conveyance alternatives..

Rationale: One of the recommendations from the CALFED Science Panel peer review was to study engineering solutions to "separate water from fish." This action is intended to address that recommendation. Years of studies have shown that the loss of migrating salmonids within Georgiana Slough and the Delta interior is approximately twice that of fish remaining in the Sacramento River main stem (Kjelson and Brandes 1989; Brandes and McLain 2001; Vogel 2004, 2008; and Newman 2008). Based on the estimated survival rate of 35 percent in Georgiana Slough (Perry and Skalski 2008), the fraction of emigrating salmonids that would be lost to the population is 6 to 15 percent of the number entering the Delta from the Sacramento River basin. Keeping emigrating fish in the Sacramento River would increase their survival rate. This action is also intended to allow for engineering experiments and possible solutions to be explored on the San Joaquin river/Southern Delta corridor to benefit out-migrating steelhead. For example, non-physical barrier (i.e., "bubble curtain") technology can be further vetted through this action.

Action Suite IV.2 Delta Flow Management

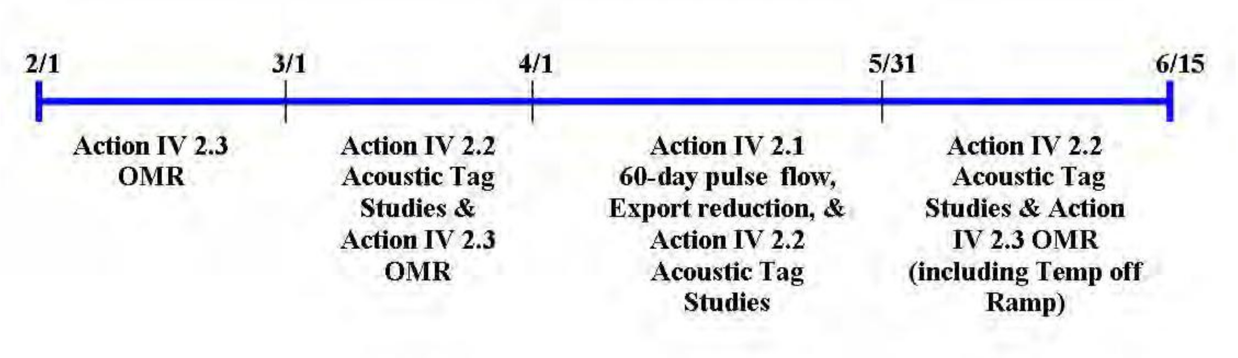
Objective: Maintain adequate flows in both the Sacramento River and San Joaquin River basins to increase survival of steelhead emigrating to the estuary from the San Joaquin River, and of winter-run, spring-run, CV steelhead, and green sturgeon emigrating from the Sacramento River through the Delta to Chipps Island.

Rationale for the Suite of Actions: Numerous studies have found positive associations between increased river flows and increased survival of salmon smolts through the Delta and the adult escapement of that cohort several years later when they return to spawn. Increased flows and greater smolt survival have been positively associated in other river systems as well Increased flows reduce the travel time of smolts moving through the river and Delta system, thus reducing the duration of their exposure to adverse effects from predators, water diversions, and exposure to contaminants.

Action IV.2.1 San Joaquin River Inflow to Export Ratio

Objectives: To reduce the vulnerability of emigrating CV steelhead within the lower San Joaquin River to entrainment into the channels of the South Delta and at the pumps due to the diversion of water by the export facilities in the South Delta, by increasing the inflow to export ratio. To enhance the likelihood of salmonids successfully exiting the Delta at Chipps Island by creating more suitable hydraulic conditions in the main stem of the San Joaquin River for emigrating fish, including greater net downstream flows.

Action: The following timeline indicates the annual schedule for implementing related San Joaquin actions that will occur concurrent with this action.



Phase I: Interim Operations in 2010-2011.

From April 1 through May 31:

1. Flows at Vernalis (7-day running average shall not be less than 7 percent of the target requirement) shall be based on the New Melones Index[20]. In addition to the Goodwin flow schedule for the Stanislaus River prescribed in Action III.1.3 and Appendix 2-E, Reclamation shall increase its releases at Goodwin Reservoir, if necessary, in order to meet the flows required at Vernalis, as provided in the following table. NMFS expects that tributary contributions of water from the Tuolumne and Merced rivers, through the SJRA, will continue through 2011 and that the installation of a fish barrier at the Head of Old River will continue to occur during this period as permitted.

New Melones Index (TAF)	Minimum flow required at Vernalis (cfs)
0-999	No new requirements
1000-1399	D1641 requirements or 1500, whichever is greater
1400-1999	D1641 requirements or 3000, whichever is greater
2000-2499	4500
2500 or greater	6000

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[20] The New Melones Index is a summation of end of February New Melones Reservoir storage and forecasted inflow using 50% exceedance from March through September.

2. Combined CVP and SWP exports shall be restricted through the following:

Flows at Vernalis (cfs)	Combined CVP and SWP Export
0-6,000	1,500 cfs
6,000-21,750[21]	4:1 (Vernalis flow:export ratio)
21,750 or greater	Unrestricted until flood recedes below 21,750

In addition:

1) Reclamation/DWR shall seek supplemental agreement with the SJRGA as soon as possible to achieve minimum long term flows at Vernalis (see following table) through all existing authorities.

San Joaquin River Index (60-20-20)	Minimum long-term flow at Vernalis (cfs)
Critically dry	1,500
Dry	3,000
Below normal	4,500
Above normal	6,000
Wet	6,000

Rationale:

1) Flows at Vernalis: Reclamation has limited discretion to require additional flows from the Tuolumne and Merced rivers that are necessary in the long run to meet the needs of outmigrating juvenile steelhead. Modeling for our analysis of the East Side Division show that relying on New Melones Reservoir to provide the flows at Vernalis cannot be sustained, and attempting to do so would likely have additional adverse effects on CV steelhead. Reclamation and DWR have obtained additional flows in the Tuolumne and Merced rivers through CVPIA authorities, including options to purchase water from willing sellers, and entered into the SJRA which expires on December 31, 2009. Reclamation is in negotiations to extend the current agreement to 2011. The flows required in Phase I at Vernalis were developed through iterative modeling and will provide an important increment of additional flow to provide for outmigration of steelhead smolts, while not unduly depleting New Melones Reservoir storage. Using CVPIA authorities, it is important that Reclamation seek to immediately change the terms of the existing SJRA to achieve the long-term flows.

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[21] Flood warning stage at Vernalis is 24.5 feet, flow is 21,750 cfs at this point. Flood stage is 29 feet with a corresponding flow of 34,500 cfs. Data from CDEC looking at April 8-9, 2006 period. As such, recognizing that the flows associated with these stages do vary, the trigger allowing unrestricted exports will be a Vernalis stage of 24.5 feet.

2) The rationale for the export curtailments is provided in the rationale for Phase II.

3) The SWRCB has initiated proceedings to establish minimum flows in the San Joaquin River basin. The proceedings are scheduled to conclude in 2011. Flow requirements for fish will be provided by this action in the interim.

Phase II: Beginning in 2012:

From April 1 through May 31:

1. Reclamation shall continue to implement the Goodwin flow schedule for the Stanislaus River prescribed in Action III.1.3 and Appendix 2-E.

2. Reclamation and DWR shall implement the Vernalis flow-to-combined export ratios in the following table, based on a 14-day running average.

San Joaquin Valley Classification	Vernalis flow (cfs):CVP/SWP combined export ratio[22]
Critically dry	1:1[23]
Dry	2:1
Below normal	3:1
Above normal	4:1
Wet	4:1
Vernalis flow equal to or greater than 21,750 cfs	Unrestricted exports until flood recedes below 21,750 cfs.

Exception procedure for multiple dry years: If the previous 2 years plus current year of San Joaquin Valley "60-20-20" Water Year Hydrologic Classification and Indicator as defined in D-1641 and provided in following table, is 6 or less, AND the New Melones Index is less than 1 MAF, exports shall be limited to a 1:1 ratio with San Joaquin River inflow, as measured at Vernalis.

San Joaquin Valley Classification	Indicator
Critically dry	1
Dry	2
Below normal	3
Above normal	4
Wet	5

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[22] Exception to the ratio is provided for floods, where exports are not restricted until the flood recedes. See footnote 2 above.

[23] Minimum combined CVP and SWP exports is for health and safety.

Exception procedure for Health and Safety: If, by February 28 of a given year, Reclamation and DWR predict that they will not be able to achieve these ratios and make deliveries required for human health and safety, even after pursuing all options to augment inflow while preserving the ability to meet fish flow needs in all seasons, the agencies may submit a plan to NMFS to maximize anadromous fish benefits while meeting health and safety needs. The project agencies' current estimate of health and safety needs is a combined CVP/SWP export rate of 1,500 cfs. The plan must demonstrate that all opportunities for purchasing water in the San Joaquin Basin have been or will be exhausted, using b(3) or other water purchasing authority.

Meeting the long-term biological requirements of listed species and providing adequate water deliveries for these needs under the current system configuration may not be compatible, particularly considering anticipated hydrologic patterns associated with climate change. For this reason, Reclamation and DWR may propose a reconfiguration of the water conveyance system to allow diversion from the Sacramento River. Such an alteration of the conveyance system is being considered in the BDCP planning process. The operation of a conveyance structure that diverts water directly from the Sacramento River carries additional risk for listed species that migrate, spawn, or rear in the Sacramento River or North Delta. As detailed in this Opinion, the status of those species is precarious. Any new conveyance will be subject to section 7 consultation, and issues of injury or mortality of juvenile fish associated with all diversion facilities, reduction of flow variability for fish life history functions, reduction of Shasta Reservoir storage necessary for mainstem temperature control, and other potential adverse effects must be adequately addressed in any conveyance proposal.

Rationale: VAMP studies of CWT Chinook salmon smolts indicate that in general, fish released downstream of the zone of entrainment created by the export pumps (*e.g.*, Jersey Point) have higher survival indices to Chipps Island than fish released higher up in the system (*e.g.*, Durham Ferry, Mossdale, or Dos Reis). Studies identify increased flows as a factor that increases survival of tagged Chinook salmon smolts. To date, most VAMP experiments have utilized San Joaquin River flows to export pumping ratios of approximately 2:1. Survival to Chipps Island of smolts released upstream has been relatively low under these conditions. (Kjelson *et al*. 1981, Kjelson and Brandes 1989, SJRGA 2007). Historical data indicates that high San Joaquin River flows in the spring result in higher survival of outmigrating Chinook salmon smolts and greater adult returns 2.5 years later (Kjelson *et al.* 1981, Kjelson and Brandes 1989, USFWS 1995) and that when the ratio between spring flows and exports increase, Chinook salmon production increases (CDFG 2005, SJRGA 2007). NMFS, therefore, concludes that San Joaquin River Basin and Calaveras River steelhead would likewise benefit under higher spring flows in the San Joaquin River in much the same way as fall-run do. For a full explanation of data and analysis supporting this action, see appendix 5.

1) Increased flows within the San Joaquin River portion of the Delta will also enhance the survival of Sacramento River salmonids. Those fish from the Sacramento River which have been diverted through the interior Delta to the San Joaquin River will benefit by the increased net flow towards the ocean caused by the higher flows in the San Joaquin River from upstream and the reduced influence of the export pumps. Such flows will reduce

the proportion of Sacramento River fish that continue southwards toward the pumps and increase the percentage that move westwards toward Chipps Island and the ocean. Although the real environment is much more complex than this generality, in theory, increasing the speed of migration through a particular reach of river, or shortening the length of the migratory route decrease the extent of exposure to factors causing loss (Anderson *et al.* 2005).

Action IV.2.2 Six-Year Acoustic Tag Experiment

Objective: To confirm proportional causes of mortality due to flows, exports and other project and non-project adverse effects on steelhead smolts out-migrating from the San Joaquin basin and through the southern Delta.

Action: Reclamation and DWR shall fund a 6-year research-oriented action concurrent with Action IV.2.1.

The research shall be composed of studies utilizing acoustically-tagged salmonids, and will be implemented to assess the behavior and movement of the outmigrating fish in the lower San Joaquin River. The studies will include three releases of acoustic tagged fish, timed to coincide with different periods and operations: March 1 through March 31, April 1 through May 31, and June 1 through June 15. NMFS anticipates that studies will utilize clipped hatchery steelhead and hatchery fall-run as test fish.

During the period from March 1 through March 30, the exports will be operated in accordance with the requirements dictated by action IV.2.3. During the 60-day period between April 1 and May 30, exports will be dictated by the requirements of action IV.2.1. Reclamation shall operate to a minimum 1:1 inflow to export ratio during the period between June 1 and June 15, allowing exports to vary in relation to inflows from the San Joaquin to test varying flow to export ratios during this period. If daily water temperatures at Mossdale exceed 72°F for seven consecutive days during the period between June 1 and June 15, then the inflow to export ratio may be relaxed. NMFS anticipates that warm water conditions in the lower San Joaquin River will not be suitable for steelhead under these conditions.

Implementation procedures:

1) By September 1, 2009, Reclamation/DWR shall convene DOSS for the purpose of refining the study design for this experiment. The experiments shall be developed to ensure that results are statistically robust and uncertainties due to experimental design have been minimized to the fullest extent possible. Additional expertise may be included in the workgroup, at the discretion of the agencies.

2) Issues relevant to listed anadromous fish species that shall be addressed include, but are not limited to:

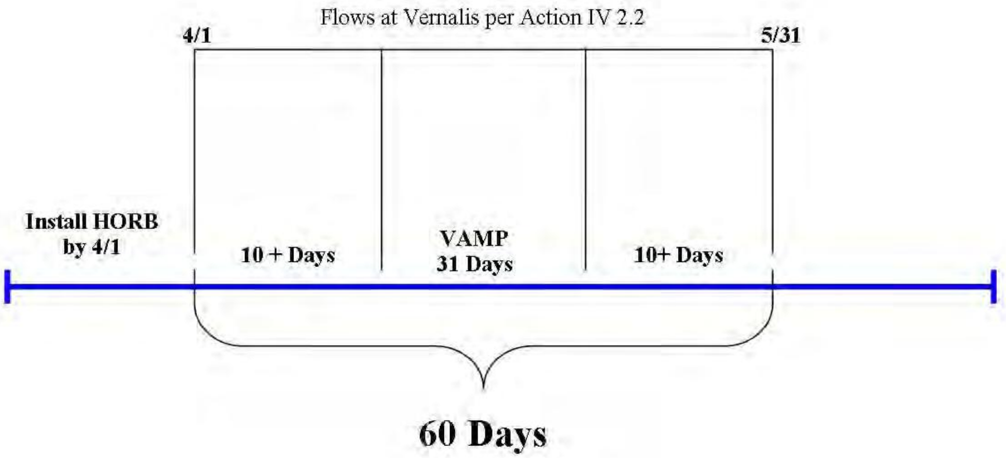
a) Increasing survival of emigrating smolts from the tributaries into the main stem of the San Joaquin River.
b) Increasing survival of emigrating smolts through the main stem of the San Joaquin River downstream into the Delta.
c) Increasing survival of emigrating smolts through the Delta to Chipps Island.
d) The role and influence of flow and exports on survival in these migratory reaches.
e) Selection of routes under the influence of flows and exports.
f) Identifying reach-specific mortality and or loss.
g) The effectiveness of experimental technologies, if any, *e.g.,* non-physical barrier (“bubble curtain.”)

3) Annual reviews of the study results shall be conducted by the DOSS group. At the end of the 6-year period, a status review of Action IV.2.1 shall be prepared by the DOSS group. The status review shall be used to assess the success of Action IV.2.1 in increasing survival through the Delta for San Joaquin River basin salmonids, but in particular, steelhead. Based on the findings of the status review, the DOSS group will make recommendations to NMFS, Reclamation, CDFW, DWR, and USFWS on future actions to be undertaken in the San Joaquin River basin as part of an adaptive management approach to the basin's salmonid stocks.

4) Complementary studies to achieve performance goals**:** At its discretion, Reclamation and DWR also may develop and propose complementary studies to examine alternative actions that would accomplish the targeted survival performance goals. A primary effort of these studies will be to establish an appropriate survival goal for out-migrating steelhead smolts from Vernalis to Chipps Island in all water year types. Reclamation and DWR may propose studies which test actions that incorporate non-flow or non-export related actions. The studies shall contain specific actions within the authority and discretion of Reclamation and/or DWR, an evaluation of the projected benefits of each action with respect to increasing survival to the performance goal, evidence used to support this evaluation including literature citations, particle tracking modeling and other predictive tools, to demonstrate that the survival will be achieved, and a demonstration that the actions are reasonably certain to occur within the term of the study period. Any complementary study proposal shall be peer reviewed by the Calfed Science Program (or other comparable science group) and by the DOSS workgroup prior to being submitted to NMFS.

Upon receipt of the complementary study proposal, NMFS will review the draft proposal for sufficiency of information, experimental design, and likelihood to meet performance goals and provide comments back to Reclamation and DWR within 30 days of receipt. If NMFS concurs with the complementary study proposal, and finds the studies do not conflict with the actions implemented under the RPA, then the study may be conducted concurrently with the actions set forth above (Action IV.2.1 and IV.2.2). Throughout the six years of study, all new data will be annually evaluated by the proposed DOSS group, which will then provide recommendations through a written report to the management of NMFS and Reclamation for continuing actions in the San Joaquin River basin in support of CV steelhead.

Exception: If, despite Reclamation and DWR's best efforts, the new experiment is not ready for implementation in 2010, then VAMP study design may continue for 1 year, upon written concurrence of NMFS. A generalized representation of the design is provided, as follows:



Rationale: This experiment will provide important information about the response of fish migration to flows, exports, and other stressors in the San Joaquin River corridor. Flows and exports will be varied according to time period. From March 1 through March 31, the studies will assess the relationship of the Vernalis flow-to-export ratio under the OMR flow restriction (see Action IV.2.3) to route selection at channel bifurcations in the South Delta and mainstem San Joaquin River, survival in the different channels reaches of the South Delta, and ultimately through the Delta to Chipps Island as a whole.

From April 1 through May 30, the studies will assess the effectiveness of varying ratios by water year type (see Action IV.2.1) by comparing channel selection, route survival, and overall through-Delta survival during this period of stabilized conditions to the other two periods.

From June 1 to June 15, the studies will focus on the relative importance of exports, as compared to flows, by deliberately varying exports under similar flow conditions. Acoustic tagging studies have the potential to provide this level of resolution. Results from these studies may be able to indicate, at a fine temporal and spatial scale, how exports and flow influence route selection of migrating fish and their survival probabilities in the different channel reaches. Knowledge of these factors should aid in the management decision process and reduce project impacts to listed salmonids based on findings with strong scientific foundations.

Action IV.2.3 Old and Middle River Flow Management

Objective: Reduce the vulnerability of emigrating juvenile winter-run, yearling spring-run, and CV steelhead within the lower Sacramento and San Joaquin rivers to entrainment into the channels of the South Delta and at the pumps due to the diversion of water by the export facilities in the South Delta. Enhance the likelihood of salmonids successfully exiting the Delta at Chipps Island by creating more suitable hydraulic conditions in the mainstem of the San Joaquin River for emigrating fish, including greater net downstream flows.

Action: From January 1 through June 15, reduce exports, as necessary, to limit negative flows to -2,500 to -5,000 cfs in Old and Middle Rivers, depending on the presence of salmonids. The reverse flow will be managed within this range to reduce flows toward the pumps during periods of increased salmonid presence. The negative flow objective within the range shall be determine based on the following decision tree:

Date	Action Triggers	Action Responses
January 1 – June 15	January 1 – June 15	Exports are managed to a level that produces a 14-day running average of the tidally filtered flow of (minus) -5,000 cfs in Old and Middle River (OMR). A five-day running average flow shall be calculated from the daily tidally filtered values and be no more than 25 percent more negative than the targeted requirement flow for the 14-day average flow.[24]

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[24] Daily OMR flows used to compute the 14-day and 5-day averages shall be tidally filtered values reported by the USGS for the Old River at Bacon Island and Middle River at Middle River monitoring stations. The 14-day running average shall be no more negative than the targeted flow requirement. The 5-day running average shall be no more than 25 percent more negative than the targeted flow requirement. (Transition explanations below are based on personal communication Ryan Olah, USFWS, to ensure consistency of OMR measurements and averaging periods with implementation of OMR in Smelt Biological Opinion).

Transition to more restrictive (less negative) OMR limit

When a more restrictive Old and Middle River flow (OMR) limit is decided upon, the water projects may continue to operate to the old limit for up to two additional days, with both 5-day and 14-day averaging periods in effect. On the third day, the moving daily OMR will be no more negative than the new limit, and no moving averages will apply. New moving averages will be calculated from the third day forward. On the fourth day, OMR can be no more than 25% more negative than the daily OMR on the third day; On the fifth day, OMR can be no more than 25% more negative than the midpoint between the daily OMRs on the third day and the fourth day; on the sixth day, OMR can be no more than 25% more negative than the average of the OMRs on the third, fourth, and fifth day; and so on. From the 8th day forward, if OMR restrictions due to triggers are still be implemented, a full 5-day moving average will exist, and daily OMR on any day cannot be more than 25% more negative than the 5-day moving average. On the 17th day, a 14-day moving average will be available. Consequently, from the 17th day forward, the 14-day moving average cannot be more negative than the OMR limit.

January 1 – June 15 First Stage Trigger (increasing level of concern)	(1) Daily SWP/CVP older juvenile Chinook salmon[25] loss density (fish per TAF) is greater than incidental take limit divided by 2000 (2 percent WR JPE ÷ 2000), with a minimum value of 2.5 fish per TAF, or (2) daily SWP/CVP older juvenile Chinook salmon loss is greater than 8 fish/TAF multiplied by volume exported (in TAF) or (3) CNFH CWT LFR or LSNFH CWT WR cumulative loss greater than 0.5% for each surrogate release group, or (4) daily loss of wild steelhead (intact adipose fin) is greater than 8 fish/TAF multiplied by volume exported (in TAF)[26]	Reduce exports to achieve an average net OMR flow of (minus) -3,500 cfs for a minimum of 5 consecutive days. The five day running average OMR flows shall be no more than 25 percent more negative than the targeted flow level at any time during the 5-day running average period (*e.g.*, -4,375 cfs average over five days). Resumption of (minus) -5,000 cfs flows is allowed when average daily fish density is less than trigger density for the last 3 days of export reduction[27]. Reductions are required when any one criterion is met.
January 1 - June 15 Second Stage Trigger (analogous	(1) Daily SWP/CVP older juvenile Chinook salmon loss density (fish per TAF) is greater than incidental take limit (2 percent of WR JPE) divided by 1000 (2 percent of WR JPE ÷ 1000), with a minimum value	Reduce exports to achieve an average net OMR flow of (minus) -2,500 cfs for a minimum 5 consecutive days. Resumption of (minus) -5,000 cfs flows is allowed when average daily fish density is less than trigger

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Transition to less restrictive (more negative) OMR limit

When a less restrictive OMR limit is decided upon, the water projects may begin to operate to that limit on the same day. The 5-day and 14-day averaging periods will continue to be computed through the transition. However, the 5-day averaging period will not provide 25% flexibility from the day the new OMR is imposed through the 7th day after the new limit is adopted. Through the 7th day after imposition, daily OMR may not be more negative than the new limit.

[25] "Older juvenile Chinook salmon" is defined as any Chinook salmon that is above the minimum length for winter-run Chinook salmon, according to the "Delta Model" length-at-date table used to assign individuals to race.

[26] NMFS assumes that the loss of winter-run Chinook salmon and steelhead are similar in nature based on annual loss estimates. As an initial trigger, the density of steelhead, which includes smolts and adults, will be used in the same equation as the older juvenile salmon trigger to change OMR flows. This will be reviewed by the DOSS group annually and recommendations to the trigger criteria made based on an assessment of the results.

[27] Three consecutive days in which the loss numbers are below the action triggers are required before the OMR flow reductions can be relaxed to -5,000 cfs. A minimum of 5 consecutive days of export reduction are required for the protection of listed salmonids under the action. Starting on day three of the export curtailment, the level of fish loss must be below the action triggers for the remainder of the 5-day export reduction to relax the OMR requirements on day 6. Any exceedance of a more conservative trigger restarts the 5-day OMR action response with the three consecutive days of loss monitoring criteria.

to high concern level)	of 2.5 fish per TAF, or (2) daily SWP/CVP older juvenile Chinook salmon loss is greater than 12 fish/TAF multiplied by volume exported (in TAF), or (3) daily loss of wild steelhead (intact adipose fin) is greater than 12 fish/TAF multiplied by volume exported (in TAF)	density for the last 3 days of export reduction. Reductions are required when any one criterion is met.
End of Triggers	Continue action until June 15 or until average daily water temperature at Mossdale is greater than 72ºF (22ºC) for 7 consecutive days (1 week), whichever is earlier.	If trigger for end of OMR regulation is met, then the restrictions on OMR are lifted.

Implementation procedures: Combined exports will be managed to provide for an OMR flow of -5,000 cfs, tidally filtered over 14-days during the period between January 1 and June 15. The 5-day running average shall be no more than 25 percent more negative than the targeted flow requirement. Further reductions in exports will occur in a tiered fashion depending on the magnitude of Chinook salmon and steelhead salvage at the CVP and SWP fish salvage facilities. There are two export reductions triggered by increases in fish salvage rates at the fish collection. The first reduction decreases exports to achieve a net average OMR flow of -3,500 cfs over a minimum of 5 consecutive days. The second reduction, based on higher salvage numbers, further reduces exports to achieve a net average OMR flow of -2,500 cfs over a minimum of 5 days.

Alternatively, to provide flexibility in operations, once an action trigger is met, combined exports could be reduced immediately to a floor of 1,500 cfs (*i.e*., the project operators would not be required to reduce combined exports to less than 1,500 cfs) until the required OMR limit is met.

These actions will be taken in coordination with USFWS RPA for Delta smelt and State-listed longfin smelt 2081 incidental take permit. During the January 1 through June 15 period, the most restrictive export reduction shall be implemented. If the USFWS Delta smelt RPA requires greater reductions in exports than those required by NMFS for salmonids, to achieve a more positive OMR flow, then the smelt action will be implemented, since it also will increase survival of listed salmonids. Likewise, if the NMFS RPA criteria are more restrictive than those called for under the Delta smelt RPA, then NMFS RPA criteria will prevail and will increase survival of Delta smelt as well as salmonids.

Rationale: Juvenile listed salmonids emigrate downstream in the main channel of the San Joaquin River during the winter and spring period. Juvenile listed steelhead from the San Joaquin River basin, the Calaveras River basin, and the Mokelumne River basin also utilize the lower reaches of the San Joaquin River as a migration corridor to the ocean. The river reach between the Port of Stockton and Jersey Point has many side channels leading south toward the export facilities. High export levels draw water through these channels toward the pumps, as these channels are the conduits that supply water to the pumps from the north. Outputs from PTM simulations, as well as data from acoustic tagging studies (Vogel 2004, SJRGA 2006, 2007), show that migrating fish are vulnerable to diversion into these channels and respond to flow within the channels, including the net migration speed downstream (SJRGA 2008).

The acoustic tagging studies also indicate that fish behavior is complex, with fish exhibiting behavior that is not captured by the "tidal surfing' model utilized as one of the options in the PTM simulations. Fish made their way downstream in a way that was more complicated than simply riding the tide, and no discernable phase of the tide had greater net downstream movement than another. Furthermore, tagged fish chose channels leading south more frequently when exports were elevated, than when exports were lower (Vogel 2004). Fish that moved into channels leading south may eventually find their way back to the main channel of the San Joaquin, but this roundabout migratory path exposes fish to higher predation risks as well as the potential to become lost within the Delta interior, increasing migration route length and duration of the outmigration. Increased time in the channels of the Central and South Delta exposes fish to unscreened agricultural diversions, discharges of agricultural irrigation return water to the Delta, increased water temperature later in the season, and the risk of predation from pelagic predators such as striped bass and localized ambush predators such as largemouth bass. In order to increase the likelihood of survival, emigrating steelhead from the San Joaquin Basin and the east-side tributaries should remain in the mainstem of the San Joaquin River to the greatest extent possible and reduce their exposure to the adverse effects that are present in the channels leading south toward the export facilities.

Reducing the risk of diversion into the central and southern Delta waterways also will increase survival of listed salmonids and green sturgeon entering the San Joaquin River via Georgiana Slough and the lower Mokelumne River. As described in the effects section of the Opinion, these fish also are vulnerable to entrainment by the far-field effects of the exports. The data output for the PTM simulation of particles injected at the confluence of the Mokelumne River and the San Joaquin River (Station 815) indicate that as net OMR flow increases southwards from -2,500 to -3,500 cfs, the risk of particle entrainment nearly doubles from 10 percent to 20 percent, and quadruples to 40 percent at -5,000 cfs. At flows more negative than -5,000 cfs, the risk of entrainment increases at an even greater rate, reaching approximately 90 percent at -7,000 cfs. Even if salmonids do not behave exactly as neutrally buoyant particles, the risk of entrainment escalates considerably with increasing exports, as represented by the net OMR flows. The logical conclusion is that as OMR reverse flows increase, risk of entrainment into the channels of the South Delta is increased. Conversely, the risk of entrainment into the channels of the South delta is reduced when exports are lower and the net flow in the OMR channels is more positive -- that is, in the direction of the natural flow toward the ocean.

Rationale for 2011 amendments:

1) First OMR trigger: This was clarified to identify the loss as pertaining to older juvenile Chinook salmon.
2) Second OMR trigger: The second trigger, as described in the 2009 RPA, was not workable as drafted[28]. During 2010, DOSS convened a subgroup to revise the second trigger (both the first and second stages), based on discussions that led to the development of the salmon decision tree.
3) Third OMR trigger:
   a) First stage trigger: This was clarified to reflect that the trigger applies to each surrogate release group.
   b) Second stage trigger: The first and second stage triggers for surrogate release groups are exactly the same. Therefore, the second stage trigger for surrogate releases was deleted to avoid confusion in implementation of the action response.
4) Fourth OMR trigger: The fourth OMR trigger was the same as the second OMR trigger, but applied to steelhead. As with the second OMR trigger (applied to Chinook salmon), it was not workable as drafted. The fourth OMR trigger was corrected.
5) Action response: In the 2009 RPA, the action response read as if the 3 days of average daily fish density less than the trigger density had to occur after the 5 days of export reductions. The language for both the first and second stage triggers was clarified in the 2011 amendment so that the average daily fish density is less than the trigger density for the last 3 consecutive days of export reductions.
6) Footnote 16: The last sentence was clarified to say that a new action response applies only if a more conservative (*i.e.*, less negative) OMR flow trigger is met.

Rationale for 2011 amendment to implementation procedure: What the fish need is a rapid response to redirect their migration from the south Delta and pumps. OMR flows are influenced by tidal and other physical forces that are beyond the control of the project operators, and therefore, may prevent strict adherence to the specific OMR flow limits. As a result, combined exports quickly reduced to 1,500 cfs will be deemed compliance if OMR flows do not actually meet the required action responses specified in the table, above. There may be more flexibility in the OMR, and therefore, exports, later in the averaging period. This amendment was supported by the ISP.

Action IV.3 Reduce Likelihood of Entrainment or Salvage at the Export Facilities

Objective: Reduce losses of winter-run, spring-run, CV steelhead, and Southern DPS of green sturgeon by reducing exports when large numbers of juvenile Chinook salmon are migrating into the upper Delta region, at risk of entrainment into the central and south Delta and then to the export pumps in the following weeks.

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[28] See Attachment 1 for discussions regarding how the second trigger was not workable.

Action: From November 1 through April 30, operations of the Tracy and Skinner Fish Collection Facilities shall be modified according to monitoring data from upstream of the Delta. In conjunction with the two alerts for closure of the DCC (Action IV.1.1), the Third Alert shall be used to signal that export operations may need to be altered in the near future because of large numbers of juvenile Chinook salmon migrating into the upper Delta region, increasing their risk of entrainment into the central and south Delta and then to the export pumps.

Third Alert: The catch index is greater than 10 fish captured per day from November 1 to February 28, or greater than 15 fish captured per day from March 1 to April 30, from either the Knights Landing catch index or the Sacramento catch index.

Response: From November 1 through December 31, when salvage numbers reach the action triggers, exports shall be reduced as follows:

Date	Action Triggers	**Action Responses**
November 1 – December 31	Daily SWP/CVP older juvenile loss density greater than 8 fish/TAF, or daily loss is greater than 95 fish per day, or Coleman National Fish Hatchery coded wire tagged late fall-run Chinook salmon (CNFH CWT LFR) or Livingston Stone National Fish Hatchery coded wire tagged winter-run (LSNFH CWT WNT) cumulative loss is greater than 0.5%.	Reduce exports to a combined 6,000 cfs for 3 days or until CVP/SWP daily density is less than 8 fish/taf. Export reductions are required when any one of the four criteria is met.
	Daily SWP/CVP older juvenile loss density greater than 15 fish/TAF, or daily loss is greater 120 fish per day, or CNFH CWT LFR or LSNFH CWT WNT cumulative loss greater than 0.5%.	Reduce exports to a combined 4,000 cfs for 3 days or until CVP/SWP daily density is less than 8 fish/taf. Export reductions are required when any one of the four criteria is met.

From January 1 through April 30, implement Action IV.2.3 which include restrictions on OMR flows rather than set levels of combined export pumping. Alert triggers will remain in effect to notify the operators of the CVP and SWP that large numbers of juvenile Chinook salmon are entering the Delta system.

Rationale: As explained previously, juvenile salmonids and green sturgeon have a lower chance of survival to the ocean if they are diverted from their migratory routes on the main Sacramento and San Joaquin rivers into the central and south Delta. Export pumping changes flow patterns and increases residence time of these diverted fish in the central Delta, which increases the risk of mortality from predation, water diversions, poor water quality, and contaminant exposure, as well as the likelihood of entrainment at the pumps. When more fish are present, more fish are at risk of diversion and losses will be higher. The Third Alert is important for the real-time operation of the export facilities because the collection and dissemination of field data to the resource agencies and coordination of response actions may take several days. This action is designed to work in concert with the OMR action in IV.2.3.

Action Suite IV.4 Modifications of the Operations and Infrastructure of the CVP and SWP Fish Collection Facilities

Objective: Achieve 75 percent performance goal for whole facility salvage at both state and Federal facilities. Increase the efficiency of the Tracy and Skinner Fish Collection Facilities to improve the overall salvage survival of winter-run, spring-run, CV steelhead, and green sturgeon.

Action: Reclamation and DWR shall each achieve a whole facility salvage efficiency of 75 percent at their respective fish collection facilities. Reclamation and DWR shall implement the following actions to reduce losses associated with the salvage process, including: (1) conduct studies to evaluate current operations and salvage criteria to reduce take associated with salvage, (2) develop new procedures and modifications to improve the current operations, and (3) implement changes to the physical infrastructure of the facilities where information indicates such changes need to be made. Reclamation shall continue to fund and implement the CVPIA Tracy Fish Facility Program. In addition, Reclamation and DWR shall fund quality control and quality assurance programs, genetic analysis, louver cleaning loss studies, release site studies and predation studies. Funding shall also include new studies to estimate green sturgeon screening efficiency at both facilities and survival through the trucking and handling process.

By January 31 of each year, Reclamation and DWR shall submit to NMFS an annual progress report summarizing progress of the studies, recommendations made and/or implemented, and whole facility salvage efficiency. These reports shall be considered in the Annual Program Review.

Action IV.4.1 Tracy Fish Collection Facility (TFCF) Improvements to Reduce Pre-Screen Loss and Improve Screening Efficiency

Objective: Implement specific measures to reduce pre-screen loss and improve screening efficiency at Federal facilities.

Action: Reclamation shall undertake the following actions at the TFCF to reduce pre-screen loss and improve screening efficiency:

1) By December 31, 2012, improve the whole facility efficiency for the salvage of Chinook salmon, CV steelhead, and Southern DPS of green sturgeon so that overall survival is greater than 75 percent for each species.

a) By December 31, 2011, Reclamation shall complete studies to determine methods for removal of predators in the primary channel, using physical and non-physical removal methods (*e.g.*, electricity, sound, light, CO_2), leading to the primary louver screens with the goal of reducing predation loss to ten percent or less. Findings shall be reported to NMFS within 90 days of study completion. By December 31, 2012, Reclamation shall implement measures to reduce pre-screen predation in the primary channel to less than ten percent of exposed salmonids.

b) By March 31, 2011, Reclamation shall complete studies for the re-design of the secondary channel to enhance the efficiency of screening, fish survival, and reduction of predation within the secondary channel structure and report study findings to NMFS. NMFS shall review study findings and if changes are deemed feasible, Reclamation shall initiate the implementation of the study findings by January 31, 2012.

c) No later than June 2, 2010, Reclamation shall submit to NMFS, one or more potential solutions to the loss of Chinook salmon and green sturgeon associated with the cleaning and maintenance of the primary louver and secondary louver systems at the TFCF. In the event that a solution acceptable to NMFS is not in place by June 2, 2011, pumping at the Tracy Pumping Plant shall cease during louver cleaning and maintenance operations to avoid loss of fish during these actions.

2) By December 31, 2011, Reclamation shall implement operational procedures to optimize the simultaneous salvage of juvenile salmonids and Delta smelt at the facility.

3) Immediately upon issuance of this biological opinion, Reclamation shall begin removing predators in the secondary channel at least once per week. By June 2, 2010, Reclamation shall install equipment to monitor for the presence of predators in secondary channel during operations. This could include an infrared or low light charged coupled device camera or acoustic beam camera mounted within the secondary channel.

4) Reclamation shall operate the facility to meet design criteria for louver bypasses and channel flows at least 75 percent efficiency.

5) Reclamation shall maintain a head differential at the trash rack of less than 1.5 ft. between the ambient Old River water surface elevation and the primary intake channel at all times.

6) By January 2, 2010, Reclamation shall install and maintain flow meters in the primary and secondary channels to continuously monitor and record the flow rates in the channel. Deviations from design flow criteria shall initiate immediate corrective measures to remedy deficiencies and return channel flows to design flow specifications.

7) Reclamation shall change its operations of the TFCF to meet salvage criteria, while emphasizing the following actions: (a) Primary Bypass Ratio; (b) Secondary Bypass

Ratio; (c) Primary Average Channel Velocity; and (d) Secondary Average Channel Velocity.

8) Records of all operating actions shall be kept and made available to NMFS engineers upon request. NMFS shall be notified of any major or long-term deviations from normal operating design criteria within 24 hours of occurrence.

Action IV.4.2 Skinner Fish Collection Facility Improvements to Reduce Pre-Screen Loss and Improve Screening Efficiency

Objective: Implement specific measures to reduce pre-screen loss and improve screening efficiency at state facilities**.**

Action: DWR shall undertake the following actions at the Skinner Fish Collection Facility:

1) By December 31, 2012, operate the whole Skinner Fish Protection Facility to achieve a minimum 75 percent salvage efficiency for CV salmon, steelhead, and Southern DPS of green sturgeon after fish enter the primary channels in front of the louvers.

2) Immediately commence studies to develop predator control methods for Clifton Court Forebay that will reduce salmon and steelhead pre-screen loss in Clifton Court Forebay to no more than 40 percent.

   a) On or before March 31, 2011, improve predator control methods. Full compliance shall be achieved by March 31, 2014. Failure to meet this timeline shall result in the cessation of incidental take exemption at SWP facilities unless NMFS agrees to an extended timeline.
   b) DWR may petition the Fish and Game Commission to increase bag limits on striped bass caught in Clifton Court Forebay.

3) Remove predators in the secondary channel at least once per week.

Action IV.4.3 Tracy Fish Collection Facility and the Skinner Fish Collection Facility Actions to Improve Salvage Monitoring, Reporting and Release Survival Rates

Objective: To improve overall survival of listed species at facilities through accurate, rapid salvage reporting and state-of-the-art salvage release procedures. This reporting is also necessary to provide information needed to trigger OMR actions.

Action: Reclamation and DWR shall undertake the following actions at the TFCF and the Skinner Fish Collection Facility, respectively. Actions shall commence by October 1, 2009, unless stated otherwise.

1) Sampling rates at the facilities for fish salvage counts shall be no less than 30 minutes every 2 hours (25 percent of operational time) year-round to increase the accuracy of salvage estimates used in the determination of trigger levels. Exceptions to the 30-minute count may occur with NMFS' concurrence under unusual situations, such as high fish densities or excessive debris loading.

2) By October 1, 2010, websites shall be created or improved to make salvage count data publicly available within 2 days of observations of the counts. Information available on the website shall include at a minimum:

    a) duration of count in minutes;
    b) species of fish salvaged;
    c) number of fish salvaged including raw counts and expanded counts;
    d) volume of water in acre-feet, and average daily flow in cfs;
    e) daily average channel velocity and bypass ratio in each channel, primary and secondary;
    f) average daily water temperature and electrical conductivity data for each facility; and
    g) periods of non-operation due to cleaning, power outages, or repairs.

3) Release Site Studies shall be conducted to develop methods to reduce predation at the "end of the pipe" following release of salvaged fish. Studies shall examine but are not limited to:

    a) potential use of barges to release the fish in different locations within the western Delta, with slow dispersion of fish from barge holding tanks to Delta waters;
    b) multiple release points (up to six) in western Delta with randomized release schedule; and
    c) conducting a benefit to cost analysis to maximize this ratio while reducing predation at release site to 50 percent of the current rate.

4) By June 15, 2011, predation reduction methods shall be implemented according to analysis in 3. By June 15, 2014, achieve a predation rate that has been reduced 50 percent from current rate.

5) Add salt to water within the tanker trucks hauling fish to reduce stress of transport. Assess use of other means to reduce stress, protect mucous slime coat on fish, and prevent infections from abrasions (*i.e.*, commercially available products for this purpose).

6) All personnel conducting fish counts must be trained in juvenile fish identification and have working knowledge of fish physiology and biology.

7) Tanker truck runs to release salmonids should be scheduled at least every 12 hours, or more frequently if required by the "Bates Table" calculations (made at each count and recorded on the monthly report).

8) Reclamation and DWR shall use the Bates Table to maintain suitable environmental conditions for fish in hauling trucks. Trucks should never be overcrowded so that the carrying capacity of the tanker truck is exceeded.

Rationale: The process for salvaging listed salmonids and green sturgeon that are drawn into the pumping facilities is not efficient. For salmonids, at the Skinner Fish Protection Facility, loss rates can be as high as five fish lost for every fish salvaged. Most of this loss occurs in the forebay before the fish even encounter the fish screen louvers and the screening process. Conversely, at the Federal TFCF, most loss occurs because of poor screening efficiency in the louver array, although predation also occurs in front of the trash racks and in the primary channel leading to the primary louver array. Louver array cleaning protocols also lead to high loss rates because louvers are removed during cleaning, but pumping continues and fish are drawn directly into the facilities. The efficiency of the salvage process for green sturgeon is unknown, and this is a significant gap in the operational protocol for the facilities. The 2004 CVP/SWP operations Opinion identified terms and conditions to be implemented regarding salvage improvements, including evaluations for operational improvements. Some of those terms and conditions have been implemented but many have not.

Action IV.5 Formation of Delta Operations for Salmonids and Sturgeon (DOSS) Technical Working Group

Objective: Create a technical advisory team .that will provide recommendations to WOMT and NMFS on measures to reduce adverse effects of Delta operations of the CVP and SWP to salmonids and green sturgeon and will coordinate the work of the other technical teams.

Action: The DOSS group will be comprised of biologists, hydrologists, and other staff with relevant expertise from Reclamation, DWR, CDFW, USFWS, and NMFS. Invitations to EPA, USGS, and Regional Water Quality Board biologists will be extended to provide expertise on issues pertinent to Delta water quality, hydrology and environmental parameters. By October 1, 2009, Reclamation shall, jointly with NMFS, convene the DOSS working group. The working group will have biweekly phone conferences, or more frequently if necessary for real-time operations, and meet at least quarterly to discuss and review information related to project operations and fisheries issues. Either Reclamation or NMFS may call for a special meeting of the DOSS group if they deem it necessary.

The team will:

1) provide recommendations for real-time management of operations to WOMT and NMFS, consistent with implementation procedures provided in this RPA;
2) review annually project operations in the Delta and the collected data from the different ongoing monitoring programs;

3) track the implementation of Actions IV.1 through IV.4;

4) evaluate the effectiveness of Actions IV.1 through IV.4 in reducing mortality or impairment of essential behaviors of listed species in the Delta;

5) oversee implementation of the acoustic tag experiment for San Joaquin fish provided for in Action IV.2.2;

6) coordinate with the SWG to maximize benefits to all listed species; and

7) coordinate with the other technical teams identified in this RPA to ensure consistent implementation of the RPA.

The DOSS team shall provide annual written reports to Reclamation, DWR, and NMFS, including a summary of major actions taken during the year to implement Action Suite IV of this RPA, an evaluation of their effectiveness, and recommendations for future actions. At the technical staff level, the working group will coordinate with the DAT, the SWG, and other workgroups to ensure coherent and consistent implementation of actions in the Delta. Every five years, the DOSS working group will produce a summary report of the previous five years of operations, actions taken, and the effectiveness of those actions in achieving the objectives of the Delta actions in this RPA. Included in this report will be recommendations for adaptive management changes consistent with the objectives of this RPA. The report will be provided to NMFS, Reclamation, DWR, CDFW and USFWS.

The DOSS group shall also provide a coordinating function for the other technical working groups, to assure that relevant information from all technical groups is considered in actions to implement this RPA.

Rationale: This RPA contains a series of measures to minimize adverse effects of project operations in the Delta. An interagency technical team is necessary to track implementation of these measures, recommend actions within the boundaries of the implementation procedures in this document, and to build expertise over time to recommend changes to Delta operations. Any significant changes to Operations will trigger re-initiation of this opinion.

Action IV.6 South Delta Improvement Program—Phase I (Permanent Operable Gates)

Action: DWR shall not implement the South Delta Improvement Program, which is a proposal to replace temporary barriers with permanent operable gates.

Rationale: In a separate formal consultation (2009/01239), NMFS issued a 2008 biological opinion on the installation and operation of temporary barriers through 2010 (NMFS 2008). That biological opinion concluded that the temporary barriers would not jeopardize the continued existence of listed species or adversely modify critical habitat. This CVP/SWP operations Opinion concludes that on the basis of the best information available, the proposed replacement of these temporary barriers with permanent operable gates will adversely modify critical habitat. NMFS has not identified an alternative to the proposed permanent gates that meets ESA obligations.

After analyses of the operations of the temporary barriers are completed, as specified in the 2008 biological opinion, DWR may request that Reclamation reinitiate consultation with NMFS on the South Delta Improvement Program or may pursue permitting under ESA section 10. Additionally, DWR may apply information developed from Action IV.1.2 to modify the barrier design.

V. Fish Passage Program

Introduction: The duration of the proposed action is more than two decades. The long time horizon of the consultation requires NMFS to anticipate long-term future events, including increased water demand and climate change. The effects analysis in this Opinion highlights the difficulty of managing cold water aquatic species below impassible barriers, depending entirely on a fluctuating and often inadequate cold water reservoir pool. The analysis shows that even after all discretionary actions are taken to operate Shasta and Folsom reservoirs to reduce adverse effects of water operations on listed anadromous fish, the risk of temperature-related mortality of fish and eggs persists, especially in critically dry years. This mortality can be significant at the population level. The analysis also leads us to conclude that due to climate change, the frequency of these years will increase.

Therefore, NMFS believes it is necessary for Reclamation, in cooperation with NMFS, other fisheries agencies, and DWR, to undertake a program to provide fish passage above currently impassable artificial barriers for Sacramento River winter-run, spring-run, and CV steelhead, and to reintroduce these fish to historical habitats above Shasta and Folsom Dams. Substantial areas of high quality habitat exist above these dams: there are approximately 60 mainstem miles above Lake Shasta and 50 mainstem miles above Lake Folsom. These high-elevation areas of suitable habitat will provide a refuge for cold water fish in the face of climate change.

An RPA requiring a fish passage program has recently been issued by the Northwest Region of NMFS, as part of the Willamette Projects Biological Opinion (NMFS 2008). This jeopardy biological opinion resulted from the operation of a series of Federal projects in Oregon. That RPA represents the state-of-the-art program to address passage concerns such as residualism (failure to complete the downstream migration) and predation. The following suite of actions is similar, but not identical, to those in the Willamette projects Opinion. There are several designs available for passage, and some are likely to be more effective in some locations than others. Consequently, while NMFS suggests that Reclamation learn from the Willamette experience, the actions allow Reclamation to follow different critical paths, particularly with respect to the construction of a downstream passage prototype.

The Fish Passage Program includes a fish passage assessment for evaluating steelhead passage above Goodwin, Tulloch, and New Melones Dams on the Stanislaus River. The assessment will develop information necessary for consideration and development of fish passage options for the Southern Sierra Diversity Group of CV steelhead. Although pilot testing of passage in the Stanislaus is encouraged, it is not specifically required.

The Fish Passage Program Action includes several elements that are intended to proceed in phases. The near-term goal is to increase the geographic distribution and abundance of listed species. The long-term goal is to increase abundance, productivity, and spatial distribution, and to improve the life history and genetic diversity of the target species. Several actions are included in this program, as indicated in the following outline of the program:

Near-Term Fish Passage Actions:

NF 1. Formation of Interagency Fish Passage Steering Committee
NF 2. Evaluation of Habitat Above Dams
NF 3. Development of Fish Passage Pilot Plan
NF 4. Implementation of Pilot Reintroduction Program
    NF 4.1. Adult Fish Collection and Handling Facilities
    NF 4.2. Adult Fish Release Sites above Dams, and Juvenile Fish Sites Below Dams
    NF 4.3. Capture, Trapping, and Relocation of Adults
    NF 4.4. Interim Downstream Fish Passage through Reservoirs and Dams
    NF 4.5. Juvenile Fish Collection Prototype
    NF 4.6. Pilot Program Effectiveness Monitoring and Evaluation
    NF 4.7. Stanislaus River Fish Passage Assessment
NF 5. Comprehensive Fish Passage Report

Long-Term Fish Passage Actions:

LF 1. Long-term Funding and Support for the Interagency Fish Passage Steering Committee.
LF 2. Long-term Fish Passage Program
    LF 2.1. Construction and Maintenance of Adult and Juvenile Fish Passage Facilities
    LF 2.2. Development of Supplementation and Management Plan
    LF 2.3. Construction and Maintenance of Long-term Adult and Juvenile Release Locations and Facilities.
    LF 2.4. Development of Fish Passage Monitoring and Evaluation Plan

NEAR-TERM FISH PASSAGE ACTIONS

NF 1. Formation of Interagency Fish Passage Steering Committee

Objective: To charter, and support through funding agreements, an interagency steering committee to provide oversight and technical, management, and policy direction for the Fish Passage Program.

Action: By December 2009, Reclamation shall establish, chair and staff the Interagency Fish Passage Steering Committee. The Committee shall be established in consultation with and the approval of NMFS and shall include senior biologists and engineers with experience and expertise in fish passage design and operation, from Reclamation, NMFS, DWR, CDFW, and USFWS. The Steering Committee also shall include academic support by including at least one academic member from a California University with and established fishery program. The committee shall be limited to agency membership unless otherwise approved by Reclamation and NMFS. Steering committee membership shall include on lead member and one alternate.

Rationale: Interagency coordination and oversight is critical to ensuring the success of the fish passage program.

NF 2. Evaluation of Salmonid Spawning and Rearing Habitat Above Dams

Objective: To quantify and characterize the location, amount, suitability, and functionality of existing and/or potential spawning and rearing habitat for listed species above dams operated by Reclamation.

Action: Beginning in January 2010 and continuing through January 2012, Reclamation, shall conduct habitat evaluations to quantify and characterize the location, amount, suitability, and functionality of existing and/or potential spawning and rearing habitat for listed species above the project reservoirs. Reclamation shall obtain the Steering Committee's assistance in designing and implementing the habitat evaluations. Evaluations shall be conducted using established field survey protocols such as the USFS Region 5 Stream Condition Inventory, Field Intensive and Field Extensive protocols; and habitat models including the Salmon Habitat Integrated Resource Analysis (Shiraz) in combination with the Distributed Hydrology Soil Vegetated Model (DHSVM) or RIPPLE. Shiraz is a life-cycle model that incorporates stream flow and temperature inputs from DHSVM to develop future projections of salmon population sizes. Ripple uses digital terrain information with aquatic habitat and biological data to identify habitat limitations that affect salmon production. Both modeling approaches have been applied in the Washington and Oregon assess the value of providing passage to salmonids to historically available habitat.

Rationale: The condition and suitability of historical habitats located above impassable barriers is likely to have changed considerably since last occupied by anadromous fish. The location, quantity, and condition of habitat must be inventoried and assessed in order to evaluate the current carrying capacity and restoration potential. This information is essential to determine where passage and reintroduction, if feasible, are most likely to improve reproductive success for listed fish.

NF 3. Development of Fish Passage Pilot Plan

Action: From January 2010 through January, 2011, Reclamation, with assistance from the Steering Committee, shall complete a 3-year plan for the Fish Passage Pilot program. The plan shall include: (1) a schedule for implementing a 3-year Pilot Passage program on the American River above Nimbus and Folsom dams, and on the Sacramento River above Keswick and Shasta dams; and (2) a plan for funding the passage program. This plan and its annual revisions shall be implemented upon concurrence by NMFS that it is in compliance with ESA requirements. The plan shall include, but not be limited to, the following:

1) Identify any operational requirements needed for the passage and re-introduction program.

2) Identify protocols for optimal handling, sorting, and release conditions for ESA-listed fish collected at Reclamation or partner agency-funded fish collection facilities when they are constructed.

3) Identify the number, origin, and species of fish to be released into habitat upstream of Reclamation dams, incorporated into the hatchery broodstock, or taken to other destinations.

4) Identify fish collection and transportation requirements (*e.g*., four wheel-drive vehicles, smooth-walled annular tanks, large vertical slide gates, provisions for tagging/marking, *etc*.) for moving fish from below project dams to habitats above reservoirs, avoiding the use of facilities or equipment dedicated for other purposes (*e.g*., existing transport trucks).

5) Identify optimal release locations for fish, based on access, habitat suitability, disease concerns, and other factors (*e.g*., those which would minimize disease concerns, recreational fishery impacts, interbreeding with non-native *O. mykiss* strains, regulatory impacts, special authorities for studies/construction, complications from upstream dams, *etc*.).

6) Identify and evaluate options for providing tailored ESA regulatory assurances for non-Federal landowners above the dams where species could be re-introduced.

7) Identify interim downstream fish passage options through reservoirs and dams with the objective of identifying volitional downstream passage scenarios and alternatives for juvenile salmon and steelhead migrating through or around project reservoirs and dams. If these options are not considered feasible, identify interim non-volitional alternatives. Near-term operating alternatives that are determined to be technically and economically feasible and biologically justified shall be identified by Reclamation and the steering committee agencies.

8) Describe scheduled and representative types of unscheduled, maintenance of existing infrastructure (dams, transmission lines, fish facilities, *etc*.) that could adversely impact listed fish, and describe measures to minimize these impacts.

9) Describe procedures for coordinating with Federal and state resource agencies in the event of scheduled and unscheduled maintenance.

10) Describe protocols for emergency events and deviations.

Reclamation and partner agencies shall annually revise and update the Fish Passage Pilot Plan. The revisions and updates shall be based on results of Fish Passage Pilot Plan activities, construction of new facilities, recovery planning guidance, predicted annual run size, and changes in hatchery management. By January 15 of each year, Reclamation shall submit a revised draft plan to NMFS. By February 15, NMFS shall advise Reclamation and partner agencies whether it concurs that the revised Fish Passage Plan is likely to meet ESA requirements. Reclamation and partner agencies shall release a final updated Fish Passage Pilot Plan by March 14 of each year.

Rationale: The Fish Passage Pilot Plan is a critical link between measures in the Proposed Action and this RPA and the long-term fish passage program. The plan will provide a blueprint for obtaining critical information about the chances of successful reintroduction of fish to historical habitats and increasing the spatial distribution of the affected populations. By including emergency operations within the Plan, field staff will have a single manual to rely on for all fish-related protocols, including steps that should be taken in emergency situations to minimize adverse effects to fish.

NF 4. Implementation of Pilot Reintroduction Program

Objective: To implement short-term fish passage actions that will inform the planning for long-term passage actions.

Actions: From January 2012 through 2015, Reclamation shall begin to implement the Pilot Reintroduction Program (see specific actions below). The Pilot Program will, in a phased approach, provide for pilot reintroduction of winter-run and spring-run to habitat above Shasta Dam in the Sacramento River, and CV steelhead above Folsom Dam in the American River. This interim program will be scalable depending on source population abundance, and will not impede the future installation of permanent facilities, which require less oversight and could be more beneficial to fish. This program is not intended to achieve passage of all anadromous fish that arrive at collection points, but rather to phase in passage as experience with the passage facilities and their benefits is gained.

Rationale: The extent to which habitats above Central Valley dams can be successfully utilized for the survival and production of anadromous fish is currently unknown. A pilot reintroduction program will allow fishery managers to incrementally evaluate adult reintroduction locations, techniques, survival, distribution, spawning, and production, and juvenile rearing, migration. The pilot program also will test juvenile collection facilities.

This action requires facility improvements or replacements, as needed, and establishes dates to complete work and begin operation. In some cases, work could be initiated sooner than listed above, and NMFS expects Reclamation and partner agencies to make these improvements as soon as possible.

Because these facilities will be used in lieu of volitional fish passage to provide access to historical habitat above the dams, this measure is an essential first step toward addressing low population numbers caused by decreased spatial distribution, which is a key limiting factor for Chinook salmon and CV steelhead.

Upstream fish passage is the initial step toward restoring productivity of listed fish by using large reaches of good quality habitat above project dams. Restriction to degraded habitat below the dams has significantly impaired reproductive success and caused steep declines in abundance.

NF 4.1. Adult Fish Collection and Handling Facilities

Beginning in 2012, Reclamation, with assistance from the Steering Committee, shall design, construct, install, operate and maintain new or rebuilt adult fish collection, handling and transport facilities at the sites listed below. The objective is to provide interim facilities to pass fish above project facilities and reservoirs.

Reclamation and partner agencies shall incorporate NMFS' Fish Screening Criteria for Anadromous Salmonids (NMFS 1997a) and the best available technology. During the design phase, Reclamation and partner agencies shall coordinate with NMFS to determine if the design should accommodate possible later connection to improved facilities, if necessary in years beyond 2015.

Reclamation and partner agencies shall complete all interim steps in a timely fashion to allow them to meet the following deadlines for completing construction and beginning operation of the facilities listed below. These steps may include completing plans and specifications. Reclamation and partner agencies shall give NMFS periodic updates on their progress. The order in which these facilities are completed may be modified with NMFS' concurrence, based on interim analyses and biological priorities.

1) Sacramento River Fish Facility – Collection facility shall be operational no later than March 2012.

2) American River Fish Facility – Collection facility shall be operational no later than March 2012.

NF 4.2. Adult Fish Release Sites above Dams and Juvenile Fish Sites Below Dams

Reclamation shall provide for the safe, effective, and timely release of adult fish above dams and juvenile fish below dams. The Fish Passage Plan must identify and release sites. Fish transport and release locations and methods shall follow existing State and Federal protocols. With assistance from the Steering Committee, and in coordination with applicable landowners and stakeholders, Reclamation shall complete construction of all selected sites by March 2012.

NF 4.3. Capture, Trapping, and Relocation of Adults

By March 2012, Reclamation shall implement upstream fish passage for adults via "trap and transport" facilities while it conducts studies to develop and assess long-term upstream and downstream volitional fish passage alternatives. At least one fish facility must be in place at terminal upstream passage points for each river that is subject to this measure. Facilities to capture adults currently exist at or below Keswick and Nimbus Dams, though these may need to be upgraded. The Pilot Program is a first step in providing anadromous fish passage to historical habitat above Project dams but will not be sufficient by itself.

The number of fish that shall be relocated is expected to vary depending on the source population, source population size, and the results of fish habitat evaluations and modeling of carrying and production capacity. The Steering Committee will work in consultation with the NMFS Southwest Fishery Science Center to develop adult relocation source populations and abundance targets. The Steering Committee shall evaluate the use of wild and hatchery sources and develop strategies that minimize risk to existing wild populations.

NMFS considers volitional passage via a fish ladder or other fishway to be the preferable alternative in most circumstances. In the short term, upstream passage can be provided with fish trap and transport mechanisms, while Reclamation evaluates program effectiveness and passage alternatives.

NF 4.4. Interim Downstream Fish Passage through Reservoirs and Dams

Beginning in 2012, following the emergence of the first year class of reintroduced fish, and until permanent downstream passage facilities are constructed or operations are established at Project dams, Reclamation shall carry out interim operational measures to pass downstream migrants as safely and efficiently as possible through or around Project reservoirs and dams under current dam configurations and physical and operational constraints, consistent with authorized Project purposes.

Near-term operating alternatives shall be identified, evaluated, and implemented if determined to be technically and economically feasible and biologically justified by Reclamation and partner agencies, within the framework of the Annual Operating Plan updates and revisions, and in coordination with the Fish Passage Plan Steering Committee. Interim devices shall be constructed to collect emigrating juvenile salmonids and emigrating post-spawn adult steelhead from tributaries, main stems above project reservoirs, or heads of reservoirs. Fish shall be safely transported through or around reservoirs as necessary and released below currently impassible dams.

Reclamation and partner agencies shall evaluate potential interim measures that require detailed environmental review, permits, or Congressional authorization as part of the Fish Passage Plan. Reclamation shall complete this component of the Plan by April 30, 2011, including seeking authorization (if necessary) and completing design or operational implementation plans for the selected operations. Measures to be evaluated include, but are not limited to, partial or full reservoir drawdown during juvenile outmigration period, modification of reservoir refill rates, and using outlets, sluiceways, and spillways that typically are not opened to pass outflow.

NF 4.5. Juvenile Fish Collection Prototype

Objective: To determine whether the concept of a head-of-reservoir juvenile collection facility is feasible, and if so, to use head-of-reservoir facilities in Project reservoirs to increase downstream fish survival. Safe and timely downstream passage of juvenile Chinook salmon and juvenile and adult post-spawn steelhead is a critical component to the success of the Fish Passage Program.

Beginning in January, 2010, with input from the CVP/SWP operations Fish Passage Steering Committee, Reclamation shall plan, design, build, and evaluate a prototype head-of-reservoir juvenile collection facility above Shasta Dam. Construction shall be complete by September 2013.

Because the head-of-reservoir fish collection concept is virtually untested, it would be imprudent to require such facilities without prior field studies, design, and prototype testing to validate the concept. For this measure, NMFS defines “prototype” to refer to temporary facilities intended for concept evaluation, not long-term operations. Further, “prototype” does not necessarily refer to a single concept; multiple concepts may be tested simultaneously. Possible options include, among others: (1) floating collectors in the reservoir near the mouths of tributaries, (2) use of curtained or hardened structures near mouths of tributaries, that block surface passage into reservoirs, (3) fish collection facilities on tributaries above the reservoir pools, and (4) a combination of the above to maximize collection in high flow and low flow conditions.

By the end of 2010, Reclamation, with assistance from the Fish Passage Steering Committee and concurrence by NMFS, shall identify a preferred location(s) and design(s) for construction of the prototype(s). Construction of the prototype facility(s) must be completed in time to conduct two years of biological and physical evaluations of the head-of-reservoir prototype collection facilities by the end of 2016. The Fish Passage Steering Committee shall have opportunity to comment on study proposals and a draft report on the effectiveness of the facilities, including recommendations for installing full-scale head-of-reservoir facilities at this and other reservoirs. By December 31, 2016, after receiving concurrence from NMFS and USFWS on the draft report, Reclamation and partner agencies shall make necessary revisions to the draft report and issue a final report. The report shall recommend technically and biologically feasible head-of-reservoir facilities, capable of safely collecting downstream migrating fish, and capable of increasing the overall productivity of the upper basins, then Reclamation and partner agencies shall include such facilities in the design alternatives that they consider in the Fish Passage Plan studies.

NF 4.6. Pilot Program Effectiveness Monitoring and Evaluation

From 2012 to 2015, Reclamation shall study, and provide annual reports on, the elements of the pilot program, including adult reintroduction locations, techniques, survival, distribution, spawning, and production; and juvenile rearing, migration, recollection, and survival. The objective is to gather sufficient biological and technical information to assess the relative effectiveness of the program elements and determine the feasibility of long-term passage alternatives. A final summary report of the 5-year pilot effort shall be completed by December 31, 2015.

NF 4.7. Stanislaus River Fish Passage Assessment

Objective: To develop information needed in order to evaluate options for achieving fish passage on the Stanislaus River above Goodwin, Tulloch, and New Melones Dams.

Action: By March 31, 2011, Reclamation shall develop a plan to obtain information needed to evaluate options for fish passage on the Stanislaus River above Goodwin, Tulloch and New Melones Dams and shall submit this plan to NMFS for review. This plan shall identify reconnaissance level assessments that are needed to support a technical evaluation of the potential benefits to CV steelhead that could be achieved with passage above the dams, a general assessment of logistical and engineering information needed, and a schedule for completing those assessments by December 31, 2016. Reclamation is encouraged to use information developed for the American and Sacramento Rivers in Action NF 3 above, when also applicable for the Stanislaus River.

By December 31, 2016, Reclamation shall submit a report, including the results of the assessments and proposed options for further consideration, to NMFS. By December 31, 2018, Reclamation shall include recommendations for fish passage on the Stanislaus River in the Comprehensive Feasibility Report (Action NF 6.) The report will outline the costs of potential projects, their biological benefits and technical feasibility, potential alternatives, and steps necessary to comply with all applicable statutes and regulations.

Rationale: This assessment process will develop foundational information necessary for consideration and development of fish passage options above New Melones Reservoir to relieve unavoidable effects of project operations on the Southern Sierra Diversity Group of CV steelhead and on adverse modification of critical habitat.

NF 5. Comprehensive Fish Passage Report

Objective: To evaluate the effectiveness of fish passage alternatives and make recommendations for the development and implementation of long-term passage alternatives and a long-term fish passage program.

Action: By December 31, 2016, Reclamation shall prepare a Comprehensive Fish Passage Report. The Report shall include preliminary determinations by Reclamation and partner agencies regarding the feasibility of fish passage and other related structural and operational alternatives. The report should include specific recommendations for improvements to highest priority sub-basins and/or features and to include recommendations for major operational changes. It will also include identification and evaluation of high priority actions and may suggest modifying the scope or timelines of these high priority actions, based on the predicted outcome of long-term efforts.

Re-initiation trigger: If the downstream fish passage improvements are determined not likely to be technically or biologically feasible at this milestone, then Reclamation and the Steering Committee shall identify other alternatives that would be implemented within the same timelines as those identified in this RPA. Reclamation and partner agencies shall submit specific implementation plans for alternative actions to NMFS, and NMFS shall evaluate whether the actions proposed in the implementation plans are likely to have the biological results that NMFS relied on in this Opinion. The alternatives must be within the same Diversity Group as the affected population, identify high elevation habitats above dams that provide similar habitat characteristics in terms of water temperatures, habitat structure (sufficient pool depths and spawning gravels), ability to withstand long-term effects of climate change, and must demonstrate an ability to support populations that meet the characteristics of a population facing a low risk of extinction according to the population parameters identified in Lindley *et al.* (2007), "Framework for Assessing Viability of Threatened and Endangered Chinook Salmon and Steelhead in the Sacramento-San Joaquin Basin." If Reclamation and partners believe that the proposed passage locations may not be feasible, the Fish Passage Steering Committee should be directed to develop early assessments of alternative actions that meet the performance standards described above in order to maintain the schedule proposed in this action. NMFS shall notify Reclamation and partner agencies as to whether the proposal is consistent with the analysis in this Opinion. If not, Reclamation will request re-initiation of consultation.

LONG-TERM FISH PASSAGE ACTIONS

In the event that the decision is made by 2016 to pursue a comprehensive fish passage program, the following actions will be implemented.

LF 1. Long-term Funding and Support to the Interagency Fish Passage Steering Committee

If the Comprehensive Fish Passage Report indicates that long-term fish passage is feasible and desirable, Reclamation shall continue to convene, fund, and staff the Fish Passage Steering Committee.

LF 2. Action Suite: Long-Term Fish Passage Plan and Program

Objective: Provide structural and operational modifications to allow safe fish passage and access to habitat above and below Project dams in the Central Valley.

Actions: Based on the results of the Comprehensive Fish Passage Report, Reclamation, with assistance from the Steering Committee, shall develop a Long-term Fish Passage Plan and implement a Long-term Fish Passage Program. Reclamation and partner agencies shall submit a plan to NMFS on or before December 31, 2016, which shall describe planned long-term upstream and downstream fish passage facilities and operations, based on the best available information at that time. The plan shall include a schedule for implementing a long-term program for safe, timely, and effective anadromous fish passage by January 31, 2020.

The Long-term Fish Passage Plan and Program shall target the following performance standards: (1) demonstrated ability to withstand long-term effects of climate change, (2) must support populations in the target watersheds that meet the characteristics of a population facing a moderate risk of extinction by year 5 (2025) and a low risk of extinction by year 15 (2030), according to the population parameters identified in Lindley *et al.* (2007), "Framework for Assessing Viability of Threatened and Endangered Chinook Salmon and Steelhead in the Sacramento-San Joaquin Basin."

The structural and operational modifications needed to implement the program shall be developed as high priority measures in the plan. The plan shall include an evaluation of a range of structural and operational alternatives for providing fish passage above Reclamation dams in the Sacramento, American, and Stanislaus River watersheds. Reclamation and partner agencies will evaluate the information gathered through plan development, the NEPA process, ESA recovery planning (including life cycle modeling developed as part of the recovery planning process), university studies, local monitoring efforts public comment, and other relevant sources, to determine which alternative(s), will provide the most cost-effective means to achieve adequate passage benefits to avoid jeopardy to ESA-listed fish from the water projects in the long term. Reclamation and partner agencies shall proceed with the action(s) that sufficiently address the adverse effects of the Project, in the context of future baseline conditions. Reclamation and DWR shall submit specific implementation plans to NMFS, and NMFS shall evaluate whether the actions proposed in the implementation plans meet ESA requirements, consistent with this Opinion. NMFS will notify Reclamation and partner agencies as to whether the proposal is consistent with ESA obligations.

Reclamation and DWR also shall analyze structural and operational modifications to provide downstream fish passage as part of the plan, following the same process as that for providing upstream passage.

The time frame for implementing the long-term passage measures may extend beyond the time frame of this Opinion. However, Reclamation and DWR must begin some actions during the term of this Opinion, including as investigating feasibility, completing plans, requesting necessary authorization, and conducting NEPA analysis

Rationale: This suite of actions ensures that fish passage actions will be taken by specified dates, or that the Project will be re-analyzed based upon new information. As noted in this Opinion, lack of passage is one of the most significant limiting factors for the viability of the affected populations of Chinook salmon and steelhead. As described in the effects analysis of the biological opinion, this also exposes populations to additional and significant stressors from project operations that also limits their viability and ability to survive below dams. Providing fish passage to historical spawning and rearing habitats would effectively mitigate for unavoidable adverse impacts of the projects on listed fish.

NMFS chose the passage in the Sacramento and American rivers based on the best available information at the time of this Opinion. The choice of location of passage facilities, as well as the method of passage, may change based on additional information, including additional assessment of necessity and feasibility of passage in the Stanislaus River. Passage methods may vary based on the specific requirements of each site, as well as fish behavior at a specific location. If information indicates that a different location or passage method is preferable, then Reclamation and DWR must coordinate with the Fish Passage Plan committee and obtain NMFS' concurrence that a proposed change is likely to meet ESA obligations.

Long-term fish passage should significantly increase abundance and spatial distribution of winter-run, spring-run, and CV steelhead because the fish will have access to upstream spawning and rearing habitat, and the juveniles will have access downstream to the ocean for growth to maturity. This action will address the Habitat Access pathway of critical habitat by improving access past physical barriers, thereby improving the status of PCEs for spawning, rearing, and migration of winter-run, spring-run, and CV steelhead populations.

LF 2.1. Long-term Adult and Juvenile Fish Passage Facilities

Based on the results of the Comprehensive Fish Passage Report and the Fish Passage Plan, and with the assistance of the Steering Committee, Reclamation shall construct long-term fish passage facilities necessary to successfully allow upstream and downstream migration of fish around or through project dams and reservoirs on the Sacramento and American Rivers by 2020, and Stanislaus River depending on results of study provided for in Action NF 4.7.

LF 2.2. Supplementation and Management Plan

Based on the results of the Comprehensive Fish Passage Report and the Fish Passage Plan, and with the assistance of the Steering Committee, in consultation with the NMFS Southwest Fishery Science Center, Reclamation shall develop and implement a long-term population supplementation plan for each species and fish passage location identified in V. *Fish Passage Program*, with adult recruitment and collection criteria developed with consideration for source population location, genetic and life history diversity, abundance and production. The purpose is to ensure that long-term abundance and viability criteria are met for all reintroduced populations, with contingencies for supplementing populations with wild and/or conservation hatchery fish if necessary. The plan shall be developed by 2020. The plan shall identify wild and/or hatchery sources for adult reintroductions and long-term supplementation, and the specific NMFS-approved hatchery management practices that qualify a hatchery for conservation purposes. Species-specific conservation hatchery programs may be developed to supplement reintroductions and maintain long-term performance standards for abundance and viability.

LF 2.3. Long-term Fish Passage Monitoring and Evaluation

Reclamation, through the Steering Committee shall develop a Long-term Fish Passage Monitoring and Evaluation Plan by 2020, to monitor all elements of the Long-term Fish Passage Program including adult reintroduction locations, techniques, survival, distribution, spawning, and production; and juvenile rearing, migration, recollection, and survival. The objective is to gather sufficient biological and technical information to assess the relative effectiveness of the program elements and determine the feasibility of long-term passage alternatives. Annual reports shall be submitted to NMFS by September 30 of each year.

11.3 ANALYSIS OF RPA

This section presents NMFS' rationale for concluding that with adoption of this RPA, Reclamation would avoid jeopardizing the listed species and adversely modifying their proposed and designated critical habitats. This rationale is presented for the following species and critical habitats that NMFS concluded would be jeopardized or adversely modified by the proposed action:

- Sacramento River winter-run and its designated critical habitat,
- CV spring-run and its designated critical habitat,
- CV steelhead and its designated critical habitat,
- Southern DPS of green sturgeon and its proposed critical habitat, and
- Southern Resident killer whales.

Each section summarizes the main stressors and the actions within the RPA that alleviate those stressors, both in the short-term and the long-term. This analysis relies heavily on the tables presented for each species. The supporting biological information for each action referenced in the table is contained in the "objective" and "rationale" sections for each action in the preceding section. Each action of the RPA is linked to at least one main stressor for at least one species, identified in the effects analysis and the integration and synthesis sections of this Opinion. Many RPA actions are designed to minimize adverse effects of project operations on multiple species and life stages.

11.3.1 Sacramento River Winter-Run Chinook Salmon and its Designated Critical Habitat

Throughout this Opinion, NMFS has explained that a species' viability (and conversely extinction risk) is determined by the VSP parameters of spatial structure, diversity, abundance, and productivity. In addition, NMFS has explained the need for the proper functioning of the PCEs that comprise the critical habitat designation. In sections 9.1 and 9.2, NMFS summarized various project-related stressors that reduced the VSP parameters and the conservation value of PCEs.

The winter-run ESU is currently at a high risk of extinction. As described in the Status of the Species section of this Opinion, weaknesses in all four VSP parameters -- spatial structure, population size, population growth rate, and diversity -- contribute to this risk. In particular (1) multiple populations of this ESU have been extirpated; the ESU now is composed of only one population, and this population has been blocked from all of its historical spawning habitat; (2) habitat destruction and modification throughout the mainstem Sacramento River have dramatically altered the ESU's spatial structure and diversity; (3) the ESU is at risk from catastrophic events, considering the remaining population's proximity to Mt. Lassen and its dependency on the cold water management of Shasta Reservoir; (4) the population has a "high" hatchery influence (Lindley *et al*. 2007); and (5) the population experienced an almost seven fold decrease in 2007. In addition, many of the physical and biological features of critical habitat that are essential for the conservation of winter-run are currently impaired and provide limited habitat value.

The proposed action increases the population's extinction risk and continues to degrade the PCEs of critical habitat by adding numerous stressors to the species' baseline stress regime, as is generally depicted in figure 9-4. The RPA specifies many significant actions that will reduce the adverse effects of the proposed action on winter-run and its critical habitat. Many of the RPA actions specifically address key project-related limiting factors or threats facing the ESU and its critical habitat, as described in the "Objectives" and "Rationale" parts of the actions. Some of these factors are lack of passage to historical spawning habitat above Keswick and Shasta Dams, passage impediments (*e.g.*, RBDD), degraded quantity and quality of the remaining habitat downstream of Keswick and Shasta Dams, and the entrainment influence of the Federal and state export facilities. As shown in table 11-1, there is a need for both short-term and long-term actions, including:

- providing passage to and from historical habitat;
- increasing Shasta reservoir storage to provide for temperature control and improve the quantity and quality of downstream habitat;
- providing interim and long-term modifications to RBDD;
- providing increased rearing habitat;
- modifying operation of the DCC; and
- implementing a revised decision process for Delta operations, including timing and amount of export reduction..

Implementation of some RPA actions will reduce the adverse effects of project operations on winter-run and its critical habitat immediately or in the near term. Other actions will take longer to plan and implement, and will not provide needed results for many years. We discuss the near-term and long-term actions separately.

Near Term

In the near term, adverse effects of project operations to winter-run will be reduced primarily through the following measures:

1) Modifications to Shasta reservoir management will result in more reliable provision of suitable water temperatures for spawning and egg incubation in the summer months. The new year-round Shasta management program is expected to minimize frequency and duration of temperature related egg mortality in dry and critically dry years, thus reducing, though not eliminating, the population level stress of these temperature related mortalities. The new Shasta program will allow for an expanded range of habitat suitable for spawning and egg incubation in wetter year types (i.e. through meeting downstream compliance points more often). Over time, this will help to preserve diversity of run-timing and decrease the risk of a single event in a localized area causing a population level effect. Temperature related effects on winter-run will persist into the future, and

cannot be fully off-set through Shasta reservoir storage actions, due to physical and hydrological constraints on the CVP system, and the delivery of water to non-discretionary CVP contractors (e.g. Sacramento River Settlement Contractors). Given a fixed supply of cold water in any given year starting in May, as an overall strategy, the RPA prioritizes temperature management in favor of winter-run due to their endangered status and complete dependence on suitable habitat downstream of Keswick for their continued survival.

2) Interim operations of RBDD (until 2012) will allow for significant increased passage of adult winter-run, a significant reduction in juvenile mortality associated with downstream passage, and elimination of emergency gate closures in early spring.
3) Continuation of installation of fish screens that meet NMFS criteria along the Sacramento River and Delta thereby reducing entrainment of winter run juveniles throughout their migration path down the Sacramento river and through the Delta.;
4) Additional closures of the DCC gates at key times of year triggered to winter-run needs, thereby will keep a greater percentage of winter-run emigrating through the northern Delta out to sea.
5) Old and Middle River reverse flow restrictions on combined exports in January through spring months, will significantly reduce winter-run juveniles that are drawn further into the Interior and Southern Delta, and therefore exposed to risks due to export facilities.
6) Additional measures will reduce entrainment and improve efficiency of salvage operations at both the State and Federal export facilities. Collectively, these measures will ensure that the winter-run that are exposed to the export facilities have a greater likelihood of survival.
7) Overall, the interim RBDD, DCC gate operations, and OMR restrictions are timed to minimize adverse effects to a greater proportion of the entire winter-run life history run-timing. By ensuring the persistence in a greater proportion of run-timing, more diversity is preserved within the ESU. This diversity of run-timing will ensure greater resiliency of the winter-run ESU to environmental changes. For example, ocean conditions and the timing and duration of upwellings may play a significant role in the survival of any given cohort of winter-run. However, modifying operations to allow for the expansion of ocean entry timing for winter-run will increase the probability that at least a portion of each cohort will enter the ocean when prey are readily available, thereby increasing the cohort's survival.

Long Term

In addition to the continuation of near-term actions, long-term actions are necessary to avoid an appreciable reduction in survival and recovery of the species. The long-term effects analysis for winter-run reveals that climate change and growth are likely to increase adverse effects especially associated with temperature related egg mortality on the Upper Sacramento River in the summertime. A prolonged drought could result in extinction of the species by resulting in significant egg mortality for three years in a row. In order to address the underlying issues of inadequate spatial structure and diversity and quality of critical habitat, and therefore, increased risk of extinction over the long-term, a passage program to provide for winter-run to access their historical habitat is necessary in order to avoid jeopardy. Such a program has many unknowns, and therefore cannot be relied upon to produce results in the near-term. In the long-term however, the RPA includes a structured passage program with pilot reintroductions, an interagency work team, and milestones and re-initiation triggers. This structured program, while not guaranteed to be effective, greatly reduces the likelihood of an appreciable reduction to winter-run survival and recovery in the long-term due to on-going project operations by allowing access of a portion of the population to historical cold-water, high elevation habitat. Furthermore, there are some near-term benefits to the passage pilot reintroduction program, including immediate expansion of the geographical rang of the single population.

In addition to upstream passage, the follow actions will minimize project effects in the long-term to the extent that the species is not jeopardized:

1. The RPA specifies long-term RBDD gate configuration is gates out all year. This will greatly reduce the significant losses associated with current and also the more modest losses associated with interim operations.
2. The RPA ensures that the Battle Creek experimental winter-run re-introduction program will proceed in a timely fashion. This Battle Creek program is critical in creating a second population of winter-run. This second population increases the species spatial structure and diversity and should increase growth rate and abundance over time as well.
3. The RPA ensures that in the long-term, Salmonid rearing habitat actions in the lower Sacramento River and Northern Delta will minimize adverse effects of project operations on winter-run critical habitat in the long-term and off-set effects of ongoing flood control operations. These habitat actions will increase the growth rates of individuals that utilize this habitat. These fish are predicted to enter the estuary and ocean with a higher degree of fitness, and therefore, greater resiliency to withstand stochastic events in these later phases of their life history, thereby increasing the viability of the ESU and reducing the likelihood of appreciable reductions in the survival or recovery of the species.

In conclusion, NMFS believes that if all parts of the RPA pertaining to Sacramento River winter-run Chinook salmon are implemented, the RPA is not likely to reduce appreciably the likelihood of survival and recovery of winter-run or adversely modify its critical habitat, in either the near term or the long term.

11.3.2 Central Valley Spring-Run Chinook Salmon and Its Designated Critical Habitat

As previously stated in the Status of the Species section, the spring-run ESU is currently likely to become endangered within the foreseeable future due to multiple factors affecting spatial structure, diversity, productivity and abundance. Specific factors include: (1) the ESU currently has only three independent populations. All three of these independent populations are in one diversity group, the Northern Sierra Nevada Diversity Group. The other diversity groups contain dependent populations; (2) habitat elimination and modification throughout the Central Valley have drastically altered the ESU's spatial structure and diversity; (3) the ESU has a risk associated with catastrophes, especially considering the remaining independent populations' proximity to Mt. Lassen and the probability of a large scale wild fire occurring in those watersheds (Lindley *et al*. 2007), (4) the presence of dams precludes access to historical spawning areas and (5) for some populations, the genetic diversity of spring-run has been compromised by hybridization with fall-run.

Table 11-1. Summary of actions to minimize or alleviate proposed action-related stressors on Sacramento River winter-run Chinook salmon and its designated critical habitat.

Life Stage/ Habitat Type	Stressor	Response/Rationale for Magnitude of Effect	Magnitude of Effect	Short-term Action to Minimize/Alleviate Stressor	Long-term Action to Minimize/Alleviate Stressor
Adult immigration and holding	RBDD gate closures from May 15 - Sept 15 every year until 2019.	~15 % of adults delayed in spawning, more energy consumed, greater pre-spawn mortality, less fecundity; continues every year until 2019.	High	Action I.3.2: RBDD Interim Operations.	Action I.3.1: RBDD Operations After May 14, 2012.
Adult immigration and holding	RBDD emergency 10 day gate closures prior to May 15	Greater proportion of run blocked or delayed; sub lethal effects on eggs in fish and energy loss. These emergency gate closures have occurred twice in the past 10 years and the frequency of occurrence may increase with climate change.	High	Action I.3.2: RBDD Interim Operations.	Action I.3.1: RBDD Operations After May 14, 2012.

Life Stage/ Habitat Type	Stressor	Response/Rationale for Magnitude of Effect	Magnitude of Effect	Short-term Action to Minimize/Alleviate Stressor	Long-term Action to Minimize/Alleviate Stressor
Spawning	Reduced spawning area from moving TCP upstream in almost every year from April 15 to Sept 30	Introgression or hybridization with spring/fall-run/late fall-run Chinook salmon; loss of genetic integrity and expression of life history Density dependency - aggressive behavior among spawning fish could cause higher prespawn mortality, increased for suitable spawning sites, adults forced downstream into unsuitable areas Redd superimposition - spawning on top of other redds, destroys eggs	High Medium - may increase as abundance increases Medium - may increase as abundance increases	Action I.2.1: Maintain suitable water temperatures for winter-run Chinook salmon. Action I.2.2: Maintain minimum Shasta Reservoir storage. Action I.2.3: February forecast and plan of operation for the Sacramento River. Action I.1.4: Improve and maintain effectiveness of the Spring Creek temperature control curtain. Action I.4: Wilkins Slough Operations Action V: Fish Passage Program (Near-term actions)	Continued implementation of Action I.2.1. Continue implementation of Action I.2.2. Continue implementation of Action I.2.3. Continue implementation of Action I.1.4. Continue implementation of Action I.4. Action V: Fish Passage Program (Long-term actions)
Spawning	Water temperatures warmer than life history stage requirements below TCP, every year April 15 -Sept 30)	Prespawn mortality; reduced fecundity	High		

Life Stage/ Habitat Type	Stressor	Response/Rationale for Magnitude of Effect	Magnitude of Effect	Short-term Action to Minimize/Alleviate Stressor	Long-term Action to Minimize/Alleviate Stressor
Embryo incubation	Water temperatures warmer than life history stage requirements, every year from April 15 - Sept 30. (No carry-over storage target designed for fish protection is included in the proposed action. Without such a target, the risk of running out of coldwater in Shasta Reservoir increases.)	Egg mortality - 16 % in critically dry years and increases to 65% in critically dry years with climate change. On average, for all water year types, mortality is 5-12% with climate change and 2-3% without. 56F is exceeded at Balls Ferry in 30% of the years in August and 55% of the years in September Sub-lethal effects, such as developmental instability and related structural asymmetry have been reported to occur to salmonids incubated at warm water temperatures (Turner *et al*. 2007, Myrick and Cech 2001, Campbell *et al*. 1998). These sub-lethal effects decrease the chance of winter-run to survive during subsequent life stages (Campbell *et al*. 1998). Campbell *et al*. (1998) concluded that chronic thermal stress produced both selectively lethal and sub-lethal effects that increased structural asymmetry and directly decreased salmon fitness.	High	Action I.2.1: Maintain suitable water temperatures for winter-run Chinook salmon. Action I.2.2: Maintain minimum Shasta Reservoir storage. Action I.2.3: February forecast and plan of operation for the Sacramento River. Action I.1.4: Improve and maintain effectiveness of the Spring Creek temperature control curtain. Action I.4: Wilkins Slough Operations Action V: Fish Passage Program (Near-term actions)	Continued implementation of Action I.2.1. Continue implementation of Action I.2.2. Continue implementation of Action I.2.3. Continue implementation of Action I.1.4. Continue implementation of Action I.4. Action V: Fish Passage Program (Long-term actions)

Life Stage/ Habitat Type	Stressor	Response/Rationale for Magnitude of Effect	Magnitude of Effect	Short-term Action to Minimize/Alleviate Stressor	Long-term Action to Minimize/Alleviate Stressor
Juvenile rearing and downstream movement	RBDD passage downstream through dam gates May 15 - Sept 15	Mortality as juveniles pass through Lake Red Bluff and RBDD reportedly ranges from 5 to 50 %; delayed emigration. Based on passage estimates of when juveniles are present at RBDD (USFWS 1997-2007), approximately 10 % of winter-run would be exposed to higher concentrations of predators when the gates are in (TCCA 2008).	High	Action I.3.2: RBDD Interim Operations	Action I.3.1: RBDD Operations After May 14, 2012

Life Stage/ Habitat Type	Stressor	Response/Rationale for Magnitude of Effect	Magnitude of Effect	Short-term Action to Minimize/Alleviate Stressor	Long-term Action to Minimize/Alleviate Stressor
Juvenile rearing and downstream movement	Reduced quality of juvenile rearing habitat related to the formation of Lake Red Bluff when the RBDD gates are in.	Delayed juvenile emigration, increased predation; change in riparian habitat, change in river conditions, change in food supply, every year since 1967	High	Action I.3.2: RBDD Interim Operations Action I.6.1: Restoration of floodplain rearing habitat. Action I.6.2: Implement near-term actions at Liberty Island/Lower Cache Slough and lower Yolo Bypass. Action I.6.3: Lower Putah Creek enhancements. Action I.6.4: Improvements to Lisbon Weir	Action I.3.1: RBDD Operations After May 14, 2012 Continue implementation of Actions I.6.1, I.6.2, I.6.3, and I.6.4.
Juvenile rearing and downstream movement	Unscreened CVP diversions between Red Bluff and the Delta	Entrainment	High	Action I.5: Funding for CVPIA anadromous fish screen program	Continue implementation of Action I.5

Life Stage/ Habitat Type	Stressor	Response/Rationale for Magnitude of Effect	Magnitude of Effect	Short-term Action to Minimize/Alleviate Stressor	Long-term Action to Minimize/Alleviate Stressor
Juvenile rearing	Lack of channel forming flows and reversed natural flow pattern (high flows in summer, low flows in late fall/winter), modifies critical habitat, including impaired geomorphic process	Loss of rearing habitat and riparian habitat and natural river function impaired (e.g., formation of side channels, sinuosity); loss of cottonwood recruitment impacting food availability, juveniles spend longer time in areas of poor water quality, greater predation, less growth from less food sources, greater stress reduces response to predators	High	Action I.6.1: Restoration of floodplain rearing habitat. Action I.6.2: Implement near-term actions at Liberty Island/Lower Cache Slough and lower Yolo Bypass. Action I.6.3: Lower Putah Creek enhancements. Action I.6.4: Improvements to Lisbon Weir	Continue implementation of Actions I.6.1, I.6.2, I.6.3, and I.6.4.

Life Stage/ Habitat Type	Stressor	Response/Rationale for Magnitude of Effect	Magnitude of Effect	Short-term Action to Minimize/Alleviate Stressor	Long-term Action to Minimize/Alleviate Stressor
Smolt emigration	Cumulative direct and indirect loss associated with export operations (DCC operations, loss in Delta interior, loss at export facilities, creation of artificial freshwater system, altered hydrodynamics).	During dry and critical years in December and January, modeling estimates of monthly mortality of up to approximately 15 % of the total winter-run population entering the Delta at Freeport is associated with exports (Greene 2008). Of those winter-run entering the *interior* of the Delta (through DCC or Georgiana Slough), mortality is estimated to be approximately 66 % (range of 35-90 % mortality). This equates to approximately 5-20 % of the total population entering the Delta at Freeport. Anticipated delays in migration due to export operations.	High	Action IV.1.1: Monitoring and alerts to trigger changes in DCC operations. Action IV.1.2: DCC gate operation. Action IV.1.3: Engineering studies of methods to reduce loss of salmonids in Georgiana Slough and South Delta channels. Action IV.2.1: San Joaquin River inflow to export ratio. Action IV.2.2: Old and Middle River Flow Management. Action IV.3: Reduce the likelihood of entrainment or salvage at the export facilities.	Continue implementation of Actions IV.1 through IV.6.

Life Stage/ Habitat Type	Stressor	Response/Rationale for Magnitude of Effect	Magnitude of Effect	Short-term Action to Minimize/Alleviate Stressor	Long-term Action to Minimize/Alleviate Stressor
				Action IV.4.1: Tracy fish collection facility improvements. Action IV.4.2: Skinner fish collection facility improvements. Action IV.4.3: Additional improvements at Tracy and Skinner fish collection facilities. Action IV. 6: Formation of Delta operations for salmon and sturgeon technical working group. Action IV.6: South Delta improvement program – phase I	

The effects of the proposed action and their affect on spring-run are contained in the sections of the Opinion on project effects and integration and synthesis. The effects are presented for the Clear Creek population, the mainstem Sacramento River population and for the other populations that are effected by project operations, by diversity group. Ultimately all spring-run must migrate through the Delta and are affected by Delta operations. The proposed action increases the extinction risk of spring-run and continues to degrade the PCEs of critical habitat by adding numerous stressors to the species' baseline stress regime and reducing the viability of all extant spring-run populations, as is generally depicted in figure 9-4. Throughout this Opinion, NMFS acknowledged that a species' viability (and conversely extinction risk) is determined by the VSP parameters of spatial structure, diversity, abundance, and productivity. In addition, NMFS acknowledged the need for the proper functioning of the PCEs that comprise the critical habitat designation. In sections 9.3 and 9.4, NMFS summarized the various stressors that reduced the VSP parameters and conservation value of the PCEs.

The RPA specifies actions that, in total, will minimize the adverse effects of the proposed action on spring-run individuals, populations and the ESU and bring about the proper functioning of PCEs of its critical habitat. Many of the RPA actions, as described in their objectives and rationale, specifically address key limiting factors/threats facing the ESU and its critical habitat, for example, lack of passage to historic spawning habitat above Keswick and Shasta Dams, passage impediments (*e.g.*, RBDD), degraded water quantity and quality of the habitat, and entrainment influence of the Federal and state export facilities. Table 11-2 provides the linkage between specific project related stressors identified in the Opinion's Integration and Synthesis, and the specific RPA actions necessary to minimize those stressors in both the near-term and the long-term. All actions that address spring-run in the RPA are necessary to minimize project effects to the extent where they do not appreciably reduce the likelihood of survival and recovery of the ESU in the near-term and the long-term, or adversely modify spring-run critical habitat. This written analysis summarizes some of the most significant RPA actions that NMFS relied on in its analysis.

The RPA contains numerous actions that minimize project effects to critical habitat of spring-run in both the near-term and the long-term. The rationales for the actions include specific PCEs addressed. It is not technologically or physically feasible, or necessary, to remove all adverse effects of project operations on critical habitat. These actions reduce adverse effects to the point where they no longer adversely modify critical habitat.

Summary of RPA effects on Central Valley Spring-run Chinook Salmon in the Near-Term

RPA actions that reduce adverse effects of project operations to spring-run and its critical habitat in the near-term include:

1) Clear Creek actions will be implemented immediately and will significantly reduce project effects to spring-run by stabilizing that population and thereby increasing the likelihood of survival of that one population in the near-term. Ensuring adequate flows to

meet temperature requirements in most years, implementing new pulse flows to assist with adult migratory cues, and implementing geomorphic flows that will disperse restored spawning gravel all will minimize project effects to this population. The Clear Creek population is important to the viability of the ESU as a whole because of its geographic location; ie, if it becomes an independent population it could considerably increase the viability of the ESU. The actions in the RPA are not recovery actions per se, but they will ensure that ongoing project operations do not appreciably reduce the likelihood of recovery of this one population.

2) Modifications to Shasta reservoir management will primarily reduce adverse effects on winter-run. Effects of the year-round Shasta management program on spring-run are more difficult to predict and quantify. The Shasta RPA will result in more carryover storage in some years, as compared to current operations, and therefore, increase ability to meet suitable spring-run spawning and egg incubation temperatures in the Fall in some years, depending on ambient weather conditions and the extent of the cold water pool in Shasta reservoir. The new year-round Shasta management program is expected to minimize frequency and duration of temperature related egg mortality in dry and critically dry years, thus reducing, though not eliminating, the population level stress of these temperature related mortalities. Temperature related effects on spring-run in the mainstem Sacramento River will persist into the future, and cannot be fully off-set through Shasta reservoir storage actions, due to physical and hydrological constraints on the CVP system, and the delivery of water to non-discretionary CVP contractors (e.g. Sacramento River Settlement Contractors). Given a fixed supply of cold water in any given year starting in May, as an overall strategy, the RPA prioritizes temperature management in favor of winter-run due to their endangered status and complete dependence on suitable habitat downstream of Keswick for their continued survival. Despite continued significant project related temperature effects on mainstem spring run, the RPA, in total, does not appreciably reduce the likelihood of survival and recovery of spring-run ESU when all populations and diversity groups are considered.

3) Near-term improvements to Battle Creek through actions identified in the RPA are expected to expand the holding, spawning and rearing habitat for spring-run in Battle Creek. It is difficult to predict the exact timing of Battle Creek projects, though funding has been secured and work is projected to start on the first phase in Summer 2009. NMFS finds that the Battle Creek program is reasonably likely to occur and contribute to the spring-run population in the long-run; however, these beneficial effects to the population may or may not occur in the near-term.

4) Interim operations of RBDD (until 2012, or with an extension until 2013) will allow for significant increased passage of adult spring-run, and a significant reduction in juvenile mortality associated with downstream passage. Extending the “gates out” operation from May 15th until June 15th will allow a very large additional portion of spring run to migrate unimpeded by the diversion dam. This improved passage will increase the likelihood that

these individuals will reach cold water pools necessary for summer holding life history in the near-term and will reduce effects of delayed passage on energy consumption and fecundity, thus improving the viability of populations above RBDD. Near-term effects of interim gate operations on remaining spring-run that are delayed due to the June 15th closure of gates will be offset by passage improvement restoration projects implemented over the next few years.. Abundance, growth rate, and spatial structure are expected to increase with the implementation of the passage restoration projects on Mill, Deer, and Antelope creeks.

5) Continuing installation of fish screens through the Anadromous Fish Screen Program along the Sacramento River and Delta will reduce juveniles entrainment of spring run throughout their migration path down the Sacramento river and through the Delta.

6) All populations of spring-run within the ESU must migrate through the Delta. Within the Delta, additional closures of the DCC gates at key times of year triggered to spring-run presence, will ensure that a greater percentage of spring-run emigrate through the northern Delta out to sea. These fish will avoid adverse effects of predation, water quality and hydrology in the Interior and Southern Delta.

7) Old and Middle River reverse flow restrictions on combined exports will significantly reduce project-related adverse effects on spring-run juveniles in January through June 15th. The OMR restrictions, triggered by spring-run (or their surrogates) in the salvage, will reduce the percentage of spring-run juveniles that are drawn further into the Interior and Southern Delta, and exposed to risks due to export facilities.

8) Additional actions at both the State and Federal export facilities will reduce entrainment and improve efficiency of salvage operations. Collectively, these measures will ensure that the spring-run that are exposed to the export facilities have a greater likelihood of survival.

9) Overall, the interim RBDD, DCC gate operations, and OMR restrictions are timed to minimize adverse effects to a greater proportion of the entire spring-run life history run-timing. By ensuring the persistence in a greater proportion of run-timing, more diversity is preserved within the ESU. This diversity of run-timing will ensure greater resiliency of the spring-run ESU to environmental changes. For example,, ocean conditions and the timing and duration of upwellings may play a significant role in the survival of any given cohort of spring-run. However, modifying operations to allow for the expansion of ocean entry timing for spring-run will increase the probability that at least a portion of each cohort will enter the ocean when prey are readily available, thereby increasing the cohort's survival.

Summary of RPA effects on Central Valley Spring-run Chinook Salmon in the Long Term

The analysis in the Opinion demonstrates that long-term actions are needed, especially considering continued effects of climate change and increasing water demands due to growth. In addition to a continuation of near-term actions described above, RPA actions that reduce adverse effects of project operations to spring-run and its critical habitat in the long-term include:

1) Additional actions that will minimize project-related effects to the Clear Creek population in the long-term include: replacing the Whiskytown temperature control curtain and adaptively managing to habitat suitability/IFIM study results.

2) In the long-term, improvements to Battle Creek through actions identified in the RPA are predicted to significantly improve spring-run habitat and off-set project-related effects on the mainstem population by creating a stable population in Battle Creek.

3) Starting in 2013, RBDD will be operated in the "gates out" formation all year. This operation will allow for unimpeded spring-run migration upstream and downstream of the diversion dam.

4) Salmonid rearing habitat actions in the lower Sacramento River and Northern Delta will minimize adverse effects of project operations on spring-run critical habitat in the long-term and off-set effects of ongoing flood control operations. These habitat actions will increase the growth rates of individuals that utilize this habitat. These fish are predicted to enter the estuary and ocean with a higher degree of fitness, and therefore, greater resiliency to withstand stochastic events in these later phases of their life history. Because all populations of spring-run migrate through this area, a portion of all populations will be likely to benefit from these rearing actions, thereby increasing the viability of the ESU and reducing the likelihood of appreciable reductions in the survival or recovery of the species.

5) In the long-run, in consideration of climate change, and in order to improve the likelihood of withstanding adverse effects associated with prolonged drought, the passage program will improve the diversity and spatial structure of the ESU by reintroducing spring-run to their historical habitat above Shasta reservoir. There is uncertainty associated with the likelihood of this action succeeding. This consultation must take a long-term view, given the 21 year time horizon. Within the long-term view, it is likely that advances in technologies and experimental procedures will increase the likelihood of success of this action. In addition, the quality of much of the habitat above Shasta reservoir is in relatively pristine condition, improving the likelihood of success. The RPA includes a reinitiation trigger in the event that passage is deemed to be infeasible. There are also some near-term benefits associated with the pilot reintroduction program, including immediate expansion of the geographic range of the species.

In summary, with full implementation of the RPA, NMFS expects that the RPA will result in minimizing project related effects to the level where these effects do not appreciably reduce the likelihood of survival or recovery of spring-run, or adversely modify its critical habitat.

Table 11-2. Summary of actions to minimize or alleviate proposed action-related stressors on Central Valley spring-run Chinook salmon and its designated critical habitat. The table is organized by life stage then by the number of populations affected by a particular stressor. Acronyms for diversity groups are as follows: NWC – Northwestern California; BPL – Basalt and Porous Lava; NSN – Northern Sierra Nevada.

Life Stage/Habitat Type	Diversity Group(s): Population(s)	Stressor	Response/Rationale for Magnitude of Effect	Magnitude of Effect	Short-term Action to Minimize/Alleviate Stressor	Long-term Action to Minimize/Alleviate Stressor
Adult immigration and holding	NWC: Cottonwood/ Beegum, Clear; BPL: Sacramento, Battle	RBDD gate closures from May 15 – Sept. 15 (plus 10 days in April) delaying adult immigration	~70 % of the spring-run that spawn upstream of RBDD are delayed by approximately 20 days on average, more energy consumed, greater pre-spawn mortality, less fecundity	High	Action I.3.2: RBDD Interim Operations	Action I.3.1: RBDD Operations After May 14, 2012
Adult immigration and holding	NWC: Clear	Water temperatures warmer than life history stage requirements during summer holding period	Water temp control to Igo; possibly some pre-spawn mortality in critically dry years when not enough cold water in Whiskeytown Lake	High	Action I.1.5: Clear Creek Thermal Stress Reduction.	Continue implementation of Action I.1.5.
Adult immigration and holding	NWC: Clear	Spring flows with little variability. Low summer flows (50 cfs), when b2 is unavailable	Limited cues for upstream migration resulting from spring flows with little variation. With low summer flows, Adults are impeded from accessing upstream holding areas.	High	Action I.1.1. Spring Attraction Flows	Continue implementation of Action I.1.1
Spawning	NWC: Clear	Loss of spawning gravel below Whiskeytown Dam – limited spawning habitat availability	Reduced spawning areas; spawning success diminishes	High	Action I.1.3: Clear Creek spawning gravel augmentation	Continue implementation of Action I.1.3

Life Stage/Habitat Type	**Diversity Group(s): Population(s)**	**Stressor**	**Response/Rationale for Magnitude of Effect**	**Magnitude of Effect**	**Short-term Action to Minimize/Alleviate Stressor**	**Long-term Action to Minimize/Alleviate Stressor**
Spawning	NWC: Clear	Low summer flows (50 cfs), when b2 is unavailable	Adults spawn further downstream in less suitable conditions (*i.e.*, in areas with relatively warm water temps.)	High	Action I.1.6: Adaptively manage to Clear Creek habitat suitability/IFIM study results.	Continue implementation of Action I.1.6
Embryo incubation	NWC: Clear	Water temperatures warmer than life history stage requirements in September only for fish that spawn below TCP (Igo)	Mortality varies with exceedance rate and number of redds; loss of some portion of those eggs; reduced chance of survival for fry	High	Action I.1.5: Clear Creek Thermal Stress Reduction	Continue implementation of Action I.1.5:

Life Stage/Habitat Type	Diversity Group(s): Population(s)	Stressor	Response/Rationale for Magnitude of Effect	Magnitude of Effect	Short-term Action to Minimize/Alleviate Stressor	Long-term Action to Minimize/Alleviate Stressor
Embryo incubation	BPL: Sacramento	Water temperatures warmer than life history stage requirements, during September and October	Under near-term operations (Study 7.1) mortality is expected to range from approximately 9% in wet years up to approximately 66 % in critically dry years, with an average of approximately 21 % over all water year types; under modeled climate change projections, average egg mortality over all water year types is expected to be 50 % and during the driest 15 % of years is expected to be 95 %. Sub-lethal effects, such as developmental instability and related structural asymmetry have been reported to occur to salmonids incubated at warm water temperatures (Turner *et al*. 2007, Myrick and Cech 2001, Campbell *et al*. 1998). These sub-lethal effects decrease the chance of spring-run to survive during subsequent life stages (Campbell *et al*. 1998). Campbell *et al*. (1998) concluded that chronic thermal stress produced both selectively lethal and sub-lethal effects that increased structural asymmetry and directly decreased salmon fitness.	High	Action Suite I.2: Shasta operations. Action I.1.4: Spring Creek temperature control curtain. Action I.4: Wilkins Slough Operations Action V: Fish Passage Program (Near-term actions)	Continued implementation of Action suite I.2. Continue implementation of Action I.1.4. Continue implementation of Action I.4. Action V: Fish Passage Program (Long-term actions)

Life Stage/Habitat Type	Diversity Group(s): Population(s)	Stressor	Response/Rationale for Magnitude of Effect	Magnitude of Effect	Short-term Action to Minimize/Alleviate Stressor	Long-term Action to Minimize/Alleviate Stressor
Juvenile rearing	NWC: Cottonwood/ Beegum, Clear; BPL: Sacramento, Battle	RBDD passage downstream through dam gates May15 - Sept 15, plus 10 days in April during emergencies	Mortality as juveniles pass through Lake Red Bluff and RBDD reportedly ranges from 5 to 50%; delayed emigration. Based on passage estimates of when juveniles are present at RBDD (USFWS 1997-2007), approximately 5 % of the spring-run ESU spawned above RBDD would be exposed to higher concentrations of predators when the gates are in (TCCA 2008).	High	Action I.3.2: RBDD Interim Operations	Action I.3.1: RBDD Operations After May 14, 2012

Life Stage/Habitat Type	Diversity Group(s): Population(s)	Stressor	Response/Rationale for Magnitude of Effect	Magnitude of Effect	Short-term Action to Minimize/Alleviate Stressor	Long-term Action to Minimize/Alleviate Stressor
Juvenile rearing	NWC: Cottonwood/ Beegum, Clear; BPL: Sacramento, Battle	Lake Red Bluff, river impounded May15 - Sept 15, plus 10 days in April during emergencies	Delayed juvenile emigration, increased predation; change in riparian habitat, change in river conditions, change in food supply, every year since 1967	High	Action I.3.2: RBDD Interim Operations Action I.6.1: Restoration of floodplain rearing habitat. Action I.6.2: Implement near-term actions at Liberty Island/Lower Cache Slough and lower Yolo Bypass. Action I.6.3: Lower Putah Creek enhancements. Action I.6.4: Improvements to Lisbon Weir	Action I.3.1: No later than May 2012, Reclamation shall operate RBDD with gates out all year Continue implementation of Actions I.6.1, I.6.2, I.6.3, and I.6.4.
Juvenile rearing	All diversity groups and populations	Unscreened CVP diversions between Red Bluff and the Delta	Entrainment	High	Action I.5: Funding for CVPIA Anadromous Fish Screen Program	Continue implementation of Action I.5

Life Stage/Habitat Type	Diversity Group(s): Population(s)	Stressor	Response/Rationale for Magnitude of Effect	Magnitude of Effect	Short-term Action to Minimize/Alleviate Stressor	Long-term Action to Minimize/Alleviate Stressor
Juvenile rearing	All diversity groups and populations	Lack of channel forming flows in the Sacramento River and reversed natural flow pattern (high flows in summer, low flows in late fall/winter), modifies critical habitat, including impaired geomorphic process.	Flow regulation (proposed Project stressor) and levee construction and maintenance (baseline stressor) alter ecological processes that generate and maintain the natural, dynamic ecosystem. This loss of natural river function has reduced the quality and quantity of rearing and migratory habitats (Stillwater Sciences 2007), thereby reducing juvenile growth and survival.	High	Action I.6.1: Restoration of floodplain rearing habitat. Action I.6.2: Implement near-term actions at Liberty Island/Lower Cache Slough and lower Yolo Bypass. Action I.6.3: Lower Putah Creek enhancements. Action I.6.4: Improvements to Lisbon Weir	Continue implementation of Actions I.6.1, I.6.2, I.6.3, and I.6.4.

Life Stage/Habitat Type	Diversity Group(s): Population(s)	Stressor	Response/Rationale for Magnitude of Effect	Magnitude of Effect	Short-term Action to Minimize/Alleviate Stressor	Long-term Action to Minimize/Alleviate Stressor
Smolt emigration	All diversity groups and populations	Cumulative direct and indirect loss associated with export operations (DCC operations, loss in Delta interior, loss at export facilities, creation of artificial freshwater system, altered hydrodynamics)	Project-related mortality is significant. Of the spring-run entering the *interior* of the Delta (through DCC or Georgiana Slough), mortality is estimated to be approximately 66 % (range of 35-90 % mortality) (Brandes and McClain 2001; Newman 2008; Perry and Skalski 2008).	High	Action IV.1.1: Monitoring and alerts to trigger changes in DCC operations. Action IV.1.2: DCC gate operation. Action IV.1.3: Engineering studies of methods to reduce loss of Salmonids in Georgiana Slough and South Delta channels. Action IV.2.1: San Joaquin River inflow to export ratio. Action IV.2.2: Old and Middle River Flow Management. Action IV.3: Reduce the likelihood of entrainment or salvage at the export facilities. Action IV.4.1: Tracy fish collection facility improvements.	Continue implementation of Actions IV.1 through IV. 6.

Life Stage/Habitat Type	Diversity Group(s): Population(s)	Stressor	Response/Rationale for Magnitude of Effect	Magnitude of Effect	Short-term Action to Minimize/Alleviate Stressor	Long-term Action to Minimize/Alleviate Stressor
					Action IV.4.2: Skinner fish collection facility improvements. Action IV.4.3: Additional improvements at Tracy and Skinner fish collection facilities. Action IV. 6: Formation of Delta operations for salmon and sturgeon technical working group. Action IV.6: South Delta improvement program – phase I	

11.3.3 Central Valley Steelhead and Its Designated Critical Habitat

The proposed action increases the extinction risk of CV steelhead and continues to degrade the PCEs of critical habitat by adding numerous stressors to the species' baseline stress regime and reducing the viability of all of the extant CV steelhead populations in the CVP-controlled rivers (Clear Creek, Sacramento River, American River, and Stanislaus River) and the Delta. Throughout this Opinion, NMFS acknowledged that a species' viability (and conversely extinction risk) is determined by the VSP parameters of spatial structure, diversity, abundance, and productivity. In addition, NMFS acknowledged the need for the proper functioning of the PCEs that comprise the critical habitat designation. In sections 9.5 and 9.6, NMFS summarized the various stressors that reduced the VSP parameters and conservation value of the PCEs. In general, warm water temperatures and low flows, loss of natural river function and floodplain connectivity through levee construction, direct loss of floodplain and riparian habitat, loss of tidal wetland habitat, a collapsed pelagic community in the Delta, and poor water quality associated with agricultural, urban, and industrial land use have caused fitness reductions and degraded the PCEs of critical habitat in the past. The proposed action is expected to continue to degrade the VSP parameters and conservation value of the PCEs, and the effects of climate change and increased water demand in the future are expected to exacerbate conditions that reduce the long-term viability of CV steelhead.

The RPA specifies actions that, in total, will minimize the adverse effects of the proposed action on steelhead individuals, populations and the DPS and bring about the proper functioning of PCEs of its critical habitat. Many of the RPA actions, as described in their objectives and rationale, specifically address key limiting factors/threats facing the DPS and its critical habitat, for example, lack of passage to historic spawning habitat above Keswick and Shasta Dams, and Nimbus and Folsom Dams, and New Melones, Dam, passage impediments (*e.g*., RBDD), degraded water quantity and quality of the habitat, hatchery fish compromising the genetic integrity of natural CV steelhead and entrainment influence of the Federal and state export facilities. Table 11-3 provides the linkage between specific project related stressors identified in the Opinion's Integration and Synthesis, and the specific RPA actions necessary to minimize those stressors in both the near-term and the long-term. All actions that address CV steelhead in the RPA are necessary to minimize project effects to the extent where they do not appreciably reduce the likelihood of survival and recovery of the DPS in the near-term and the long-term, or adversely modify CV steelhead critical habitat. This written analysis summarizes some of the most significant RPA actions that NMFS relied on in its analysis.

As show in table 11-3, the RPA acknowledges the need for both short-term and long-term actions, including:

- providing safe passage to and from historical habitat;
- improving the quantity and quality of habitat in all of the CVP-controlled streams through water releases;
- providing interim and long-term modifications to RBDD;
- providing increased rearing habitat;

- modifying the operation of the DCC; and
- implementing a revised decision process for Delta operations, including reduced exports.

The anticipated improvements to CV steelhead and its critical habitat are expected to begin immediately through implementation of various actions, and continue to increase over the term of this Opinion (through year 2030) with the implementation of the longer-term actions. While implementation of the RPA will occur during the term of this Opinion, its full effects on population metrics (*e.g.*, spatial structure, diversity, abundance, productivity) and the PCEs of critical habitat will occur over a considerable period of time after implementation. Therefore, NMFS expects the project operations, as modified by the RPA, to minimize effects to critical habitat so that it is not adversely modified.

In the near term, the provision of more cold water throughout the species' upstream migration, rearing, holding, and incubation period are expected to increase in-river production. RPA actions that address flow maintenance and stabilization will minimize redd dewatering and scouring, and stranding. Juveniles will be afforded more rearing habitat during their freshwater residency by reducing the inundation duration of Lake Red Bluff, and expanding access to rearing habitat within the Yolo Bypass and other areas within the Sacramento River Basin, in both the near-term and long-term. Modified operations of RBDD will provide unimpeded passage for more of the upstream spawning migration season of the upper Sacramento River and its tributaries populations. More smolts are expected to outmigrate into the Pacific Ocean as operations of the CVP and SWP are modified to reduce entrainment and mortality. Specifically, requirements in Actions Suite IV.2 will significantly increase the survival of CV steelhead smolts outmigrating from the San Joaquin River basin.

Overall, the interim RBDD, DCC gate operations, and OMR restrictions are timed to minimize adverse effects to a greater proportion of the entire steelhead life history run-timing. By ensuring the persistence in a greater proportion of run-timing, more diversity is preserved within the DPS. This diversity of run-timing will ensure greater resiliency of the CV steelhead DPS to environmental changes, for example, changed productivity in the ocean.

In the long-term, in addition to the continuation of the near-term actions, CV steelhead will be afforded the opportunity to spawn and rear in historical habitat upstream of Nimbus and Folsom Dams. Access to this historical habitat will provide steelhead with cold water temperatures necessary for increased spawning, incubation, and rearing success, especially in consideration of the environmental effects of climate change. Such a program has many unknowns, and therefore cannot be expected to immediately abate all up-river stressors in the near-term, although some near term benefits will occur, such as immediate improvements in the geographic distribution of the population to historic habitats, which would reduce jeopardizing risks to the ESU faced by individuals that remain below project dams. In the long-term however, the RPA includes a structured passage program with pilot reintroductions. Additionally, alternatives to the proposed fish passage actions may also be proposed by Reclamation and the Fish Passage Steering Committee, in the event that the proposed actions are determined to not be technically or biologically feasible, and provided they are capable of meeting similar performance standards in terms of population distribution with Diversity Groups, and viability according the parameters described in Lindley *et al.* (2007).

The long-term operation of RBDD will provide unimpeded passage opportunities for adults and juveniles, and reduce competition and predation from other salmonid species.

The genetic diversity of the CV steelhead DPS is compromised through hatchery operations, including those at Nimbus. Through preparation and implementation of a HGMP, in the long-term, genetic diversity of CV steelhead will increase, thereby increasing the viability of the DPS.

An important aspect of the RPA analysis for steelhead concerns the status of the Southern Sierra Diversity Group, which is critical to preserving spatial structure of the DPS. This diversity group, consisting of extant populations in the Calaveras, Stanislaus, Tuolumne, Merced and Mainstem San Joaquin rivers, is very unstable due to the poor status of each population. This status is due to both project-related and non-project related (baseline) stressors. In the near-term, a new flow schedule for the Stanislaus River and interim actions to increase flows at Vernalis and curtail exports will allow greater out-migration cues and survival of smolts past the state and federal export facilities. In the long-term, additional actions through additional flow to export ratios in the southern Delta, and channel forming flows and gravel augmentations in the Stanislaus river will further reduce project-related adverse-effects to this diversity group. Due to uncertainty in the flow to export ratio, the RPA six year acoustic tag experiment, which can be combined with experimental barrier technologies, will significantly enhance our knowledge base for future consultations and refinements of this RPA action. Ultimately, our analysis is clear that the long-term viability of this diversity group will depend not only on implementation of this RPA, but also on actions outside this consultation, most significantly increasing flows in the Tuolumne and Merced rivers. The SWRCB has made establishing additional flows in these rivers a priority and intends to take action within the near-term. A future CVP/SWP operations consultation that will be triggered by implementation of San Joaquin Restoration Program flows will also provide further opportunities to update and refine actions critical to this diversity group.

In summary, with full implementation of the RPA, NMFS expects the adverse effects of project operations will be minimized to the point where the likelihood of survival and recovery of the DPS is not appreciably reduced and its designated critical habitat is not adversely modified.

Table 11-3. Summary of actions to minimize or alleviate proposed action-related stressors to Central Valley steelhead and its designated critical habitat. The table is organized by life stage then by the number of populations affected by a particular stressor. Acronyms for diversity groups are as follows: NWC – Northwestern California; BPL – Basalt and Porous Lava; NSN – Northern Sierra Nevada; SSN – Southern Sierra Nevada.

Life Stage/ Habitat Type	Diversity Group(s): Population(s)	Stressor	Response/Rationale for Magnitude of Effect	Magnitude of Effect	Short-term Action to Minimize/Alleviate Stressor	Long-term Action to Minimize/Alleviate Stressor
Adult immigration and holding	NWC: Cottonwood / Beegum, Clear; BPL: Sacramento, Battle	RBDD gate closures from May 15 – Sept. 15 (plus 10 days in April) delaying adult immigration	17 % of those that spawn above RBDD, delayed in spawning, more energy consumed, greater pre-spawn mortality, less fecundity	High	Action I.3.2: RBDD interim Operations	Action I.3.1: RBDD operations after May 14, 2012
Adult immigration and holding	NWC: Clear	Water temperatures warmer than life history stage requirement for migration possible in lower reach near confluence with Sacramento River during August and September	Some adults may not enter mouth of Clear Creek, 1) delayed run timing, 2) seek other tributaries, 3) spawn in mainstem Sacramento R.; reduced in vivo egg viability	Low- except for critically dry years	Action I.1.5: Clear Creek thermal stress reduction	Continue implementation of Action I.1.5:
Adult immigration	SSN: Stanislaus River	Exposure to stressful water temperatures from the Delta to Riverbank during adult immigration	Delayed entry into river (CDFG 2007a); pre-spawn mortality; reduced condition factor	Medium	Action III.1.1: Establish Stanislaus Operations group Action III.1.2: Stanislaus River temperature management	Continue implementation of Actions III.1.1 and III.1.2

Life Stage/ Habitat Type	Diversity Group(s): Population(s)	Stressor	Response/Rationale for Magnitude of Effect	Magnitude of Effect	Short-term Action to Minimize/Alleviate Stressor	Long-term Action to Minimize/Alleviate Stressor
Spawning	NWC: Clear	Loss of spawning gravel below Whiskeytown Dam – limited spawning habitat availability	Limited areas of suitable spawning sites. Spawning in sub-optimal habitat	Medium - but could be high without continued gravel augmentation	Action I.1.3: Clear Creek spawning gravel augmentation	Continue implementation of Action I.1.3
Spawning	NSN: American River	Folsom/Nimbus releases – flow fluctuations in the American River resulting in redd dewatering	Redd dewatering and isolation prohibiting successful completion of spawning	Medium	Action II.1: Lower American River flow management, particularly management following the ARG process	Continue implementation of Action II..1
Spawning	NSN: American River; BPL: Sacramento; and potentially all other populations within the NWC, NSN, and BPL diversity groups	Nimbus Hatchery *O. mykiss* spawning with natural-origin steelhead in the American River and in other CV streams	Reduced genetic fitness of CV steelhead through the spread of Eel River genes and potentially hatchery rainbow trout genes to many below-barrier sites (Garza and Pearse 2008).	High	Action II.6.1: Preparation of hatchery genetic management plan for steelhead Action II.6.2: Interim actions prior to submittal of draft HGMP for steelhead	Continue implementation of Actions II.6.1 and II.6.2

Life Stage/ Habitat Type	Diversity Group(s): Population(s)	Stressor	Response/Rationale for Magnitude of Effect	Magnitude of Effect	Short-term Action to Minimize/Alleviate Stressor	Long-term Action to Minimize/Alleviate Stressor
Spawning	SSN: Stanislaus River	Unsuitable flows in the Stanislaus River restrict spawnable habitat and dewater redds	Limited spawning habitat availability according to Aceituno (1993). Instream flows typically drop in January from higher December levels when San Joaquin River water quality objectives are met. This increases the risk for redd dewatering and direct egg mortality.	High	Action III.1.1: Establish Stanislaus operations group Action III.1.3: Stanislaus River temperature management	Continue implementation of Actions III.1.1 and III.1.3
Spawning	SSN: Stanislaus River	Excessive fines in spawning gravel resulting from lack of overbank flow	Reduced suitable spawning habitat; For individual: increased energy cost to attempt to "clean" excess fine material from spawning site Fine material deposited in gravel beds because of lack of overbank flow to inundate floodplain and deposit fine material on floodplain, instead of in river (Kondolf *et al*. 2001).	High	Action III.2.2: Stanislaus River floodplain restoration and inundation flows	Continue implementation of Action III.2.2
Embryo incubation	NSN: American River	Exposure to stressful water temperatures in the American River during embryo incubation	Sub-lethal effects - reduced early life stage viability; direct mortality; restriction of life history diversity (*i.e.*, directional selection against eggs deposited in Mar. and Apr.)	Medium	Action II.3: Make structural improvements to improve cold water management Action V: Fish passage program (Near-term actions)	Continue implementation of Action II.3 Action V: Fish passage program (Long-term actions)

Life Stage/ Habitat Type	**Diversity Group(s): Population(s)**	**Stressor**	**Response/Rationale for Magnitude of Effect**	**Magnitude of Effect**	**Short-term Action to Minimize/Alleviate Stressor**	**Long-term Action to Minimize/Alleviate Stressor**
Egg incubation and emergence	SSN: Stanislaus River	Excessive fines in spawning gravel resulting from lack of overbank flow	Egg mortality from lack of interstitial flow; egg mortality from smothering by nest-building activities of other steelhead or fall-run; suppressed growth rates	High	Action III.2.2: Stanislaus River floodplain restoration and inundation flows	Continue implementation of Action III.2.2
Egg incubation and emergence	SSN: Stanislaus River	Exposure to stressful water temperatures in the Stanislaus River during egg incubation and emergence	Egg mortality, especially for eggs spawned in or after March; Embryonic deformities (Deas *et al*. 2008) Temperatures may be operationally managed, depending on year type	Medium	Action III.1.1: Establish Stanislaus operations group Action III.1.2: Stanislaus River temperature management	Continue implementation of Actions III.1.1 and III.1.2 Action V: Fish passage program (Long-term actions)
Juvenile rearing	BPL: Sacramento River	Provision of higher flows and cooler water temps during the summer than occurred prior to the construction of Shasta Dam	Potential fitness advantage for resident *O.mykiss* over the anadromous form, which would drive an evolutionary (*i.e.*, genetic) change if life history strategy is heritable (Lindley *et al*. 2007).	High	Action V: Fish passage program (Near-term actions)	Action V: Fish passage program (Long-term actions)

Life Stage/ Habitat Type	Diversity Group(s): Population(s)	Stressor	Response/Rationale for Magnitude of Effect	Magnitude of Effect	Short-term Action to Minimize/Alleviate Stressor	Long-term Action to Minimize/Alleviate Stressor
Juvenile rearing	NWC: Cottonwood / Beegum, Clear; BPL: Sacramento, Battle	Lake Red Bluff, river impounded May15 - Sept 15, plus 10 days in April during emergencies	Reduction in rearing habitat quality and quantity; delayed juvenile emigration, increased predation; change in riparian habitat, change in river conditions, change in food supply, every year since 1967	High	Action I.3.2: RBDD interim operations Action I.6.1: Restoration of floodplain rearing habitat Action I.6.2: Implement near-term actions at Liberty Island/Lower Cache Slough and lower Yolo Bypass Action I.6.3: Lower Putah Creek enhancements Action I.6.4: Improvements to Lisbon Weir	Action I.3.1: RBDD operations after May 14, 2012 Continue implementation of Actions I.6.1, I.6.2, I.6.3, and I.6.4
Juvenile rearing	All diversity groups and populations	Unscreened CVP diversions between Red Bluff and the Delta	Entrainment	High	Action I.5: Funding for CVPIA Anadromous Fish Screen Program	Continue implementation of Action I.5

Life Stage/ Habitat Type	Diversity Group(s): Population(s)	Stressor	Response/Rationale for Magnitude of Effect	Magnitude of Effect	Short-term Action to Minimize/Alleviate Stressor	Long-term Action to Minimize/Alleviate Stressor
Juvenile rearing	All diversity groups and populations, excluding the SSN diversity group	Lack of channel forming flows in the Sacramento River and reversed natural flow pattern (high flows in summer, low flows in late fall/winter), modifies critical habitat, including impaired geomorphic process.	Flow regulation (proposed Project stressor) and levee construction and maintenance (baseline stressor) alter ecological processes that generate and maintain the natural, dynamic ecosystem. This loss of natural river function has reduced the quality and quantity of rearing and migratory habitats (Stillwater Sciences 2007), thereby reducing juvenile growth and survival.	High	Action I.6.1: Restoration of floodplain rearing habitat Action I.6.2: Implement near-term actions at Liberty Island/Lower Cache Slough and lower Yolo Bypass Action I.6.3: Lower Putah Creek enhancements Action I.6.4: Improvements to Lisbon Weir	Continue implementation of Actions I.6.1, I.6.2, I.6.3, and I.6.4
Juvenile rearing	NWC: Clear Creek	Exposure to stressful water temperatures in Clear Creek during juvenile rearing	Limited over-summering habitat, reduced growth, increased susceptibility to disease and predation	High	Action I.1.5: Clear Creek thermal stress reduction	Continue implementation of Action I.1.5

Life Stage/ Habitat Type	Diversity Group(s): Population(s)	Stressor	Response/Rationale for Magnitude of Effect	Magnitude of Effect	Short-term Action to Minimize/Alleviate Stressor	Long-term Action to Minimize/Alleviate Stressor
Juvenile rearing	NWC: Clear Creek	Limited rearing habitat availability in Clear Creek resulting from low summer flows (< 80 cfs)	Limited rearing habitat availability; less food, reduced growth, increased predation risk	High	Action I.1.6: Adaptively manage to habitat suitability/IFIM study results	Continue implementation of Action I.1.6
Juvenile rearing	NSN: American River	Folsom/Nimbus releases resulting in flow fluctuations; low flows	Fry stranding and juvenile isolation - observations of juvenile steelhead isolation in the American River were made in both 2003 and 2004 (Water Forum 2005a). Low flows limiting the availability of quality rearing habitat including predator refuge habitat	High	Action II.4: Minimize lower American River flow fluctuation effects	Continue implementation of Action II.4

Life Stage/ Habitat Type	Diversity Group(s): Population(s)	Stressor	Response/Rationale for Magnitude of Effect	Magnitude of Effect	Short-term Action to Minimize/Alleviate Stressor	Long-term Action to Minimize/Alleviate Stressor
Juvenile rearing	NSN: American River	Exposure to stressful water temperatures in the American River during juvenile rearing	Physiological effects - increased susceptibility to disease (e.g., anal vent inflammation) and predation. Visible symptoms of thermal stress in juvenile steelhead are associated with exposure to daily mean water temperatures above 65°F (Water Forum 2005a). With the exception of 2005, from 1999 through 2007, daily mean water temperatures at Watt Avenue from August through September were warmer than 65°F for approximately 81 percent of the days, and during 2001, 2002, 2004, 2006, and 2007, water temperatures were often over 68°F (figure 30a). Under a drier and warmer climate change scenario (Study 9.5), modeled water temperatures at Watt Avenue from June through September under full build out of the proposed Project range from 65°F to 82°F (Reclamation 2009). Even if no regional climate change is assumed (Study 9.1), water temperatures at this location during this time period are expected to range from 63°F to 79°F.	High	Action II.2: Lower American River temperature management Action II.3: Make structural improvements to improve management Action V: Fish passage program (Near-term actions)	Continue implementation of Actions II.2 and II.3 Action V: Fish passage program (Long-term actions)

Life Stage/ Habitat Type	Diversity Group(s): Population(s)	Stressor	Response/Rationale for Magnitude of Effect	Magnitude of Effect	Short-term Action to Minimize/Alleviate Stressor	Long-term Action to Minimize/Alleviate Stressor
Juvenile rearing	SSN: Stanislaus River	Lack of overbank flow in the Stanislaus River to inundate rearing habitat	Reduced food supply; suppressed growth rates; starvation; loss to predation; poor energetics; indirect stress effects, smaller size at time of emigration;	High	Action III.2.2: Stanislaus River floodplain restoration and inundation flows Action V: Fish passage program (Near-term actions)	Continue implementation of Action III.2.2 Action V: Fish passage program (Long-term actions)
Juvenile rearing	SSN: Stanislaus River	Reduction in rearing habitat complexity in the Stanislaus River due to reduction in channel forming flows	Reduced food supply; suppressed growth rates; starvation; loss to predation; poor energetics; indirect stress effects, smaller size at time of emigration;	High	Action III.2.2: Stanislaus River floodplain restoration and inundation flows	Continue implementation of Action III.2.2
Juvenile rearing	SSN: Stanislaus River	Unsuitable flows in the Stanislaus River for maintaining juvenile rearing habitat	Crowding and density dependent effects relating to reduced habitat availability. Metabolic stress; starvation; loss to predation; indirect stress effects, poor growth;	High	Action III.2.2: Stanislaus River floodplain restoration and inundation flows Action III.1.3: Stanislaus River flow management	Continue implementation of Actions III.2.2 and III.1.3

Life Stage/ Habitat Type	Diversity Group(s): Population(s)	Stressor	Response/Rationale for Magnitude of Effect	Magnitude of Effect	Short-term Action to Minimize/Alleviate Stressor	Long-term Action to Minimize/Alleviate Stressor
Juvenile rearing and downstream movement	SSN: Stanislaus River	Predation in the Stanislaus River by non-native fish predators because rearing habitat is lacking	Juvenile mortality; Reduced juvenile production	High	Action III.2.2: Stanislaus River floodplain restoration and inundation flows Action III.1.3: Stanislaus River flow management Action III.2.3: Implement predation reduction projects	Continue implementation of Actions III.2.2, III.1.3, and III.2.3
Juvenile rearing	SSN: Stanislaus River	Exposure to stressful water temperatures in the Stanislaus River at the end of summer affecting rearing habitat	Metabolic stress; starvation; loss to predation; indirect stress effects, poor growth;	High	Action III.1.1: Establish Stanislaus operations group Action III.1.2: Stanislaus River temperature management	Continue implementation of Actions III.1.1 and III.1.2

Life Stage/ Habitat Type	Diversity Group(s): Population(s)	Stressor	Response/Rationale for Magnitude of Effect	Magnitude of Effect	Short-term Action to Minimize/Alleviate Stressor	Long-term Action to Minimize/Alleviate Stressor
Smolt emigration	SSN: Stanislaus River	Water temperatures warmer than life history stage (Mar - June)	Missing triggers to elect anadromous life history; failure to escape river before temperatures rise at lower river reaches and in Delta; thermal stress;	High	Action III.1.1: Establish Stanislaus operations group Action III.1.3: Stanislaus River flow management	Continue implementation of Actions III.1.1 and III.1.3
Smolt emigration	NSN: American River	Exposure to stressful water temperatures in the American River during smolt emigration	Physiological effects – reduced ability to successfully complete the smoltification process, increased susceptibility to predation	Medium	Action II.3: Make structural improvements to improve cold water management Action V: Fish passage program (Near-term actions)	Continue implementation of Action II.3 Action V: Fish passage program (Long-term actions)
Smolt emigration	SSN: Stanislaus River	Water temperatures warmer than life history stage (Mar - June)	Missing triggers to elect anadromous life history; failure to escape river before temperatures rise at lower river reaches and in Delta; thermal stress;	High	Action III.1.1: Establish Stanislaus operations group Action III.1.2: Stanislaus River temperature management	Continue implementation of Action III.1.1 and III.1.2

Life Stage/ Habitat Type	Diversity Group(s): Population(s)	Stressor	Response/Rationale for Magnitude of Effect	Magnitude of Effect	Short-term Action to Minimize/Alleviate Stressor	Long-term Action to Minimize/Alleviate Stressor
Smolt emigration	SSN: Stanislaus River	Suboptimal flow in the Stanislaus River (March – June)	Failure to escape river before temperatures rise at lower river reaches and in Delta; thermal stress; misdirection through Delta leading to increased residence time and higher risk of predation	High	Action III.1.3: Stanislaus River flow management	Continue implementation of Action III.1.3

Life Stage/ Habitat Type	Diversity Group(s): Population(s)	Stressor	Response/Rationale for Magnitude of Effect	Magnitude of Effect	Short-term Action to Minimize/Alleviate Stressor	Long-term Action to Minimize/Alleviate Stressor
Smolt emigration	All diversity groups and populations	Cumulative direct and indirect loss associated with export operations (DCC operations, loss in Delta interior, loss at export facilities, creation of artificial freshwater system, altered hydrodynamics)	Substantial mortality to steelhead from all diversity groups. Based on VAMP studies of fall-run, mortality ranges from 90 – 99 % from San Joaquin River release points to Chipps Island (SJRGA 2006). Similar results are assumed for steelhead, as shown through the CCF studies showing similar loss rates between steelhead and Chinook salmon (DWR 2008).	High	Action IV.1.1: Monitoring and alerts to trigger changes in DCC operations Action IV.1.2: DCC gate operation Action IV.1.3: Engineering studies of methods to reduce loss of Salmonids in Georgiana Slough and South Delta channels Action IV.2.1: San Joaquin River inflow to export ratio Action IV.2.2: Old and Middle River Flow Management Action IV.3: Reduce the likelihood of entrainment or salvage at the export facilities	Continue implementation of Actions IV.1 through IV.6

Life Stage/ Habitat Type	Diversity Group(s): Population(s)	Stressor	Response/Rationale for Magnitude of Effect	Magnitude of Effect	Short-term Action to Minimize/Alleviate Stressor	Long-term Action to Minimize/Alleviate Stressor
					Action IV.4.1: Tracy fish collection facility improvements Action IV.4.2: Skinner fish collection facility improvements. Action IV.4.3: Additional improvements at Tracy and Skinner fish collection facilities Action IV. 6: Formation of Delta operations for salmon and sturgeon technical working group Action IV.6: South Delta improvement program – phase I	

11.3.4 Southern DPS of Green Sturgeon and Its Proposed Critical Habitat

The Southern DPS of green sturgeon is at substantial risk to future population declines (Adams *et al*. 2007). The potential threats faced by the green sturgeon include enhanced vulnerability due to the reduction of spawning habitat into one concentrated area on the Sacramento River, habitat elimination and modification in the mainstem Sacramento River and Delta, lack of good empirical population data, vulnerability of long-term cold water supply for egg incubation and larval survival, and loss of juvenile green sturgeon due to entrainment Federal and State export facilities in the South Delta. In addition, many of the physical and biological features of critical habitat that are essential for the conservation of the Southern DPS of green sturgeon are currently impaired, and provide limited conservation value. The proposed action increases the population's extinction risk and continues to degrade the PCEs of their proposed critical habitat by adding numerous stressors to the species' baseline stress regime. Throughout this Opinion, NMFS acknowledged that a species' viability (and conversely extinction risk) is determined by the VSP parameters of spatial structure, diversity, abundance, and productivity. In addition, NMFS acknowledged the need for the proper functioning of the PCEs that comprise the proposed critical habitat. In sections 9.7 and 9.8, NMFS summarized various stressors that reduced the VSP parameters and conservation value of the PCEs.

The RPA specifies many significant actions that will reduce the adverse effects of the proposed action on Southern DPS of green sturgeon and bring about the proper functioning of PCEs of its proposed critical habitat. Many of the RPA actions, as described in their objectives and rationale, specifically address key limiting factors/threats facing the DPS and its proposed critical habitat, for example, passage impediments, degraded water quantity and quality of the remaining habitat downstream of Keswick and Shasta Dams, and entrainment influence of the Federal and state export facilities. Table 11-4 provides the linkage between specific project related stressors identified in the Opinion's Integration and Synthesis, and the specific RPA actions necessary to minimize those stressors in both the near-term and the long-term. All actions that address the Southern DPS of green sturgeon in the RPA are necessary to minimize project effects to the extent where they do not appreciably reduce the likelihood of survival and recovery of the DPS in the near-term and the long-term, or adversely modify proposed critical habitat. This written analysis summarizes some of the most significant RPA actions that NMFS relied on in its analysis.

As show in table 11-4, the RPA acknowledges the need for both short-term and long-term actions, including:

- increasing Shasta reservoir storage to provide for temperature control and improve the quantity and quality of downstream habitat;
- providing interim and long-term modifications to RBDD to providing safe passage to and from spawning habitat;
- implementing studies on Southern DPS of green sturgeon population size, and life history and habitat needs in the short-term to improve management of the species and their habitat in the long-term;

- providing increased rearing habitat;
- modifying the operation of the DCC; and
- implementing a revised decision process for Delta operations, including reduced exports.

Minimization of adverse effects of project operations on the Southern DPS of green sturgeon and its proposed critical habitat are expected to begin immediately through implementation of various actions, and continue to increase over the term of this Opinion (through year 2030) with the implementation of the longer-term actions. While implementation of the RPA will occur during the term of this Opinion, its full effects on population metrics (*e.g.*, spatial structure, diversity, abundance, productivity) and the PCEs of critical habitat will occur over a considerable period of time after implementation. In the near term, precluding an emergency gate closure, delaying the gate closure until June 15th, and increasing the height of gate openings at RBDD will immediately minimize a significant portion of the adverse effects of RBDD on green sturgeon. An increase in survival of spawning adults, and the availability of more cold water that will provide more spawning habitat in more favorable spawning and embryo incubation temperature ranges, will likely result in an increased growth rate and diversity of the population in the long run. Also in the near-term, actions within the Delta will reduce the influence of the Federal and State export facilities, increase survival of juveniles by keeping them within the mainstem Sacramento River, and reduce entrainment and mortality.

In the long term, in addition to the continuation of the near-term actions, adverse effects of project operations will be further minimized with unimpeded passage opportunities for adults and juveniles at RBDD, and reduced competition and predation. Results from the near-term studies will aid in the management and recovery of the species and their proposed critical habitat on the long-term.

In summary, with full implementation of the RPA, NMFS expects that on-going project effects on Southern DPS of green sturgeon and its proposed critical habitat will be minimized to the extent the survival and recovery are not appreciably reduced, and critical habitat is not adversely modified.

Table 11-4. Summary of actions to minimize or alleviate proposed action-related stressors to the Southern DPS of green sturgeon and its proposed critical habitat.

Life Stage/Habitat Type	Stressor	Response/Rationale for Magnitude of Effect	Magnitude of Effect	Short-term Action to Minimize/Alleviate Stressor	Long-term Action to Minimize/Alleviate Stressor
Adult immigration and holding	RBDD gate closures from May 15 - Sept 15 every year and emergency 10-day gate closures delaying adult immigration.	Passage blocked, 55 miles of spawning habitat made inaccessible upstream of RBDD after May 15. Large aggregations (25-30) of mature adults observed below RBDD gates. Estimate 30 % of run blocked based on run timing. Also, mortalities associated with downstream passage under gates post-spawn, or after fish move above gates. Mortality greater on larger, more fecund females that can not fit through 18" opening Greater proportion of run blocked or delayed (40 -50%) based on run timing; Greater mortalities associated with downstream passage under gates post spawn, or after moving above gates, sub lethal effects on eggs in fish and energy loss. Occurred twice in the past 10 years, but the frequency of occurrence may increase with climate change	High	Action I.3.2: RBDD interim operations Action I.3.3. RBDD interim operations for Green Sturgeon Action I.3.4: Measures to compensate for adverse effects of RBDD interim operations on green sturgeon	Action I.3.1: RBDD operations after May, 2012 Continue implementation of Action I.3.4

Life Stage/Habitat Type	**Stressor**	**Response/Rationale for Magnitude of Effect**	**Magnitude of Effect**	**Short-term Action to Minimize/Alleviate Stressor**	**Long-term Action to Minimize/Alleviate Stressor**
Spawning	RBDD	Unnatural spawning site created below RBDD, portion of run (only one in CV) spawning in water 2 feet deep, channel aggradation below hydraulics from gates, eggs suffocate, physiological effects, delayed hatch, greater predation on eggs due to accumulation of predators below RBDD.	High	Action I.3.2: RBDD interim operations Action I.3.3. RBDD interim operations for Green Sturgeon Action I.3.4: Measures to compensate for adverse effects of RBDD interim operations on green sturgeon	Action I.3.1: RBDD operations after May, 2012 Continue implementation of Action I.3.4
Embryo incubation	Water temperatures warmer than life history stage requirements below Hamilton City.	For eggs and fry that are spawned in areas from RBDD to Hamilton City water quality is less suitable than above RBDD where temperatures are controlled for winter-run. Eggs suffocate from less flow, physiological effects, delayed hatch, greater predation on eggs due to presence of non-native introduced warm-water species.	Medium	Action I.2.1: Maintain suitable water temperatures for Southern DPS of green sturgeon. Action I.2.2: Maintain minimum Shasta Reservoir storage. Action I.2.3: February forecast and plan of operation.	Continued implementation of Action I.2.1. Continued implementation of Action I.2.2. Continued implementation of Action I.2.3.

Life Stage/Habitat Type	Stressor	Response/Rationale for Magnitude of Effect	Magnitude of Effect	Short-term Action to Minimize/Alleviate Stressor	Long-term Action to Minimize/Alleviate Stressor
Juvenile rearing	Increased juvenile mortality related to emigration when RBDD Dam gates are in (*i.e.*, May15 - Sept 15, plus 10 days in April during emergencies)	Based on passage estimates of when juveniles are present at RBDD (USFWS 1997-2007), approximately 100 % of the green sturgeon DPS that is spawned above RBDD would be exposed to higher concentrations of predators when the gates are in (TCCA 2008). Approximately 70 % of the entire green sturgeon DPS spawns above RBDD. Mortality of juvenile salmon emigrating past RBDD when the gates are in ranges from 5 -50 % (Vogel *et al*. 1988; Tucker 1998); mortality of juvenile green sturgeon emigrating past RBDD has not been estimated, but is expected to increase when the gates are in.	High	Action I.3.2: RBDD interim operations Action I.3.3. RBDD interim operations for Green Sturgeon Action I.3.4: Measures to compensate for adverse effects of RBDD interim operations on green sturgeon	Action I.3.1: RBDD operations after May, 2012 Continue implementation of Action I.3.4
	Reduced quality of juvenile rearing habitat related to the formation of Lake Red Bluff when the RBDD gates are in.	Reduction in rearing habitat quality and quantity; increased predation; change in riparian habitat, change in river conditions, change in food supply, every year since 1967.	High		

Life Stage/Habitat Type	Stressor	Response/Rationale for Magnitude of Effect	Magnitude of Effect	Short-term Action to Minimize/Alleviate Stressor	Long-term Action to Minimize/Alleviate Stressor
Juvenile rearing	Unscreened CVP diversions	Entrainment	High	Action I.5: Funding for CVPIA Anadromous Fish Screen Program	Continue implementation of Action I.5

Life Stage/Habitat Type	**Stressor**	**Response/Rationale for Magnitude of Effect**	**Magnitude of Effect**	**Short-term Action to Minimize/Alleviate Stressor**	**Long-term Action to Minimize/Alleviate Stressor**
Juvenile and subadult	Loss at export facilitiest	Entrainment of fish at the CVP and SWP in every month of the year. Louvers function well for larger fish but are inefficient for smaller fish. Fish behavior may make them susceptible to the cleaning practices of louvers. In louver studies, fish position themselves in front of the bottom edge of the louver along the channel bottom, where they held position for prolonged periods of time.	Unknown	Action IV.1.1: Monitoring and alerts to trigger changes in DCC operations Action IV.1.2: DCC gate operation Action IV.1.3: Engineering studies of methods to reduce loss of Salmonids in Georgiana Slough and South Delta channels Action IV.2.2: Old and Middle River flow management Action IV.3: Reduce the likelihood of entrainment or salvage at the export facilities Action IV.4.1: Tracy fish collection facility improvements Action IV.4.2: Skinner fish collection facility improvements. Action IV.4.3: Additional improvements at Tracy and Skinner fish collection facilities Action IV. 6: Formation of Delta operations for salmon and sturgeon technical working group Action IV.6: South Delta improvement program – phase I	Continue implementation of Actions IV.1 through IV.6
	Impaired movements through South Delta waterways due to temporary barriers or permanent gates	Presence of green sturgeon juveniles and subadults in the South Delta as confirmed by salvage records. Presence occurs during operational season of barriers (April through November). Closure of waterways by temporary barriers or permanent gates inhibits movement of green sturgeon through these waterways. Fish located upstream of barriers are potentially trapped or delayed in their movements downstream by structures.	Unknown		

11.3.5 Southern Resident Killer Whales

NMFS evaluated effects of the proposed action on Southern Residents by evaluating effects on the availability of their preferred prey, Chinook salmon. NMFS considered effects on both listed and non-listed Chinook salmon. With respect to the listed winter-run and spring-run ESUs, the proposed action is likely to appreciably reduce the survival and recovery of the listed entities and conservation value of their designated critical habitat, which would increase their risk of extinction in the long term. If these stocks were to become extinct, there would be an increased likelihood of localized killer whale prey depletions on the Pacific coast.

As described in sections 11.3.1 and 11.3.2, full implementation of the RPA is expected to reduce adverse effects of project operations on ESA-listed winter-run and spring-run and their designated critical habitats to the point where there is not an appreciable reduction in the likelihood of survival or recovery or an adverse modification of critical habitat. NMFS anticipates that implementation of RPA actions will decrease the risk of extinction of winter-run and spring-run in the long-term, reducing the risk of localized prey depletions and thereby increasing the prey available to Southern Residents.

NMFS also considered effects of the proposed action on non-listed Chinook salmon that are available to Southern Residents (section 6.8.1.2.2). As discussed in section 6.8.1.2, we quantified effects of hatchery production and project operations on non-listed Chinook salmon available to Southern Residents. Hatchery programs included in the proposed action produce more Chinook salmon than are killed in project operations. However, artificial propagation can have harmful effects on the long-term fitness of salmon populations, and the current hatchery practices at Nimbus and Trinity River fish hatcheries are diminishing the long-term viability of these non-listed stocks over the long term. The proposed action did not identify time lines for reforming harmful hatchery practices that affect these stocks.

RPA Action Suite II.6 calls for development of hatchery management plans for fall-run at Nimbus Fish Hatchery and spring-run and fall-run at Trinity River Fish Hatchery, by June 2014. New hatchery management will be subject to future section 7 consultations and/or the 4(d) HGMP process. NMFS anticipates that implementing these RPA actions will provide long-range planning to reduce impacts of hatchery operations on natural fall-run and spring-run, increase the genetic diversity and diversity of run-timing for these stocks, and increase the likelihood that these stocks are retained as prey available to Southern Resident killer whales in the long term. Improving the genetic diversity and diversity of run timing of CV fall-run will decrease the potential for localized prey depletions and increase the likelihood that fall-run can withstand stochastic events, such as poor ocean conditions.

Many RPA actions intended to avoid jeopardy to listed winter-run and spring-run, or adverse modification of their critical habitat, are also expected to reduce adverse effects of the action on the short- and long-term abundance and the long-term viability of non-listed fall-run and late-fall run. The immediate cause of the recent fall-run decline is most likely a result of ocean conditions (Lindley *et al*. 2009). However, freshwater impacts and hatchery programs most likely contributed to the collapse (Lindley *et al.* 2009). The RPA actions address many of the freshwater impacts identified in Lindley *et al.* (2009). NMFS expects that these actions would reduce adverse impacts of the project in all years, under all hydrologic conditions. The actions include:

1) After 2012, there will be unrestricted up-stream and down-stream passage at RBDD. The interim measure of gates out on September 1 allows an additional 14 days unimpeded passage for adult fall-run.
2) A continued investment in fish screens along the Sacramento River and in the Delta would reduce entrainment of juvenile fall-run/late fall-run in unscreened diversions.
3) Improved rearing habitat in both the short-term and long-term in the Delta and lower Sacramento River (Liberty Island/Cache Slough) will improve juvenile fall-run survival.
4) Increased closures of DCC gates from October through January will reduce the percentage of juvenile outmigrants that enter the Interior Delta and are then subject to both direct and indirect mortality.
5) Additional Old and Middle River flow restrictions from January through June will reduce exposure of fall-run and late fall-run juveniles to export facilities and increase survival for fall-run leaving the San Joaquin River.
6) Improvements in salvage procedures at the Delta fish facilities will lead to higher survival of juveniles that enter the facilities and are subjected to the salvage process.
7) In the long term, implementation of fall-run hatchery management plans at Nimbus and Trinity River Hatcheries will increase genetic diversity of fall-run.
8) Increased gravel augmentation on Clear Creek and the Stanislaus River will increase spawning and rearing habitat for listed and non-listed salmonids.
9) Improved flows on Clear Creek, Stanislaus River, and the American River will enhance fall-run spawning and maintain spatial diversity between races.
10) Improved water temperature control on the Sacramento River, Clear Creek, American River, and Stanislaus River will provide more suitable habitat for Chinook salmon.
11) Greater storage levels in the fall for temperature control will improve temperatures for fall-run, as well as winter-run and spring-run.
12) Replacement of the Spring Creek temperature control curtain will provide cooler water temperatures to the Sacramento River in the fall.
13) Implementation of spring-run passage improvement projects (*i.e.*, mitigation for RBDD impacts) in the Sacramento River basin will improve fall-run passage and access to greater spawning and rearing habitat.

14) Improvements in San Joaquin River flows at Vernalis will not only improve survival of juvenile steelhead but fall-run as well

15) Export reductions based on fish densities at the fish salvage facilities will improve survival of non-listed salmonids, since they are similar in size at length.

16) Fish passage above project dams, although not intended for non-listed fish species, will benefit EFH by providing spatial and temporal separation between runs, thereby improving the genetic structure and space available for fall-run spawning (reduced competition, and introgression).

17) Restoration of Battle Creek is expected to improve EFH for fall-run as well as listed species.

18) Improvements in fish passage at flood control weirs will reduce stranding of both adult and juvenile non-listed salmonids and sturgeon.

19) Greater monitoring and reporting requirements for listed species will improve management of non-listed species as well.

20) A 6-year acoustical tag study of juvenile salmonids in the San Joaquin River and Delta will improve understanding of fall-run biological requirements.

The following actions in the RPA are expected to decrease the abundance of fall-run and late fall- run to some extent and may reduce viability in the long term:

1) Temperature control management for winter-run during the summer in the upper Sacramento River can reduce or eliminate the cold water available for fall-run spawning and egg incubation in September and October, most likely in dry or critically dry years. The RPA includes a new year-round program for temperature management at Shasta Reservoir, including requirements for carryover storage, and water temperatures until October 31. The new temperature regime will lead to more frequent End of September storage levels that will support cold water releases for spring-run and fall-run in September and October, thereby reducing the adverse effects of temperatures on fall-run and late fall-run as compared to the proposed action.

2) Temperature control management for steelhead on the American River during the summer can reduce the cold water pool available in October and November.

3) Segregation weirs on Clear Creek to reduce introgression with spring-run reduce habitat available for fall-run spawning.

4) Removal of the middle fish ladder at RBDD for green sturgeon to facilitate additional 18 inch gate opening delays passage of fall-run.

5) Wilkins Slough minimum flows in September and October to preserve cold water storage in Shasta Reservoir can delay upstream migration.

Effects numbered 3 through 5 are expected to occur in all years, during all hydrologic conditions; however, the effects, which include delayed arrival at spawning grounds or less available spawning habitat, are not anticipated to be severe enough to cause mortality of adult spawners. Additionally, RBDD will be removed in approximately three years, after which effects numbered 4 will not occur, and the dam removal will reduce adverse effects on fall-run thereafter.

Temperature control effects numbered 1 and 2 are expected to occur only during critically dry years, which represent less than 10 percent of historic years modeled and up to 25 percent of future years, based on a potential climate change scenario of dry, warming conditions (Study 8.0, 2030 Level of Development). These effects are expected to result in prespawn and early life-stage mortalities for fall-run in the mainstem Sacramento River and American River. In up to 25 percent of future years, temperature control effects numbered 1 and 2 could result in a reduction in future production of fall-run. In critically dry years, up to 8 percent of the Sacramento River population and up to 14 percent of the American River population could experience pre-spawn or egg mortality (Oppenheim 2009). A loss of 8 to13 percent future production from natural spawners in the mainstem Sacramento River and American River, respectively, would be a small reduction in the overall number of adult fish available to the whales from this stock, which is dominated by hatchery produced fish. The RPA is designed to conserve storage and will, therefore, improve the likelihood that sufficient cold water will remain in the fall, and the upper estimate of impacts will not be realized. Some impacts from temperature are likely to occur with or without the RPA, because they are linked to hydrologic factors, such as drought and climate variation.

The RPA will generally reduce adverse effects of project operation on naturally- spawning fall-run and late-fall run by improving adult passage and increasing juvenile survival. Implementation of fall-run hatchery management plans at Nimbus and Trinity River fish hatcheries will increase genetic diversity of fall-run. Increased diversity will decrease the potential for localized prey depletions and increase the likelihood that fall-run can withstand stochastic events, such as poor ocean conditions, and thereby provide a consistent food source in years with overall poor productivity. In some years temperature control actions may result in reductions in future production of fall-run in the Sacramento and American rivers; however, the aggregate of the RPA actions will reduce overall adverse effects of project operations to a level that is not likely to imperil this prey source .

In sum, the RPA is not likely to result in an increased extinction risk of winter-run and spring-run, and it is not likely to imperil the long-term viability of fall-run. Consequently, project operations under the RPA are not likely to result in local depletions of killer whale prey that could appreciably reduce the whales' likelihood of survival and recovery. Therefore, NMFS concludes that the RPA will not jeopardize the continued existence of Southern Resident killer whales.

11.3.6 Economic and Technological Feasibility of the RPA

When developing an RPA, NMFS is required by regulation to devise an RPA that is "economically and technologically feasible" in addition to avoiding jeopardy and adverse modification. These feasibility concerns were discussed and addressed in many ways throughout the period of November 2008 through May 2009, during the course of the consultation. During this period, NMFS developed an initial RPA by December 11, 2009, revised that RPA in response to feedback from the two science panels and DWR, Reclamation, CDFW, and USFWS. NMFS developed a second draft RPA by March 3, 2009, and revised that draft in response to additional feedback from the agencies prior to providing the final action. Some of the more complex RPA actions, including Shasta Storage, Habitat Rearing Actions, Passage Program, Stanislaus Flows and the San Joaquin River Inflow Export Ratio, went through many iterations of review, re-drafting, and refinement, involving interagency staff and management expertise, including biology, ecology, hydrology, and operations, in order to ensure that the actions were based on best available science, would be effective in avoiding jeopardy, and would be feasible to implement. NMFS also secured outside contractual services to provide additional modeling expertise in evaluating draft RPA actions.

Examples of Feasibility Concerns in RPA Actions

As a result of this iterative consultation process, NMFS considered economic and technological feasibility in several ways when developing the CVP/SWP operations RPA. Examples include:

1) Providing reasonable time to develop technologically feasible alternatives where none are "ready to go" – *e.g.*, the Delta engineering action (Action IV.1.3), and lower Sacramento River rearing habitat action (Action I.6.1);

2) Calling for a stepped approach to fish passage at dams, including studies and pilot projects, prior to a significant commitment of resources to build a ladder or invest in a permanent trap and haul program. A reinitiation trigger is built into this action in the event passage is not deemed feasible, prior to construction of permanent infrastructure;

3) Considering limitations of the overall capacity of CVP/SWP systems of reservoirs in determining feasibility of flow actions below reservoirs, and considering the hydrologic record and CALSIM modeling results (Shasta/Sacramento River, Folsom/American River, New Melones/Stanislaus River).

4) Tiering actions to water year type and/or storage in order to conserve storage at reservoirs and not unduly impact water supplies during drought (*e.g.*, see appendix 5);

5) Providing health and safety exceptions for export curtailments;

6) Using monitoring for species presence to initiate actions when biologically supported and most needed, in order to limit the duration of export curtailments;

7) Incorporating scientific uncertainty into the design of the action, when appropriate, in order to refine the action over time (*e.g.*, 6-year acoustic tag study for San Joaquin steelhead).

8) Incorporating performance goals into more complex actions (for example, Shasta storage, rearing habitat and San Joaquin acoustic tag study). A performance goal approach will allow for adaptation of the action over time to incorporate the most up-to-date thinking on cost-effective technologies or operations.

9) Allowing for interim, further constrained, water deliveries to TCCA through modified RBDD operations for 3 years, while an alternative pumping plant is being built.

The RPA includes collaborative research to enhance scientific understanding of the species and ecosystem, and to adapt actions to new scientific knowledge. This adaptive structure is important, given the long-term nature of the consultation and the scientific uncertainty inherent in a highly variable system. Monitoring and adaptive management are both built into many of the individual actions and are the subject of an annual program review. This annual program review will provide for additional opportunities to address any unforeseen concerns about RPA feasibility that may arise.

The rationale statements for individual actions explain more specific reasoning, and the administrative record contains specific hydrology and modeling results in support of the more complex actions (*e.g.*, Shasta and San Joaquin storage/flows).

Water Supply Costs and Projected Impacts

NMFS examined water supply costs of the RPA as one aspect of considering economic feasibility. While only costs to the action agency are considered in determining whether a RPA meets the regulatory requirement of economic feasibility, NMFS is mindful of potential social and economic costs to the people and communities that historically have depended on the Delta for their water supply. Any water supply impact is undesirable. NMFS made many attempts through the iterative consultation process to avoid developing RPA actions that would result in high water costs, while still providing for the survival and recovery of listed species.

NMFS estimates the water costs associated with the RPA to be 5-7% of average annual combined exports: 5% for CVP, or 130 TAF/year, and 7% for SWP, or 200 TAF/year[29]. The combined estimated annual average export curtailment is 330 TAF/year. These estimates are over and above export curtailments associated with the USFWS' Smelt Opinion. The OMR restrictions in both Opinions tend to result in export curtailments of similar quantities at similar times of year. Therefore, in general, these 330 TAF export curtailments are associated with the NMFS San Joaquin River Ratio actions in the RPA.

NMFS also considered that there may be additional localized water costs not associated with South Delta exports. These may include, in some years, localized water shortages necessitating groundwater use, water conservation measures, or other infrastructure improvements in the New Melones service area, and localized impacts in the North of Delta in some years, associated with

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[29] The proportional share between the CVP and SWP is attributable to CalLite programming and may not represent the true share of export reductions that would be allocated to each facility under actual conditions.

curtailments of fall deliveries used for rice decomposition. NMFS considered whether it was feasible to model and estimate any water costs associated with the Shasta or American River RPA actions, and discussed this issue with Reclamation. In general, it was decided that modeling tools were not available to assess these costs and/or that costs would be highly variable depending on adaptive management actions, and therefore, not meaningful to model.

To assess the economic feasibility associated with average annual water costs of 330 TAF, NMFS reviewed CVP/SWP project wide and statewide information regarding water availability. NMFS considered the following information as background to economic feasibility. This information is provided by the State Legislative Analyst's Office (California's Water: An LAO Primer, October 2008):

1) "The federal government has developed the most surface storage capacity in the state with over 17 MAF of capacity in ten reservoirs on multiple river systems. These reservoirs generally are part of the federal Central Valley Project (CVP), which serves about 3.1 million people, and provides irrigation water to over 2.6 million acres of land. The largest reservoir in the system is Shasta Lake with 4.6 MAF of capacity. The state, as part of the development of SWP, built Oroville Dam and reservoir on the Feather River system with a capacity of 3.5 MAF. The SWP provides all or part of the drinking water supply for 23 million people and provides irrigation water to about 755,000 acres of land."
2) "The federal government, through the Bureau of Reclamation, holds the most (in volume) water rights in the state with over 112 MAF of water held, mainly for delivery through the federal CVP. Second to this are the water rights held by the Imperial Irrigation District (44 MAF), serving mainly farms in the Colorado River region. Two private gas and electric companies hold rights to over 41 MAF of water collectively, mainly for hydroelectric power. The state, through DWR, holds rights to about 31 MAF of water."

3) "Water dedicated for environmental uses, including instream flows, wild and scenic flows, required Sacramento-San Joaquin River Delta (the Delta) outflow, and managed wetlands use, declines substantially between wet and dry years—a 62 percent reduction. Available water supplied to agricultural and urban users actually increases in dry years. From wet to dry years, urban use increases by 10 percent and agricultural use increases by 20 percent. The main reason for this increase is the need in dry years for more developed water for agricultural irrigation and residential landscaping."

4) "Agricultural use of water is significant. California agriculture uses roughly 30 MAF of water a year on 9.6 million acres. California's vast water infrastructure— including the development of the State Water Project, Central Valley Project, and Colorado River, as well as local and regional groundwater supply projects—was developed to provide water for irrigation (among other purposes), with agriculture using about 80 percent of California's developed water supply." (LAO, 2008)

NMFS also considered information on relative deliveries of water in the state, including Figure 8 from Blue Ribbon Task Force Delta Vision report, and Figure 10 from the same report, showing the relative importance of Delta exports relative to other sources of water supplies (taken from

DWR 2005 California Water Plan Update). To assess the relative impact of export reductions on Southern California urban uses, NMFS reviewed a presentation by Metropolitan Water District, entitled “Metropolitan’s Water Supply Planning,” January 31, 2009, and reviewed Figure 11 from the Delta Vision report showing the potential range of demand reductions and supply augmentations from different strategies (taken from DWR 2005 Water Plan Update).

NMFS considered the above water cost estimates in the context of the larger set of facts on California’s water supply to determine whether the RPA is economically feasible. NMFS believes that a cost of 5-7 percent of the project capacity is not unreasonable for a multi-species ESA consultation, given the factual context of the Delta ecosystem and water delivery system. 330 TAF reduction can be compared to 30 MAF for agriculture statewide, according to LAO. In addition, these amounts can be compared to the water rights held by the federal and state governments (112 MAF, and 31 MAF respectively, according to LAO).

Most important, NMFS evaluated the 5-7 percent combined export reduction in the context of future water demand and supply in California. The Delta is only one source of water supply. According to other planning documents (DWR’s California Water Plan Update, 2005), water agencies are already planning for and adjusting to reduced supplies from the Delta. Alternative supplies include: water transfers, demand reduction through conservation, conjunctive use/groundwater use during droughts, wastewater reclamation and water recycling, and desalination. For example, urban water use efficiency is estimated by DWR to potentially result in between 1.2 to 3.1 MAF annual water savings, and recycled municipal water is potentially estimated to result in .9 to 1.4 MAF annual water savings. The state of California has had an active Integrated Watershed Management Program for almost 10 years. Projects funded through these local water infrastructure investments are coming on line, and will help offset decreased water supply from the Delta.

Furthermore, NMFS considered RPA water costs in the context of b(2) water assets of 800 taf. As the Opinion explains, for purposes of the effects analysis, NMFS could not be reasonably certain that b(2) water would be available at a specific place and time needed to address adverse effects of the project on a listed species. Therefore, the Opinion analysis and RPA actions developed to avoid jeopardy and adverse modification of critical habitat are independent of the availability of b(2) assets, and are silent about how these assets should be used. The Secretary of the Interior retains discretions over how b(2) assets are dedicated to eligible water actions throughout the water year. It is NMFS understanding that water actions taken by Reclamation to implement the RPA are eligible actions. If the Secretary of the Interior so chooses, dedication of b(2) water assets to the RPA actions could completely or significantly offset the projected water costs of the RPA. In addition, limited EWA assets associated with the Yuba Accord may be available, in part, to offset water costs of the SWP. In the proposed project description, these assets were dedicated to VAMP export curtailments. The VAMP export curtailments will be replaced, in part, by the new San Joaquin River Ratio action.

In evaluating economic feasibility, NMFS examined the direct costs of the modified operations to the Federal action agency, Reclamation. According to the LAO, 85% of Reclamation’s costs are reimbursed by water users, and 95% of DWR’s SWP costs are reimbursed:

> Irrigation water users pay about 55 percent of CVP reimbursable costs ($1.6 billion), while municipal and industrial water users are responsible for the remaining 45 percent (or about $1.3 billion). These reimbursements are paid through long-term contracts with water agencies. The total capital cost to construct the CVP as of September 30, 2006, is about $3.4 billion. The federal Bureau of Reclamation calculates how much of the capital construction cost is reimbursable from water users. Currently, users pay about 85 percent of total costs. In contrast, more than 95 percent of SWP's costs are reimbursable from water users. The costs assigned to such CVP purposes as flood control, navigation, and fish and wildlife needs are not reimbursable and are paid by the federal government.

(LAO, 2008) Through this arrangement, costs to the action agency itself are minimized.

NMFS also reviewed and evaluated water cost information provided by DWR. In general, the DWR information reinforced the NMFS estimates of water costs. On March 20, 2009, DWR provided estimates of water costs associated with the March 3, 2009, draft of the RPA (letter from Kathy Kelly to Ronald Milligan; Reclamation 2009b). These modeled costs were discussed in several technical team meetings and remain the only modeled projections of water costs of the RPA that NMFS is aware of. DWR estimated that combined CVP/SWP costs, as compared to operations under D1641, are 800 TAF to 1.0 MAF (or about 15%-17%). However, because the salmon and smelt are near the export facilities during much of the same time of year (winter to spring), many export curtailments are multi-species in nature. Therefore, DWR estimates that, the average combined water supply impact of the NMFS RPA, layered on top of the USFWS smelt RPA, is an additional 150 TAF to 750 TAF (or about 3% to 15%).

The San Joaquin river ratio action changed significantly between the March 3, 2009, draft of the RPA and the final RPA. Specifically, the duration of the period changed from 90 to 60 days, in order to better focus the action on the species' biological requirements, and the ratios were more closely refined to reflect water year type in order to reflect actual available water in the watershed and in acknowledgement that acquiring (or requiring, if the SRCWB acts) additional flows on the Tuolumne and Merced rivers could be difficult or uncertain in the near-term. Both of these refinements would reduce, perhaps substantially, DWR projected water costs, and would most likely make them consistent with NMFS estimates. On April 28, 2009, DWR provided an additional analysis of on the economic impacts of estimated water costs of the March 3, 2009, draft RPA (letter from Kathy Kelly to Ronald Milligan; DWR 2009). DWR estimated that the impact of the RPA would range from $320 million to $390 million per year. The methodology used multipliers estimated indirect and well as direct impacts. Again, these costs were predicated on RPA actions that were modified after March 3rd, and would have reduced water costs.

Project Costs

In addition to water costs, Reclamation and DWR will incur project costs associated with certain RPA actions (*e.g.*, the fish passage program). The State of California has authorized $19.6 billion in water-related general obligation bonds since 2000, and these bonds often contain provisions for environmental conservation related purposes (LAO, 2008). Over $3 billion has been spent through the Calfed Bay-Delta Program. The CALFED ROD contains a commitment to fund projects through the Ecosystem Restoration Program. Similarly, the CVPIA AFRP funds eligible restoration projects, using federal authorities. Some of the projects in the RPA may qualify for those sources of funds.

<u>Summary</u>

In summary, for all the above reasons, NMFS finds that the costs associated with the RPA, while not insignificant, do not render the RPA economically infeasible. Overall, the RPA is both technologically and economically feasible.

11.3.7 Consistency with the Intended Purpose of the Action and the Action Agencies' Legal Authority and Jurisdiction

As noted in the introduction to this RPA, regulations provide that an RPA must be an alternative that, "can be implemented in a manner consistent with the intended purpose of the action, [and] that can be implemented consistent with the scope of the federal agency's legal authority and jurisdiction." 50 CFR 402.02. This RPA meets both of these criteria.

First, this RPA is consistent with the intended purpose of the action. According to the BA, "[t]he proposed action is the continued operation of the CVP and SWP." (CVP and SWP operations BA, P. 2-1) Specifically, Reclamation and DWR "propose to operate the Central Valley Project (CVP) and State Water Project (SWP) to divert, store, and convey CVP and SWP (Project) water consistent with applicable law and contractual obligations." (CVP and SWP operations BA, p.1-1) Changes in operation of the projects to avoid jeopardizing listed species or adversely modifying their critical habitats require that additional sources of water for the projects be obtained, or that water delivery be made in a different way than in the past (*e.g.*, elimination of RBDD), or that amounts of water that are withdrawn and exported from the Delta during some periods in some years be reduced. These operational changes do not, however, preclude operation of the Projects.

Second, the RPA may be implemented consistent with the scope of the federal agency's legal authority and jurisdiction. The Rivers and Harbors Act of 1937, which established the purposes of the CVP, provided that the dams and reservoirs of the CVP "'shall be used, first, for river regulation, improvement of navigation and flood control; second, for irrigation and domestic uses; and, third, for power.'" (CVP and SWP operations BA, p. 1-2). The CVP was reauthorized in 1992 through the CVPIA, which modified the 1937 Act and added mitigation, protection, and restoration of fish and wildlife as project purposes. The CVPIA provided that the dams and reservoirs of the CVP should be used "'first, for river regulation, improvement of navigation, and flood control; second, for irrigation and domestic uses and fish and wildlife mitigation, protection and restoration purposes; and, third, for power and fish and wildlife enhancement." (CVP and SWP operations BA p. 1-3) One of the stated purposes of the CVPIA is to address impacts of the CVP on fish and wildlife. CVPIA, Sec. 3406(a). The CVPIA gives Reclamation broad authority to mitigate for the adverse effects of the projects on fish and wildlife, and nothing in the Rivers and Harbors Act of 1937 requires any set amount of water delivery.

In addition to adding protection of fish and wildlife as second tier purposes of the CVP, the CVPIA set a goal of doubling the natural production of anadromous fish in Central Valley rivers and streams on a long-term sustainable basis, by 2002. Sec. 3406(b)(1). This goal has not been met. Instead, as detailed in this Opinion, natural production of anadromous fish has declined precipitously. A 2008 report on the CVPIA anadromous fish program by independent reviewers (Cummins *et al*. 2008), recommended by the Office of Management and Budget and requested by Reclamation and the USFWS, stated that

> "it is far from clear that the agencies have done what is possible and necessary to improve freshwater conditions to help these species weather environmental variability, halt their decline and begin rebuilding in a sustainable way. A number of the most serious impediments to survival and recovery are not being effectively addressed, especially in terms of the overall design and operation of the [CVP] system."

One of the review panel's specific recommendations was that the agencies

> "should develop a more expansive view of the authorities at their disposal to address the problems, especially with regard to water management and project operations. The agencies have followed a more restrictive view of their authorities than appears legally necessary or appropriate to the seriousness of the mission. "

The report notes that the CVPIA contains a "long list of operational changes, actions, tools, and authorities – some quite specific and discrete, some general and on-going – that Interior is to use to help achieve the anadromous fish restoration purposes of the CVPIA . . . ." (Cummins *et al*. 2008 at 5) The report then describes development of a Final Restoration Plan that would utilize these authorities, but concludes that "[t]he agencies implement the CVPIA . . . in a way that bears little resemblance to the integrated, coordinated, holistic vision of the Final Restoration Plan." (Cummins *et al*. 2008 at 9)

Most relevant to this consultation, the review panel observed that

> "[i]t would seem that CVPIA activities and personnel should be central to the OCAP plan, the Section 7 consultation, and the agencies' efforts to satisfy the requirements of the ESA (that is, after all, one of the directives of the CVPIA). The panel received no information or presentations on the involvement of the CVPIA program or personnel in the ESA consultation effort . . . and in the determination of what actions the agencies should be taking to meet the ESA."

(Cummins *et al*. 2008 at 11)

Reclamation and DWR operate their respective projects in close coordination, under a Coordinated Operations Agreement (COA). The COA was authorized by Congress in Public Law 99-546. Consequently, the COA "is the federal nexus for ESA section 7 consultation on operation of the SWP. Because of commitments expressed in the COA and the Congressional mandate to Reclamation to operate the CVP in conjunction with the SWP, the operations of the two projects are linked . . . ." (CVP/SWP operations BA, p. 1-10) DWR stated in a recent letter to Ren Lohoefener, Regional Director of the USFWS, "For purposes of consultations under the . . . ESA, the operations of the SWP and CVP are intentionally and inextricably connected . . . . ESA protection of Delta species under the BO is impossible without the participation and cooperation of the Department." (DWR 2009a). Consequently, DWR asserted its standing to request reinitiation of consultation, regardless of whether Reclamation did so.

Moreover, state law gives DWR authority to provide for needs of fish and wildlife independent of the connection of the two water projects. According to the BA, DWR

> "is required to plan for recreational and fish and wildlife uses of water in connection with State-constructed water projects and can acquire land for such uses (Wat. Code Sec. 233, 345,346, 12582). The Davis-Dolwig Act (Wat. Code Sec. 11900-11925) establishes the policy that preservation of fish and wildlife is part of State costs to be paid by water supply contractors, and recreation and enhancement of fish and wildlife are to be provided by appropriations from the General Fund."

(CVP/SWP operations BA, page 1-4) DWR, like Reclamation, has broad authority to preserve and enhance fish and wildlife.

The Preamble to the ESA consultation regulations states that "a Federal agency's responsibility under section 7(a)(2) permeates the full range of discretionary authority held by that agency," and that the Services can prescribe a RPA "that involves the maximum exercise of Federal agency authority when to do so is necessary, in the opinion of the Service, to avoid jeopardy." 51 Fed. Reg. 19925, 19937 (June 3, 1986). The independent review panel concluded that despite Congressional authorization and direction more than 16 years ago to restore anadromous fish populations in Central Valley rivers and streams, Reclamation continues to take an unduly narrow view of its authorities in carrying out Congress' mandate. The legal foundation of this RPA is a broader view of Reclamation's authorities, one that is consistent with the CVPIA, the ESA, and the independent review panel's recommendations.

JEOPARDY ANALYSIS AND CONCLUSION

The "Rationale for 2011 amendments" sections for those actions to which changes were made explain the reasons for the changes. With no exception, the objectives for each of the actions where changes were made will be met. With the changes in the actions or implementation procedures, the RPA, as a whole, still "can be implemented in a manner consistent with the intended purpose of the action, . . . consistent with the scope of the Federal agency's legal authority and jurisdiction, . . . is economically and technologically feasible, and . . . would avoid the likelihood of jeopardizing the continued existence of listed species or resulting in the destruction or adverse modification of critical habitat" (50 CFR 402.02).

NMFS does not believe the 2011 amendments meet any of the criteria for reinitiation of consultation listed in 50 CFR 402.16. Consequently, NMFS has not advised the action agency to reinitiate consultation. Rather, the amendments have been developed using the collaborative process established in the 2009 Opinion.

LITERATURE CITED

Anderson, J.J., R.T. Kneib, S.A. Luthy, and P.E. Smith. 2010. Report of the 2010 Independent Review Panel (IRP) on the Reasonable and Prudent Alternative (RPA) Actions Affecting the Operations Criteria And Plan (OCAP) for State/Federal Water Operations. Prepared for: Delta Stewardship Council, Delta Science Program. December 9. 39 pages.

Enclosure 3

Date: January 19, 2017

Memorandum to: CVP/SWP Operations Opinion
Administrative Record Number 151422SWR2006SA00268

From: Brycen Swart, Fisheries Biologist Brycen Swart

Subject: Draft 2017 Shasta RPA Amendment Memorandum

Introduction

Since water year 2012, California has experience five consecutive years of below-average rainfall and snowpack. This has resulted in significant adverse effects to juvenile winter-run Chinook salmon populations over the last couple of years. Due to a lack of sufficient inflow and cold water pool in Shasta Reservoir and competing water demands in 2014 and 2015, Sacramento River water temperatures rose to sub-lethal and lethal levels contributing to very low egg-to-fry survival of juvenile winter-run Chinook salmon estimated to pass Red Bluff Diversion Dam (RBDD) in brood years 2014 (5.9%) and 2015 (4.2%), well below the 18-year average of 23.6% survival (Figure 1) (Martin *et al.* 2001; NMFS 2016; Poytress *et al.* 2014, 2015; Poytress 2016). NMFS Southwest Fisheries Science Center (NMFS-SWFSC) found that in 2014 and 2015, temperature dependent mortality alone resulted in a loss of approximately 77% and 85% of the population, respectively (Martin *et al.* 2016).

The 2009 biological and conference opinion on the long-term operation of the Central Valley Project and State Water Project (CVP/SWP operations Opinion, NMFS 2009) highlights the challenging nature of maintaining an adequate cold water pool in critically dry years, extended dry periods, and under future conditions, which will be affected by increased downstream water demands and climate change. In particular, Shasta Division Reasonable and Prudent Alternative (RPA) Action Suite I.2 includes exception procedures to deal with this reality. Despite the Bureau of Reclamation's (Reclamation) best efforts, severe temperature-related effects were not avoided in 2014 and 2015. Based on lessons learned over the last five years, NMFS is adjusting RPA Action Suite I.2 in order to minimize the adverse thermal effects to winter-run Chinook salmon and to meet the objectives of the actions.

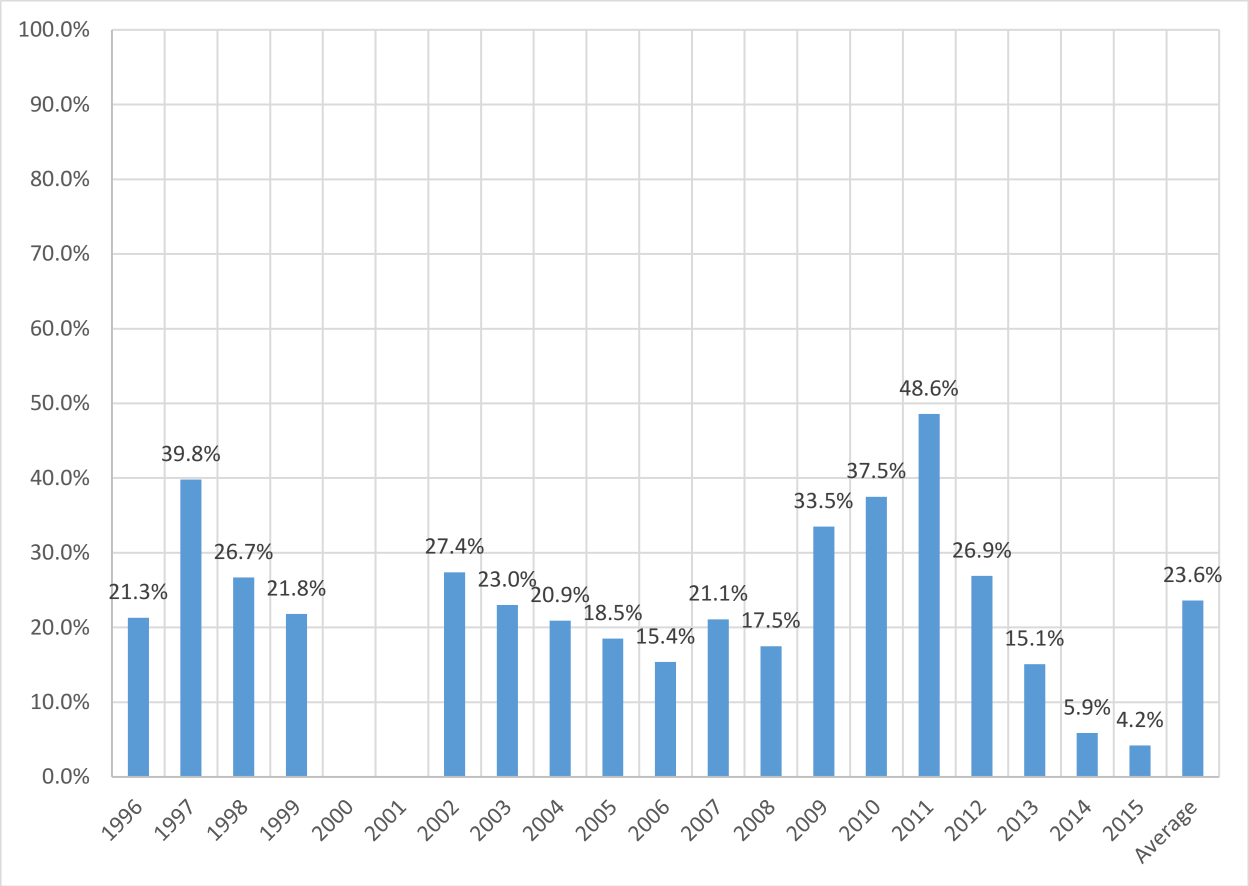


Figure 1. Estimated egg-to-fry survival from passage at Red Bluff Diversion Dam (Martin *et al.* 2001; NMFS 2016; Poytress *et al.* 2014, 2015; Poytress 2016)

Modification of RPA Action I.2.1 Performance measure to Objective-Based Management

The original objective of RPA Action I.2.1 was to establish and operate to a set of performance measures for temperature compliance points and End-of-September (EOS) carryover storage, enabling Reclamation and NMFS to assess the effectiveness of this suite of actions over time. The performance measures were to help ensure that the beneficial variability of the system from changes in hydrology would be measured and maintained. However, over the last five years, NMFS has learned that a 10-year running average is no longer an adequate metric to minimize adverse effects of temperature to the winter-run Chinook population. It does not account for the temperature-related deleterious effects to winter-run in dry and critically dry water years. Instead NMFS proposes to change the performance metrics to annual minimum requirements, as follows.

1. Shasta Reservoir storage requirements

Because of the thermal dynamics associated with seasonally stratification in Shasta Reservoir, storage levels are directly linked to cold water pool volume availability. As such, the management of reservoir storage throughout the year has a direct impact on release temperatures and the subsequent thermal dynamics of the mainstem Sacramento River. Before the Shasta Reservoir temperature control device (TCD) was built, NMFS required that a minimum 1.9 MAF EOS storage level be maintained to protect the cold water pool in Shasta Reservoir, in case the following year was critically dry (drought year insurance). This was because a relationship exists between EOS storage and the cold water pool; the greater the EOS storage level, typically the greater the cold water pool the following year. The requirement for 1.9 MAF EOS was a term and condition in NMFS's winter-run opinion (NMFS 1993). Since 1997, Reclamation has been able to control water temperatures in the upper Sacramento River through use of the TCD. The minimum 1.9 MAF EOS required to be imposed as a non-discretionary term and condition in the 2004 CVP/SWP operations Opinion.

In its 2008 CVP/SWP operations biological assessment, Reclamation proposed continuation of the 90 percent exceedance forecast for determining water allocations early in the year, starting with the February 15 forecast. However, Reclamation did not propose to manage Shasta operations to a 1.9 MAF EOS target, although CALSIM assumed this target in all analyses. Given the increased demands for water by 2030 and less water being diverted from the Trinity River, the 2009 CVP/SWP operations Opinion concluded that it will be increasingly difficult to meet the various temperature compliance points, even with a TCD, especially since Reclamation was not proposing any EOS storage target.

Based on the historical 82-year period, CALSIM II results showed that in about 10 percent of years (typically the driest water years) a 1.9 MAF EOS would not be met. Additional model runs revealed that a higher target of 2.2 MAF EOS improved the probability of meeting Balls Ferry temperature target about 10 percent over the previous 1.9 MAF target. Based on these analyses and those in Anderson (2009), the 10-year running average performance measures associated with meeting EOS carryover storage at Shasta Reservoir in order to maintain the potential to meet the various temperature compliance points as required in RPA I.2.1 were set at:

- 87% of years: Minimum EOS storage of 2.2 million acre-feet (MAF)
- 82% of years: Minimum EOS storage of 2.2 MAF and End of April (EOA) storage of 3.8 MAF in following year (to maintain potential to meet Balls Ferry compliance point)
- 40% of years: Minimum EOS storage of 3.2 MAF (to maintain potential to meet Jelly's Ferry compliance point in following year)

However, the current 8-year average also falls short of RPA Action I.2.1 Shasta storage performance metric. Since 2009, 1.9 MAF EOS, let alone 2.2 MAF, has not been met in 4 out of 8 years (*i.e.* 50% of years) (Table 1):

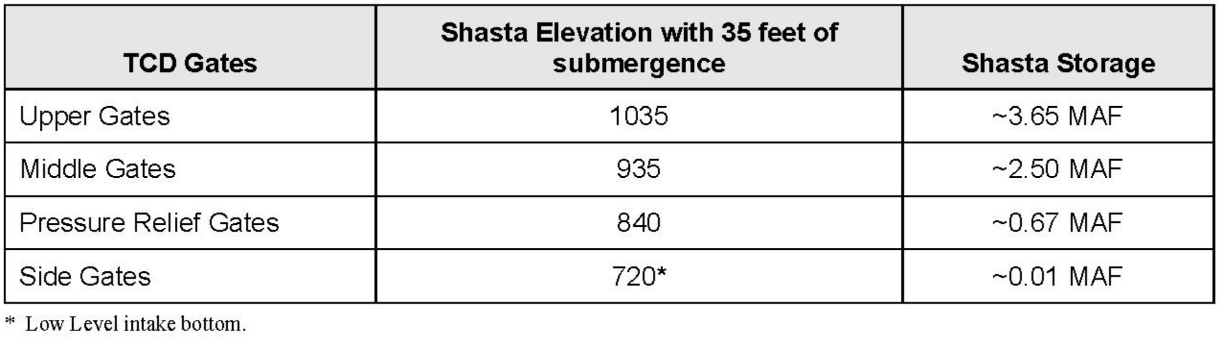
Table 1. End of April and End of September storages by water year from 2009 – 2016. Data source: Reclamation 2016.

Water Year	End of April Storage (MAF)	End of September Storage (MAF)	Water Year Type
2009	3.00	1.77	D
2010	4.39	3.32	BN
2011	4.27	3.34	W
2012	4.44	2.59	BN
2013	3.79	1.91	D
2014	2.41	1.16	C
2015	2.66	1.60	C
2016	4.23	2.81	BN

- 50% (4 out of 8) of Years: Minimum 2.2 MAF EOS storage
- 43% (3 out of 7) of Years: Minimum 2.2 MAF EOS storage and 3.8 MAF EOA storage
- 25% (2 out of 8) of Years: Minimum 3.2 MAF EOS storage

In addition to an EOS storage metric to determine whether the temperature compliance can be met for the following temperature management season, it has become clear from Shasta operations in the drought years that an end of April storage requirement is also a critical metric towards meeting temperature compliance throughout the temperature management season. A minimum of 3.65 MAF in Shasta storage enables use of the TCD upper gates which allows for the blending of warmer upper reservoir levels and less reliance on the cold water pool (Table 2). A primary issue in 2014 and 2015 was that Shasta storage was so low that the upper gates were not available, lending to the release of colder water than necessary from the middle gate and this colder water being released earlier than needed.

Table 2. Shasta Temperature Control Device Gates with Elevation and Storage (Reclamation 2008)



TCD Gates	Shasta Elevation with 35 feet of submergence	Shasta Storage
Upper Gates	1035	~3.65 MAF
Middle Gates	935	~2.50 MAF
Pressure Relief Gates	840	~0.67 MAF
Side Gates	720*	~0.01 MAF

* Low Level intake bottom.

According to analysis done by Reclamation using data from 1998 through 2015, a minimum EOA storage of 3.5 MAF is needed in order to meet a daily average temperature (DAT) of less than 56°F at CCR[1], 3.9 MAF is needed in order to meet a DAT of 53°F at CCR[2], and 4.2 MAF is needed in order to meet a DAT of less than 53°F at CCR (Figure 2).

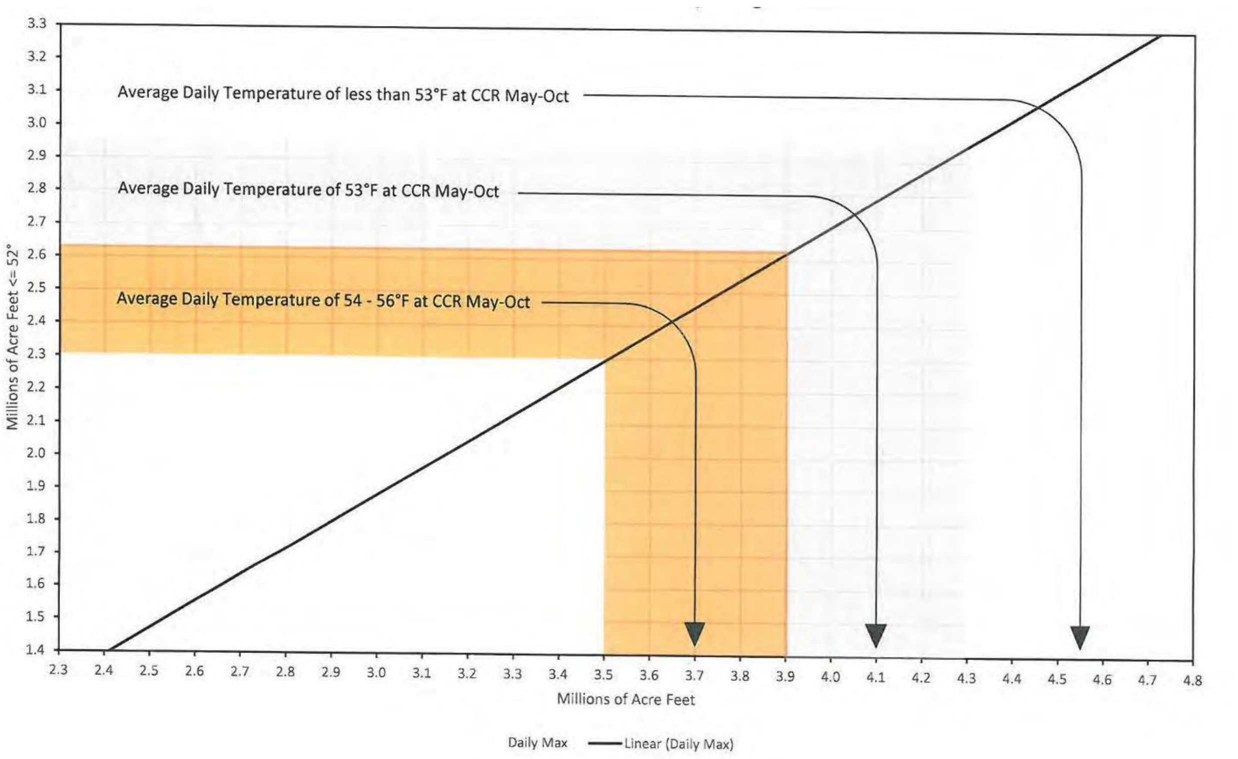


Figure 2. End of April Total Shasta Reservoir storage versus 52°F or less storage (*i.e.* cold water pool) with CCR Average Daily Temperature for May through October. Graph submitted to NMFS from Reclamation on October 27, 2016.

A review of the historical data from Anderson (2009) from 1955 to 2008 shows that minimum EOS storage in a series of critically dry and dry water years must be 1.9 MAF, in order to meet 3.3 MAF in EOA in the following year (3.3 MAF in EOA will meet a 56°F DAT at CCR). While a minimum EOS of 2.2 MAF must be achieved in order to meet 3.8 MAF in EOA that following year (3.8 MAF in EOA will meet 56°F DAT at Balls Ferry). Anderson (2009) did not recommend an EOS to meet 4.2 EOA that following year (4.2 MAF in EOA will meet 56°F DAT at Jellys Ferry).

Instead of using a 10-year running average, annual minimum EOA and EOS Shasta storage requirements based on water year type would be a better metric to provide suitable instream conditions for winter-run Chinook below Keswick Dam, especially in dry and critically dry water years. Table 3 shows the average EOA and EOS storages with corresponding CCR DAT temperatures and temperature dependent mortality (discussed further below in subsection 4) by water year type for water years 1996-2016[3].

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[1] Sacramento River above Clear Creek (CCR) (river mile 292) California Data Exchange Center gauge station

[2] In water year 2016 it was decided that 53°F daily average temperature at CCR was a surrogate for 55°F 7-day average of the daily maxima (7DADM). See section below for changes to the temperature compliance metric.

[3] 1996 is the earliest publicly available Sacramento River temperature data on Reclamation's Central Valley Operations website and it is also the year when the TCD became operational.

Table 3. End of April storage, end of September storage, CCR daily average temperature for May through October, and modeled temperature dependent mortality (from Martin *et al.* 2016) by water year type for water years 1996 to 2016.

Water Year	End of April Storage (MAF)	End of September Storage (MAF)	CCR Daily Average Temperature (May - Oct)	Modeled Temperature Dependent Mortality	Modeled Total ETF Survival	Actual ETF Survival
Critical						
2008	2.95	1.38	54.6	40.9%	18.9%	17.5%
2014	2.41	1.16	56.9	77.0%	7.1%	5.9%
2015	2.66	1.60	56.7	85.4%	4.6%	4.2%
Average	*2.68*	*1.38*	*56.1*	*67.8%*	*10.2%*	*9.2%*
Dry						
2001	4.02	2.20	53.0			
2002	4.30	2.56	52.6	1.4%	23.7%	27.4%
2007	3.90	1.88	53.3	7.0%	29.6%	21.1%
2009	3.00	1.77	54.1	18.9%	24.0%	33.5%
2013	3.79	1.91	54.0	9.6%	25.3%	15.1%
Average	*3.80*	*2.06*	*53.4*	*9.2%*	*25.6%*	*24.3%*
Below Normal						
2004	4.06	2.18	53.5	37.7%	17.9%	20.9%
2010	4.39	3.32	52.2	0.0%	33.1%	37.5%
2012	4.44	2.59	52.4	0.0%	31.9%	26.9%
2016	4.23	2.81	53.0	2.3%		
Average	*4.28*	*2.73*	*52.8*	*10.0%*	*27.6%*	*28.4%*
Above Normal						
2000	4.15	2.99	52.7			
2003	4.54	3.16	52.6	1.4%	24.6%	23.0%
2005	4.21	3.04	53.2	4.8%	17.2%	18.5%
Average	*4.30*	*3.06*	*52.8*	*3.1%*	*20.9%*	*20.8%*
Wet						
1996	4.31	3.10		7.4%	31.1%	21.3%
1997	3.94	2.31		10.5%	28.6%	39.8%
1998	4.06	3.44	52.2	2.7%	24.9%	26.7%
1999	4.26	3.33	51.6	1.2%	31.2%	21.8%
2006	4.06	3.21	51.7	0.3%	18.4%	15.4%
2011	4.27	3.34	52.1	0.0%	33.9%	48.6%
Average	*4.15*	*3.12*	*51.9*	*3.7%*	*28.0%*	*28.9%*

Based on the above information, NMFS recommends a minimum 4.2 MAF EOA storage every year in order to meet temperature management of less than 53°F at CCR in order to minimize the adverse effects to spawning, egg incubation, and fry emergence from temperature related impacts. In recognition that this minimum EOA storage will not occur every year, especially in dry and critically dry water years, NMFS developed the following annual requirements based on water year type:

- Critically dry: 3.5 MAF
- Dry: 3.9 MAF
- Below Normal: 4.2 MAF
- Above Normal: 4.2 MAF
- Wet: 4.2 MAF

In order to ensure a minimum EOS storage level be maintained to protect the cold water pool in Shasta Reservoir for the following year, NMFS developed the following annual requirements based on water year type:

- Critically dry: 1.9 MAF
- Dry: 2.2 MAF
- Below Normal: 2.8 MAF
- Above Normal: 3.2 MAF
- Wet: 3.2 MAF

2. Temperature Compliance Location Criterion

Not only does RPA Action I.2.1 require a 10-year running average performance metric for storage, but also for temperature compliance location. The 10-year running average performance measure for temperature compliance during the summer temperature management season (May 15 to October 31) in RPA Action I.2.1 is required to be:

- Meet Clear Creek compliance point 95% of time
- Meet Balls Ferry compliance point 85% of time
- Meet Jelly's Ferry compliance point 40% of time
- Meet Bend Bridge compliance point 15% of time

Based on daily average temperature data of not in excess of 56°F, since issuance of the CVP/SWP operations Opinion, Reclamation has failed to meet the summer temperature compliance point performance measure. So far the 7-year average (2010-2016) is (Table 4):

- Clear Creek was met 80% of the time
- Balls Ferry was met 67% of the time
- Jellys Ferry was met 51% of the time
- Bend Bridge was met 37% of the time

Table 4. Percentage of days each year in compliance with 56°F daily average temperature compliance location metric from May 15 – October 30, 2010 – 2016. Data source: Reclamation 2016.

Water Year	Clear Creek	Balls Ferry	Jellys Ferry	Bend Bridge
2010	100%	99%	86%	57%
2011	100%	99%	91%	58%
2012	100%	100%	92%	75%
2013	100%	77%	34%	26%
2014	44%	2%	0%	0%
2015	14%	1%	0%	0%
2016	100%	90%	52%	41%
Average	**80%**	**67%**	**51%**	**37%**

Not meeting the Clear Creek temperature compliance location in 2014 and 2015 had substantial adverse impacts to those juvenile winter-run cohorts. Based on the changes to RPA Action I.2.4, described further in this administrative memorandum, the temperature compliance metric to 55°F 7-day average of the daily maxima (7DADM) or equivalent, to the most downstream redd location must be met every year. Even in WY 2011, which was a wet water year type and there was high storage in Shasta Reservoir, the Bend Bridge temperature compliance point could not be met for the entire season. Meeting daily average temperature compliance locations as far downstream as Balls Ferry, Jellys Ferry, and Bend Bridge in water year types based on cold water supply in Shasta Reservoir is no longer appropriate, which is why NMFS is eliminating this performance measure (Anderson *et al.* 2010, 2011, 2013, 2014 and 2015; Deas *et al.* 2008).

3. Objective Based Management

The following conceptual objectives in Table 5 were adapted from the multi-year drought sequence experienced in Victoria, Australia, and applied to the Shasta RPA (Mount *et al.* 2016). Environmental water managers in Victoria use a seasonally adaptive approach that sets different environmental water objectives depending on hydrologic conditions. A change in objective in turn causes changes in the volume, location, and timing of water allocated to environmental uses. Water managers conduct extensive scenario testing to evaluate the consequences of these choices. In addition, environmental water managers have the flexibility to adjust operations depending upon unanticipated meteorological conditions, such as rainfall events and heat waves. Since these adjustments are scenario-tested in advance, this process creates greater certainty for all water users. NMFS intends for Reclamation adopt a similar approach towards their CVP operations in the Sacramento River.

Table 5. Shasta RPA objectives under different water year types.

	Critically Dry	Dry	Below Normal	Above Normal & Wet
Objectives	PROTECT - Avoid critical loss of population - Avoid catastrophic changes to habitat	MAINTAIN - Maintain river function with reduced reproductive capacity - Manage within dry-spell tolerance	RECOVER - Improve ecological health and resilience - Improve recruitment opportunities	ENHANCE - Maximize species recruitment opportunities - Restore key floodplain linkages - Restore key ecological flows
Priorities	- Undertake emergency flows to avoid catastrophic changes - Carry-over water for critical environments in the following year	- Provide priority flow components - Carry-over water for critical environmental components in the following year	- Provide all in-bank flow components - Provide out-of-bank flows if reach dry-spell tolerance - Carry-over water for large watering events	- Provide all ecological functioning flow components

4. Biological metric - temperature dependent mortality

The 2008 CALFED Science Program and Long-term Operation Biological Opinion (LOBO) annual review independent review panel recommended linking the RPA action physical metrics (*i.e.*, flows and temperature) to biological responses of the listed species (Anderson *et al.* 2010, 2011, 2013, 2014 and 2015; Deas *et al.* 2008). Newly developed by the NMFS-SWFSC (Martin *et al.* 2016) for Shasta Operations in water year 2016 was a semi-mechanistic/statistical model of temperature-dependent survival of winter-run Chinook in the Sacramento River. The modeling approach uses information on the timing and distribution of redd locations taken from aerial surveys from 1996-2015. For each known redd, a temperature exposure profile that redd would have experienced from fertilization to emergence is extracted using the River Assessment for Forecasting Temperatures (RAFT) model, a spatially explicitly hydraulic model of the Sacramento River (Pike *et al*. 2013). For each known redd, the temperature-dependent mortality model is run, with daily time steps, to calculate the probability of survival from fertilization to emergence. Predicted temperature-dependent mortality is calculated within a year by aggregating the survival of all redds within a year, and comparing the predicted mortality in a year to estimated yearly survival from egg-to-fry (ETF) by the US Fish and Wildlife Service from 1996-2015. Finally the parameters of the daily temperature-dependent mortality model are estimated by minimizing the deviations between predicted and observed survival across years. Based on laboratory data, field data, and a least squares estimate, the temperature below which there is no mortality due to temperature (or T_{crit} value) was found to be 53.7°F. As explained in further detail in changes to RPA Action I.2.4, this is a much lower temperature than the 56°F DAT that has been the focus for winter-run Chinook salmon temperature management as required by State

Water Resources Control Board Orders 90-5 and 91-1 and the 2009 CVP/SWP operations Opinion.

Over the last 20 years temperature dependent mortality has fluctuated wildly from 85% in 2015, a critically dry water year and low end of April storage, to 0% in 2010 through 2012, below normal and wet water year types with high end of April storages (Table 3). Although a small sample size, based off these data the average temperature dependent mortality by water year type is:

- 68% in critically dry years
- 9% in dry years
- 10% in below normal years
- 3% in above normal years
- 4% in wet years

Another way to look at temperature dependent mortality and quality of habitat is through the RAFT survival landscape for 1998 to 2015 (Figures 3 to 5). The RAFT survival landscape figures provide the spatiotemporal resolution used to estimate the exposure of the full distribution of redds for that year. Those exposures are applied to the temperature dependent mortality model to develop annual temperature-dependent mortality statistics.

In an effort to improve upon the historical temperature dependent mortality, especially in critically dry but also in all water year types NMFS came up with the following temperature-dependent mortality metrics for forecasting, temperature planning, and impelmentation[4]:

- Critically dry: <30% mortality
- Dry: <8% mortality
- Below Normal: <3% mortality
- Above Normal: <3% mortality
- Wet: <3% mortality

In addition, the NMFS-SWFSC is developing bioenergetics models that characterize effects of temperature on growth and survival across multiple life stages of winter-run Chinook salmon. Once finalized, this information will be incorporated into Sacramento River temperature management to better understand the effects to juvenile winter-run Chinook salmon survival.

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[4] These temperature dependent mortality numbers are preliminary and subject to further analysis to understand whether the population can withstand this level of mortality and still be viable.

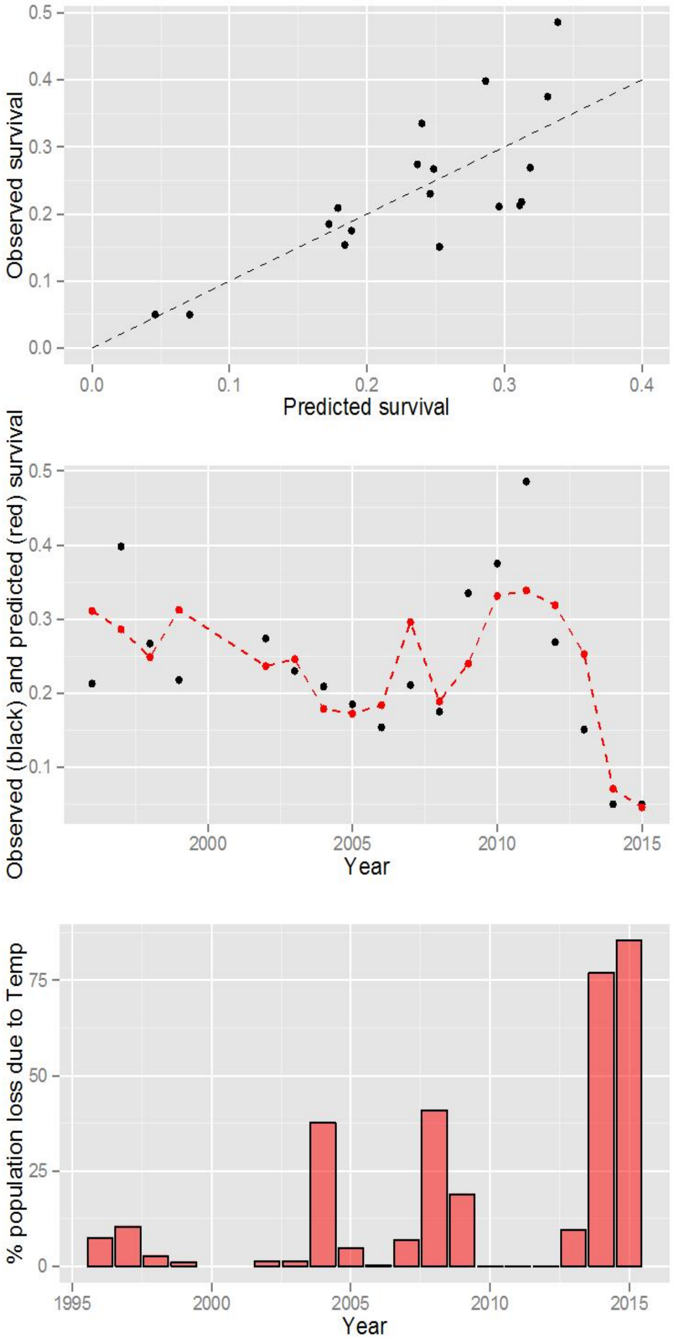
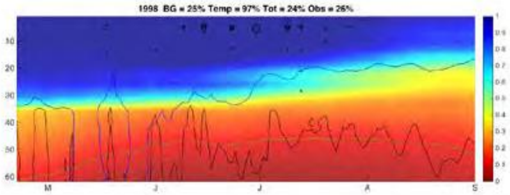


Figure 3. Martin *et al.* (2016) juvenile winter-run Chinook salmon model results include linear regression of predicted survival compared to observed survival (top), predicted survival compared to observed survival over time (middle), and percentage of temperature dependent mortality over time (bottom).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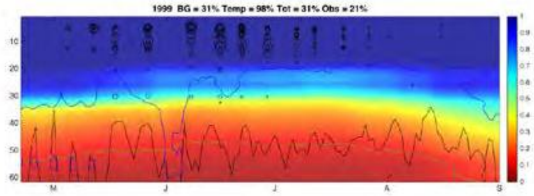
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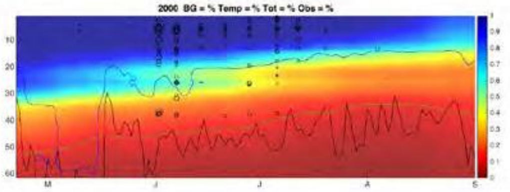
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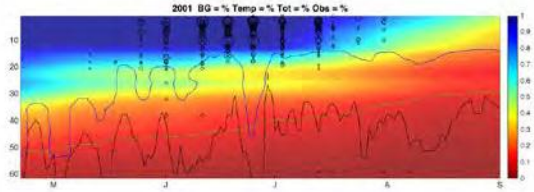
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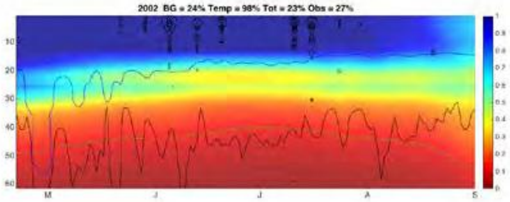
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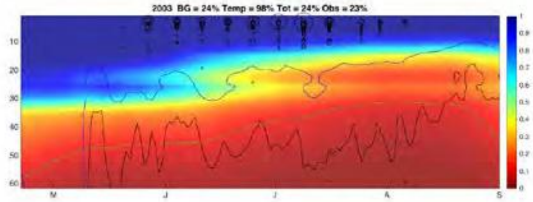
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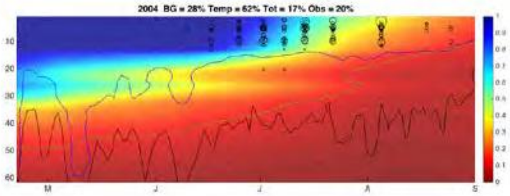
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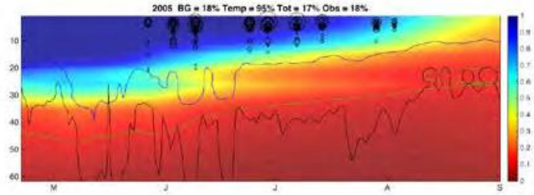
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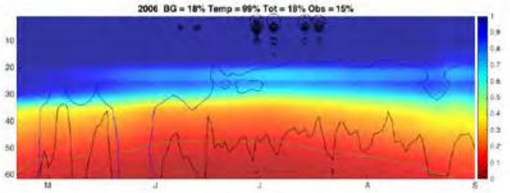
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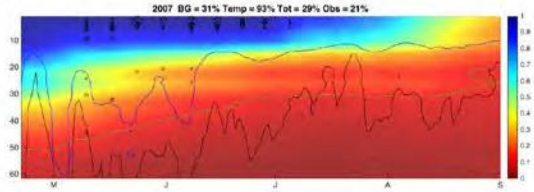
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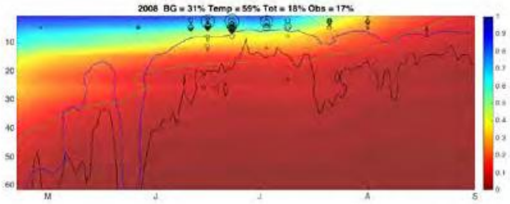
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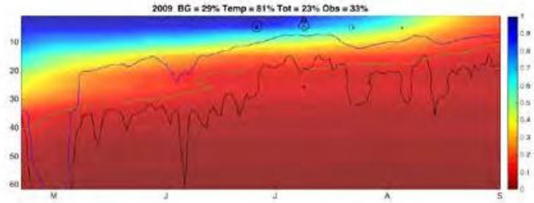
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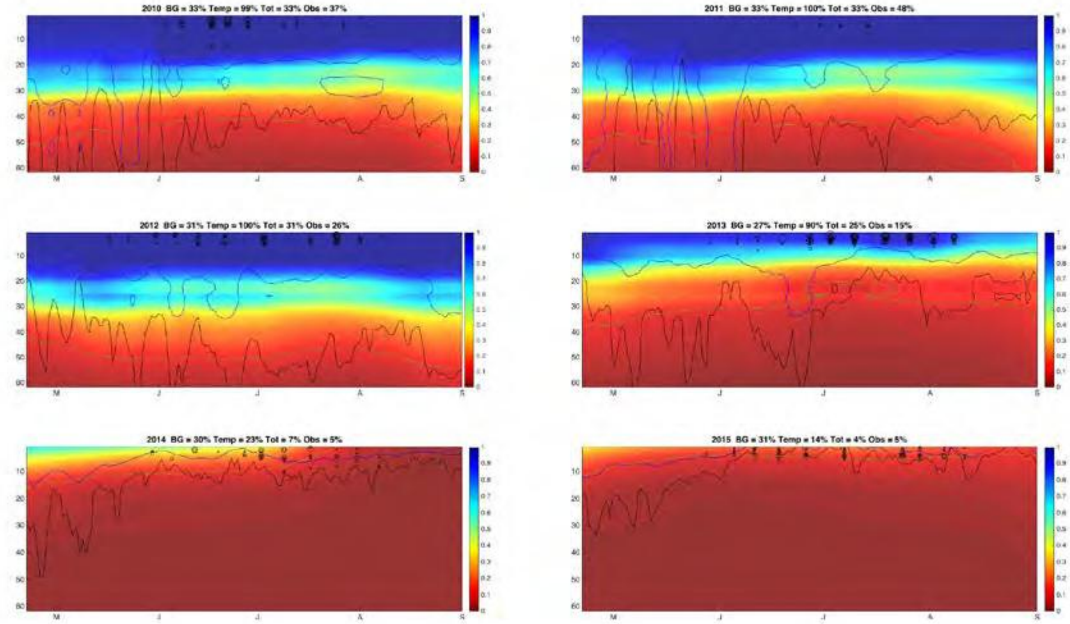

Figure 4. RAFT Sacramento River survival landscape profiles. The Y axis is the distance downstream of Keswick in miles. The X axis is time in months. The black circles represent spawning locations based on aerial redd surveys. The size of the circle indicates number of redds in that location. The colors represents cumulative temeperature based survival throughout each redd's egg incubation period, with redd indicating low survival and blue indicating high surival.

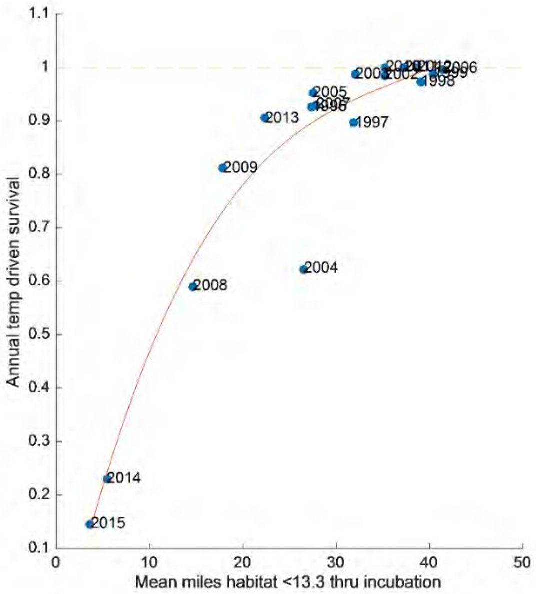

Figure 5. Average miles of habitat < 56°F (13.3°C) correlated with annual temperature dependent survival by year. Data source: NMFS RAFT model 2016.

RPA Action I.2.3 February Forecast; March – May 14 Keswick Release Schedule (Spring Actions)

5. Change to Meteorological and Hydrological Forecasting

Reclamation has a coupled river/reservoir model, the Sacramento River Water Quality Model (SRWQM), that they use to target a temperature at a compliance location along the Sacramento River based on: (1) their most recent Shasta Reservoir profile; (2) a set of operating conditions (made up of TCD gate configurations and Keswick release flows); (3) and a medium range weather forecast. From these set of inputs they generate scenarios of discharge flows from Keswick and temperatures at various points along the Sacramento River for the entire summer and fall salmon temperature management season.

Drought conditions over the last five years have highlighted the uncertainties in Reclamation's SRWQM and its inability to meet the regulatory requirements outlined in the CVP/SWP operations Opinion. Their seasonal forecasts only use the discharge temperature and flow at Keswick predicted by the SRWQM, but to get those values correct for the entire season for all of the scenarios, Reclamation needs to have all of the environmental input variables accurate: the reservoir inflows, weather, operations (gate changes, *etc*.), and reservoir dynamics over a 6-month period. In addition, the SRWQM has a difficult time reflecting actual release temperature and conditions when the critical reservoir thermocline of about 52ºF approaches the elevation of the TCD side gates and/or reservoir outlet works. Given the significant simplification of the input data (which is derived from a 12-month operations outlook), the unknowns regarding future meteorological conditions, and the fact that the actual TCD does not have infinite adjustability, the model can only realistically provide a broad brush picture of future operations and cannot provide sufficient precision to determine future operations. Furthermore, the model was not developed to manage water temperatures on a fine scale, rather it was developed to determine in general where water temperature could be managed down based on a broad set of assumptions.

Due to these limitations and uncertainty, Reclamation has historically overestimated their ability to meet the temperature compliance point (TCP) (Figure 6). Over the past 10 years, the, 56ºF DAT at a TCP specified at the beginning of the season was exceeded ~33% of the time (11% in May, 20% in June, 29% in July, 41% in Aug, 54% in Sept, and 44% in Oct). The TCPs can change over the course of a season, which does minimize the frequency and magnitude of exceeding the 56°F DAT, but Reclamation exceeds the 56°F DAT at any TCP a significant amount of the time, and often by a significant temperature differential (Figure 7). The higher that differential, the higher the likelihood of egg mortality.

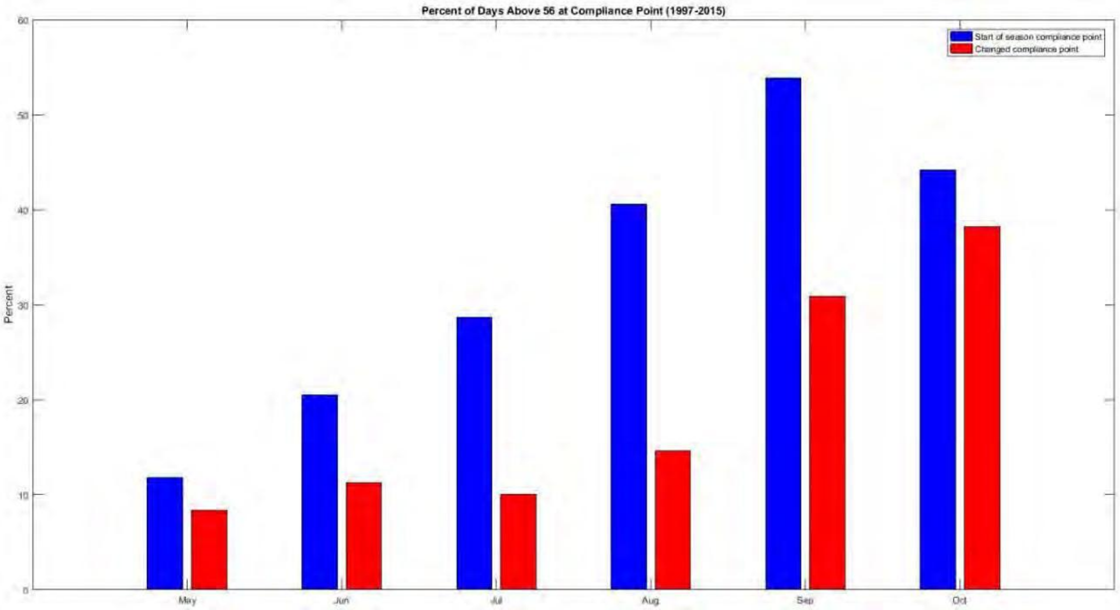

Figure 6. Percent of days above 56^{o}F DAT at temperature compliance point by month (1997-2015). Blue bars indicate start of the season compliance location. Red bars indicate a changed temperature compliance location. Data source: Reclamation 2016.

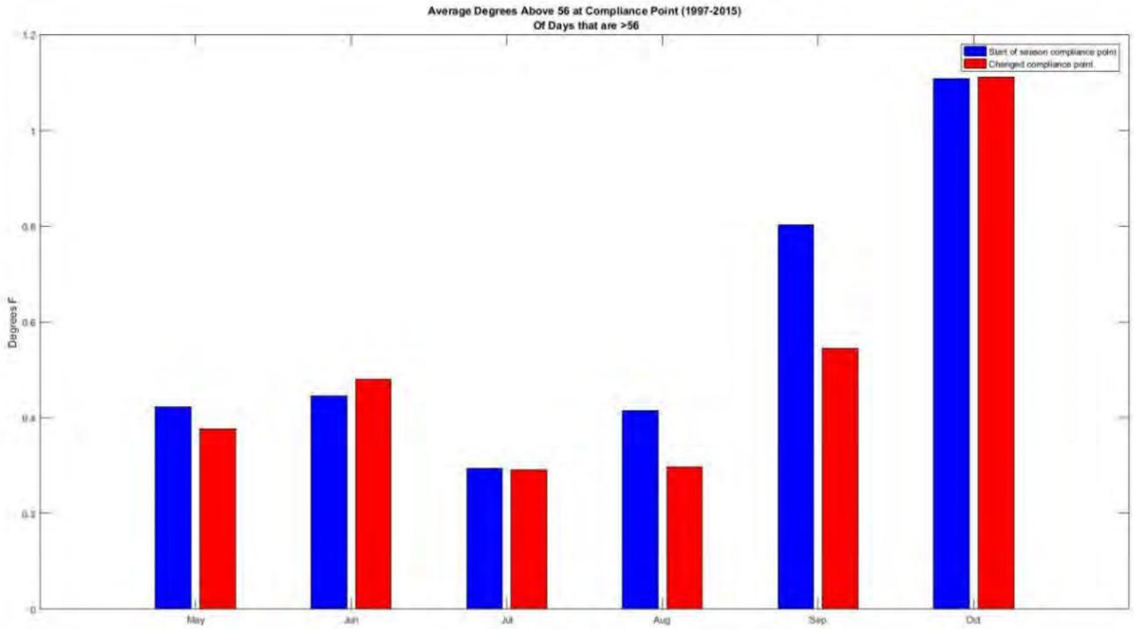

Figure 7. Average degrees (^{o}F) above 56^{o}F DAT at temperature compliance point by month (1997-2015). Blue bars indicate start of the season compliance location. Red bars indicate a changed temperature compliance location. Data source: Reclamation 2016.

Some model improvements have been made over time using lessons learned from previous years. For example, in 2014, the upper 5 to 6 miles of the Sacramento River read 0.6^{o}F warmer than the model, so in 2015 Reclamation adjusted the model 0.6^{o}F for better accuracy when they ran simulations for temperature compliance locations at or upstream of CCR. Additionally, due to the higher ambient air temperature in the past few years, in 2015, Reclamation began using more conservative (*i.e.*, warmer) meteorological forecasts from the local 3-month temperature outlook (L3MTO) rather than continuing to use average temperature as an input to the Sacramento River water temperature profile.

Given the poor performance and uncertainties associated with Reclamation's model and the extreme importance to manage for higher juvenile winter-run survival during the temperature management season in 2016, NMFS proposes some buffers to help address the unavoidable uncertainty in temperature model and potential adjustments to the Sacramento River temperature criteria: (1) use the more conservative (*i.e.*, warmer) L3MTO meteorological forecast inputs of 10% and 25% in addition to the standard 50%; (2) use 75% and 99% hydrological forecasts, in addition to the 50% and 90%; and (3) apply a Shasta Reservoir temperature profile stratification scenario from the historical record that shows a steep cold water decline in the spring (*e.g.*, what happened in 2015).

6. Limiting Keswick Releases

In 2014, 2015, and 2016, limiting Keswick releases in June and July was an important and effective strategy to stretch the cold water temperature management season through September and October (Table 6). Table 7 shows the differences in monthly Keswick discharge by water year type over the last 21 years. In critically dry years, Keswick discharges were significantly lower than other water year types.

Table 6. Keswick Dam average monthly releases April to October, 1996-2016. Data source: Reclamation 2016.

Year	WY	Keswick Monthly Mean Discharge (cfs)						
	Type	Apr	May	Jun	Jul	Aug	Sep	Oct
1996	W	5,453	10,590	13,950	14,470	14,330	9,748	5,468
1997	W	5,816	9,122	13,330	14,870	11,140	8,110	5,663
1998	W	11,660	14,770	15,590	14,840	14,700	11,110	4,671
1999	W	8,136	10,510	11,720	13,330	10,400	7,987	6,745
2000	AN	7,841	10,930	12,790	15,070	11,580	7,493	6,298
2001	D	6,308	9,820	13,650	14,900	11,160	8,588	6,043
2002	D	5,488	9,476	12,960	14,600	11,030	7,837	6,048
2003	AN	7,720	16,380	13,030	13,980	10,470	7,847	7,137
2004	BN	8,550	9,970	14,580	15,550	11,130	8,748	6,873
2005	AN	4,087	14,660	12,100	14,200	10,640	8,702	7,249
2006	W	29,270	12,600	14,250	14,580	13,300	9,501	7,749
2007	D	7,799	9,869	12,340	14,720	11,600	8,602	6,160
2008	C	6,823	9,405	11,720	12,750	10,470	7,534	6,488
2009	D	6,249	8,724	10,530	12,560	10,920	7,395	7,102
2010	BN	4,693	8,942	11,970	12,540	10,340	7,542	6,170
2011	W	12,730	8,606	12,540	12,630	11,950	10,020	6,176
2012	BN	4,220	9,142	12,150	14,980	12,560	7,861	7,876
2013	D	7,212	11,980	13,980	14,770	10,840	7,409	6,208
2014	C	3,576	7,496	9,726	9,908	8,364	5,974	6,781
2015	C	4,361	7,578	7,337	7,304	7,210	7,074	5,038
2016	BN	5,049	6,353	8,473	10,340	10,560	8,893	6,361
Average		7,760	10,300	12,300	13,500	11,200	8,280	6,400

Table 7. Keswick Dam monthly flows by water year type 1996 – 2016. Data source: Reclamation 2016.

Year	End of April Storage (MAF)	End of September Storage (MAF)	Keswick Monthly Mean Discharge (cfs)						
			Apr	May	Jun	Jul	Aug	Sep	Oct
Critical									
2008	2.95	1.38	6823	9405	11720	12750	10470	7534	6488
2014	2.41	1.16	3576	7496	9726	9908	8364	5974	6781
2015	2.66	1.60	4361	7578	7337	7304	7210	7074	5038
Average	*2.68*	*1.38*	*4920*	*8160*	*9594*	*9987*	*8681*	*6861*	*6102*
Dry									
2001	4.02	2.20	6308	9820	13650	14900	11160	8588	6043
2002	4.30	2.56	5488	9476	12960	14600	11030	7837	6048
2007	3.90	1.88	7799	9869	12340	14720	11600	8602	6160
2009	3.00	1.77	6249	8724	10530	12560	10920	7395	7102
2013	3.79	1.91	7212	11980	13980	14770	10840	7409	6208
Average	*3.80*	*2.06*	*6611*	*9974*	*12692*	*14310*	*11110*	*7966*	*6312*
Below Normal									
2004	4.06	2.18	8550	9970	14580	15550	11130	8748	6873
2010	4.39	3.32	4693	8942	11970	12540	10340	7542	6170
2012	4.44	2.59	4220	9142	12150	14980	12560	7861	7876
2016	4.23	2.81	5049	6353	8473	10340	10560	8893	6361
Average	*4.28*	*2.73*	*5628*	*8602*	*11793*	*13353*	*11148*	*8261*	*6820*
Above Normal									
2000	4.15	2.99	7841	10930	12790	15070	11580	7493	6298
2003	4.54	3.16	7720	16380	13030	13980	10470	7847	7137
2005	4.21	3.04	4087	14660	12100	14200	10640	8702	7249
Average	*4.30*	*3.06*	*6549*	*13990*	*12640*	*14417*	*10897*	*8014*	*6895*
Wet									
1996	4.31	3.10	5453	10590	13950	14470	14330	9748	5468
1997	3.94	2.31	5816	9122	13330	14870	11140	8110	5663
1998	4.06	3.44	11660	14770	15590	14840	14700	11110	4671
1999	4.26	3.33	8136	10510	11720	13330	10400	7987	6745
2006	4.06	3.21	29270	12600	14250	14580	13300	9501	7749
2011	4.27	3.34	12730	8606	12540	12630	11950	10020	6176
Average	*4.15*	*3.12*	*12178*	*11033*	*13563*	*14120*	*12637*	*9413*	*6079*

Ambient air temperature and volume of Keswick releases may play a more significant role in trying to meet downstream temperature compliance locations at Balls Ferry, Jellys Ferry, and

Bend Bridge. However water temperatures at upstream redd locations (CCR and upstream) are not strongly correlated with flow but are strongly correlated with Keswick release temperatures (i.e., water quality, not water quantity). Based on RAFT model runs using a constant flow and temperature at Keswick, under average meteorological conditions, the NMFS-SWFSC generated contour plots of the 55°F 7DADM at CCR in relation to the flow and temperature at Keswick for each month (*i.e.*, the release temperatures at Keswick that would be needed to meet 7DADM at CCR for each month) (Figure 8). In general, there is about a one degree difference in Keswick release temperature between 5,000 and 7,500 cfs in order to meet 55°F 7DADM at CCR, but above that, small increases in flow (*e.g.*, 500 cfs) do not make much of a difference in the Keswick release temperature in order to meet 55°F 7DADM at CCR. Figure 9 shows that based on historical data, a mean daily Keswick discharge of 7,500 cfs to 15,000 cfs at approximately 52°F will be able to meet a 53°F DAT at CCR. The figure is just for August but the data shows similar results for the other temperature management season months (May, June, July, September, and October).

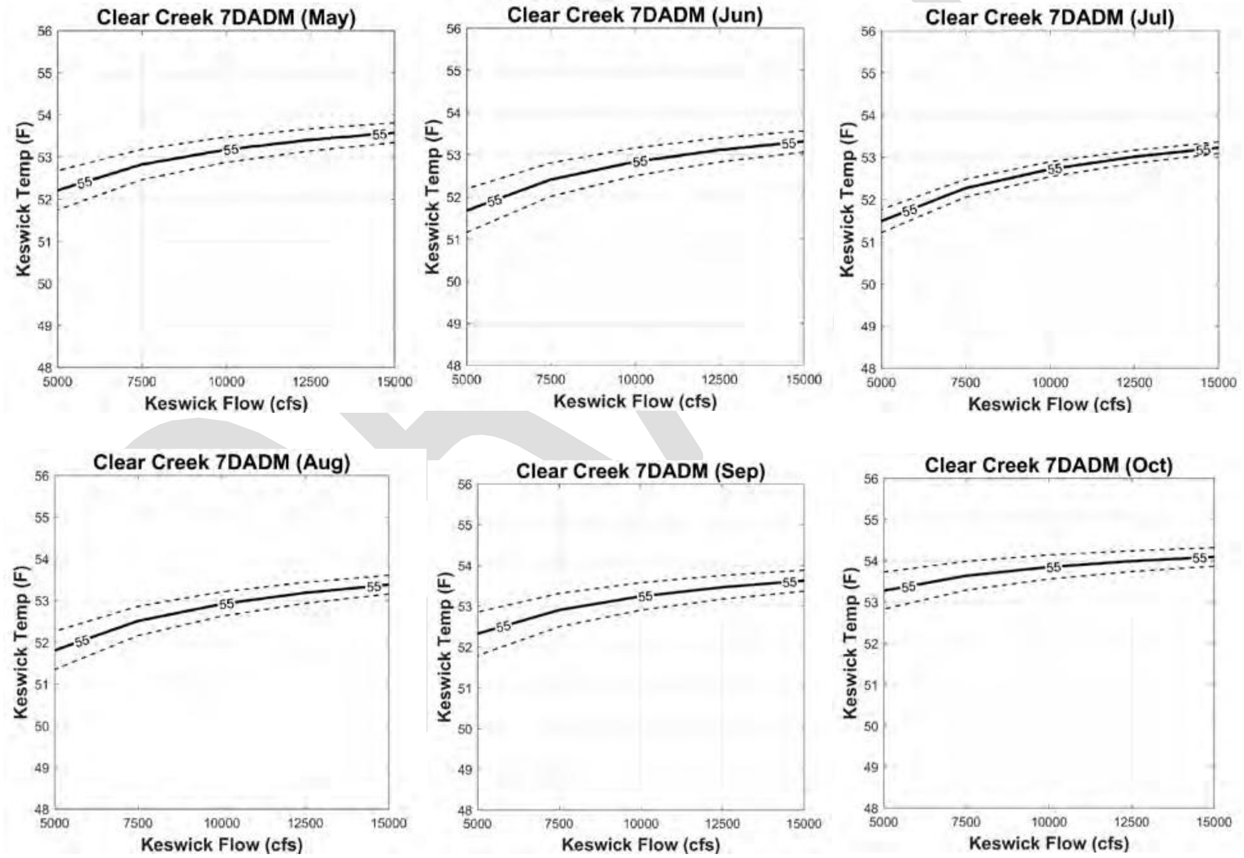

Figure 8. 55°F 7DADM at Clear Creek (CCR) in relation to the flow and temperature at Keswick by month. Dotted lines are 95% contour intervals. Data source: NMFS RAFT model 2016.

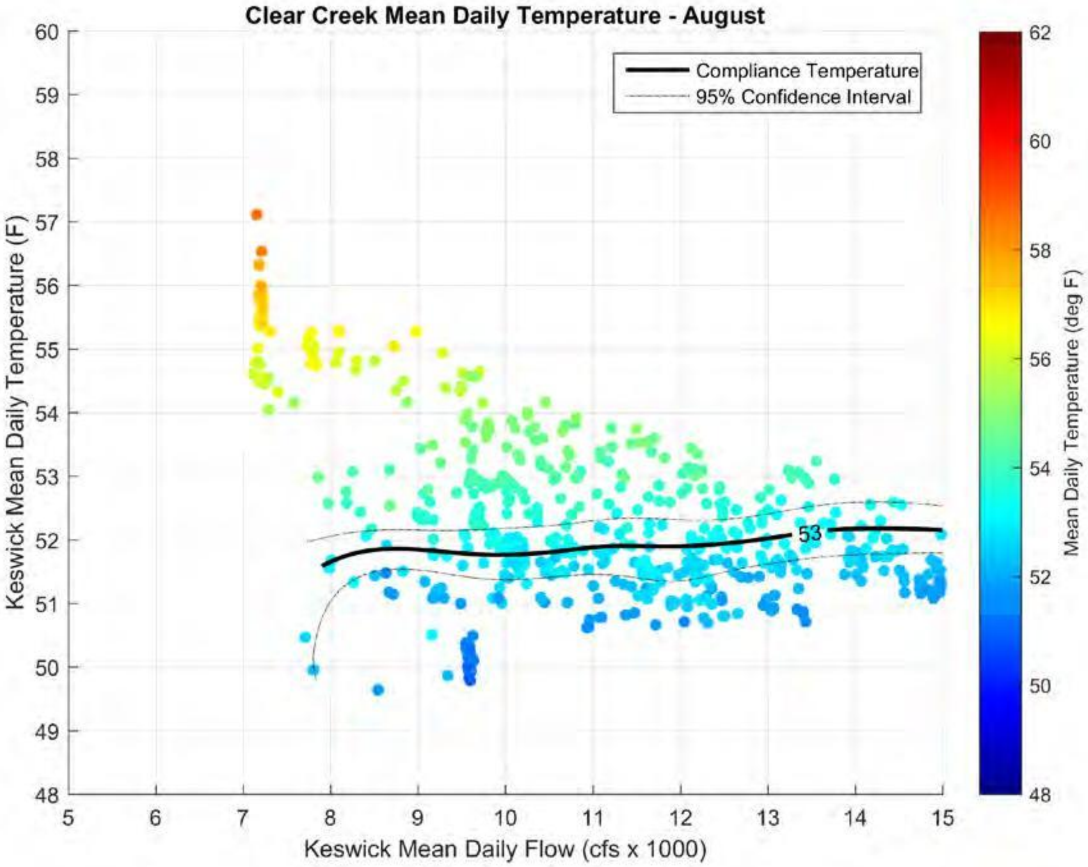

Figure 9. Relationship between discharge temperature and flow, and daily average temperature at Clear Creek. Data source: NMFS RAFT model 2016.

Based on the historic and modeled information, NMFS proposes the following Keswick maximum release flow schedule in order to ensure the temperature compliance metrics will be met for the entire temperature management season:

Table 10. NMFS proposed monthly Keswick release schedules by water year type (cfs)

	Apr	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**
Critically Dry	4000	7500	7500	7500	7500	7000	5000
Dry	6000	8000	10000	10000	10000	7500	6000
Below Normal	6000	9000	12000	12000	12000	7500	6500
Above Normal	6500	11000	12500	14500	12000	9000	7000
Wet	8000	12000	13500	14500	12000	10000	7000

7. Change in adult holding temperature compliance criterion of 56ºF daily average temperature to 61ºF 7DADM (or something similar) to Jellys Ferry

Adult winter-run Chinook enter the Sacramento River system usually with gametes not fully developed and move into the upper river where they hold until ready to spawn. After migrating from the ocean as early as December, they hold in deeper areas along the entire Upper Sacramento River from February to June as far downstream as Jellys Ferry[5].

In an effort to develop regional temperature criteria guidance that would be protective of salmonids, the United States Environmental Protection Agency (EPA) Region 10 reviewed several studies on how temperature affects salmonid physiology and behavior, the combined effects of temperature and other stressors on threatened fish stocks, the pattern of temperature fluctuations in the natural environment, and published of guidance recommendations to States and Tribes on how they can designate uses and establish temperature numeric criteria for waterbodies to protect coldwater salmonid species in the Pacific Northwest (EPA 2001, 2003). Based on the literature review in EPA (2001), holding migratory fish at constant temperatures above 55.4-60.1ºF (13-15.6ºC) impedes spawning success due to pronounced adult pre-spawn mortality and decreased survival of eggs to the eyed stage, and maximum constant temperatures of 50-54.5ºF (10-12.5ºC) provide better reproductive conditions. They recommend a 61°F (16°C) maximum 7DADM criterion for the protection of waterbodies used or potentially used for adult salmon holding prior to spawning (EPA 2003). The 7DADM metric is recommended because it describes the maximum temperatures in a stream, but is not overly influenced by the maximum temperature of a single day. Thus, it reflects an average of maximum temperatures that fish are exposed to over a weeklong period. Since this metric is oriented to daily maximum temperatures, it can be used to protect against acute effects, such as lethality, and can also be used to protect against sub-lethal or chronic effects.

Through the development of their life cycle model, NMFS-SWFSC examined the relationship between spawn timing from April to August and monthly water temperatures below Keswick from January through July (Hendrix *et al.* 2014). There is a negative relationship between April temperatures and proportion of fish spawning in May or June, and there is a positive relationship between April temperatures and proportion of fish spawning in July or August. This means that cool water in April results in earlier spawning, while warm water in April results in later spawning. If winter-run Chinook are optimizing for emergence timing of fry, fish will spawn later in warm water temperatures as warmer temperatures lead to faster egg development, and will spawn earlier in cool water temperatures as cold temperatures lead to slower egg development.

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[5] Holding winter-run Chinook salmon in the Redding area commonly seen during the late-fall run Chinook survey in February and March and the Livingston Stone National Fish Hatchery adult trapping at Keswick Dam begins collecting winter-run Chinook in late February to early March (D. Killam pers. comm. 2016). Historically some winter-run Chinook never passed RBDD when the gates were in but recently it is believed that unimpeded fish passage and combined with other fisheries and water management have conditioned the adult winter-run Chinook to migrate as far upstream as possible.

RPA Action I.2.4 May 15 through October Keswick release schedule (Summer Action)

8. **Change in spawning, egg incubation, and fry emergence temperature compliance criterion of 56ºF daily average temperature to 55ºF 7-day daily average temperature (or something similar) and the change in temperature compliance location criterion from between Balls Ferry and Bend Bridge to the most downstream redd.**

In order to protect salmon egg incubation and fry emergence from adverse thermal effects, the State Water Resources Control Board Orders 90-5 and 91-1 require Reclamation to operate Keswick and Shasta dams to meet a DAT of 56°F at RBDD or at a TCP modified when the objective cannot be met at RBDD based on Reclamation's other operational commitments, including those to water contractors, D-1641 regulations and criteria, and Shasta Reservoir projected EOS storage volume. RPA Action I.2.4 states that Reclamation shall manage Shasta Division operations to achieve a temperature compliance of not in excess of 56°F DAT between Balls Ferry and Bend Bridge from May 15 through October 31.

Recent investigations into causes of low egg-to-fry survival in 2014 and 2015 revealed that the 56°F (13.3°C) DAT criterion mandated in RPA Action I.2.4 is not adequate to protect the earliest life-stages winter-run Chinook salmon. Based on the studies in the Central Valley, and on studies of temperature requirements for northern races of Chinook salmon, temperatures from 39.2 to 53.6°F (4-12°C) tend to produce relatively high survival to hatching and emergence, with approximately 42.8-50°F (6-10°C) being optimum (Seymour 1956, Slater 1963, Healey 1979, Boles 1988, U.S. Fish and Wildlife Service 1999, EPA 2001, Myrick and Cech 2004). Exposure to temperatures above the optimal range results in sub-lethal or chronic effects (*e.g*., decreased juvenile growth, which results in smaller, more vulnerable fish; increased susceptibility to disease which can lead to mortality; and decreased ability to compete and avoid predation), as temperatures rise until at some point they become lethal (EPA 2001). Managing for 56°F (13.3°C) DAT can still result in a maximum daily temperature of over >60°F (15.5°C), which can result in sub-lethal and lethal effects to salmonids.

EPA (2003) recommends a 55°F (13°C) 7DADM criterion for the protection of waterbodies used or potentially used for salmon and trout spawning, egg incubation, and fry emergence and recommends that this criterion apply from the average date that spawning begins to the average date incubation ends (the first 7DADM is calculated 1 week after the average date that spawning begins). NMFS finds that this best available science of 55°F 7DADM shall apply to winter-run Chinook salmon spawning, egg incubation, and fry emergence from the onset of spawning (approximately May 15) to the end of incubation (approximately October 31).

Since the construction of Shasta Dam, winter-run Chinook historically spawned in the upper Sacramento River reach (50 miles) between Keswick Dam and RBDD (Vogel and Marine 1991). However, since the current aerial redd and carcass survey methodologies began in 2003, the vast majority of winter-run redds have occurred in the first 16 miles downstream of Keswick Dam and has continued since the implementation of RPA Action Suite I.2.4 in 2010 (Table 11). EPA (2003) also recommends that the water quality standard should apply to all the river miles including the lowest point downstream for egg incubation and fry emergence. In addition, the 2008 CALFED science program and the LOBO annual independent review panel has suggested that the compliance points should be re-evaluated and moved to better match actual fish habitat usage (Anderson *et al.* 2010, 2011, 2013, 2014 and 2015; Deas *et al.* 2008).

Table 11. Winter-Run aerial redd counts by river area 2010-2016. Data source: CDFW, unpublished.

Flight Sections	Redds (2010-2016)	% Average (2010-2016)
Keswick to A.C.I.D. Dam (rm 302 to 298)	**858**	**60.8%**
A.C.I.D. Dam to Highway 44 Bridge (rm 296)	**514**	**36.4%**
Highway 44 Br. to below Clear Crk. (rm 284)	**39**	**2.8%**
Below Clear Crk. to Balls Ferry Br. (rm 275)	**0**	**0.0%**
Balls Ferry Br. to Battle Creek (rm 271)	**0**	**0.0%**
Battle Creek to Jellys Ferry Br. (rm 266)	**1**	**0.1%**
Jellys Ferry Br. to Bend Bridge (rm 257)	**0**	**0.0%**
Bend Bridge to Red Bluff Diversion Dam (rm 242)	**0**	**0.0%**
Red Bluff Diversion Dam to Tehama Br. (rm 229)	**0**	**0.0%**
Total	**1412**	**100.0%**

Based on the best available science, current data that reflect actual spawning habitat usage, and the recommendations from both the EPA and the LOBO independent science panel, the temperature compliance location criterion shall be changed from "between Balls Ferry and Bend Bridge" to "the most downstream redd location." Because it is not known where that downstream most location is at the onset of spawning, an initial TCP at the Clear Creek California Data Exchange Center (CDEC) location (CCR) is sufficient. The TCP will then be adjusted upstream or downstream based on the location of spawning.

Recognizing the difficulty of changing the regulatory compliance from a DAT to a 7DADM, NMFS analyzed to see what the downstream TCP equivalency would be. Over an 18-year period (1998-2016), CCR 7DADM tracked pretty closely to Balls Ferry (BSF) DAT during the temperature management season, except for 2008, 2009, and 2012 to 2015 (*i.e.*, dry and critically dry years), where CCR 7DADM tracked somewhere between BSF DAT and Jellys Ferry (JLF) DAT (Table 12). Alternatively, the data show that a 53°F DAT at CCR and a 52°F DAT at KWK is sufficient as an indicator of the ability to meet 55°F 7DADM at CCR. In 2016, as part of the temperature management plan, Reclamation agreed to target Keswick DAT of 52°F[6]. Often times throughout the season, in order to try and manage to 55°F 7DADM at CCR, they would manage to a Keswick DAT of 51.5°F[7].

In recognition that a 55°F 7DADM or 53°F DAT at CCR cannot be achieved in some water year types (Table 3), NMFS came up with the following temperature requirements at CCR or the downstream-most winter-run redd, whichever is further downstream, by water year type:

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[6] http://www.westcoast.fisheries.noaa.gov/publications/Central_Valley/Water%20Operations/nmfs_concurrence_on_the_bureau_of_reclamation_s_sacramento_river_temperature_management_plan-_june_28__2016.pdf

[7] http://www.westcoast.fisheries.noaa.gov/central_valley/water_operations/srttg2016.html

- Critically dry: < 56°F daily average temperature
- Dry: < 54°F daily average temperature
- Below Normal: < 53°F daily average temperature
- Above Normal: < 53°F daily average temperature
- Wet: < 53°F daily average temperature

Table 12. Daily average temperature over the temperature management season (May through October) at the various temperature compliance locations, 1996 – 2016. Data source: Reclamation 2016.

WY	KWK DAT	CCR DAT	CCR 7DADM	BSF DAT	JLF DAT	BND DAT
1996	52.3			55.0	55.9	56.0
1997	51.8			54.5	55.5	56.3
1998	51.6	52.2	53.3	54.0	55.2	55.4
1999	50.5	51.6	53.3	53.4	54.6	55.1
2000	51.8	52.7	54.3	54.3	55.4	55.8
2001	52.0	53.0	54.6	54.4	55.6	56.0
2002	51.5	52.6	54.3	54.1	55.2	55.7
2003	51.6	52.6	54.2	54.2	55.4	55.9
2004	52.5	53.5	55.1	54.8	55.9	56.4
2005	52.3	53.2	54.7	54.8	56.0	56.4
2006	50.9	51.7	53.1	53.3	54.7	55.0
2007	52.5	53.3	55.0	54.8	55.7	56.2
2008	53.8	54.6	56.6	55.9	56.9	57.4
2009	53.0	54.1	55.9	55.6	56.8	57.2
2010	51.2	52.2	54.0	54.0	55.2	55.6
2011	51.0	52.1	53.8	53.8	55.0	55.5
2012	51.3	52.4	54.3	53.9	55.0	55.5
2013	53.0	54.0	55.8	55.4	56.3	56.6
2014	55.7	56.9	58.8	58.0	59.4	59.8
2015	55.2	56.7	58.8	58.1	59.5	60.1
2016	51.9	53.0	55.0	54.8	56.1	56.7
Average	52.3	53.3	55.0	54.8	56.0	56.4
Difference from CCR 7DADM	-2.7	-1.7		-0.2	1.0	1.4
Difference from KWK		1.0	2.7	2.5	3.7	4.1

9. Delay Shasta releases from full side gates

In 2014, the SRTTG and Reclamation learned that there was a loss of water temperature control when the full Shasta TCD side gates were accessed for water releases. As shown in the figure 10 below, full side gates were accessed on August 26, 2014, as indicated by the over one degree drop at both CCR and Keswick. Daily average temperatures were maintained below 56ºF for about a week before significantly rising throughout the remainder of September and all of October. More than 50% of the eggs and alevin were still in the gravel and were exposed to these lethal temperatures, not to mention the 56ºF DAT at CCR were routinely exceeded in June through August. In order to prevent the loss of cold water pool and temperature control in the future, Reclamation shall delay full side gate operations as long as possible and no earlier than October 15.

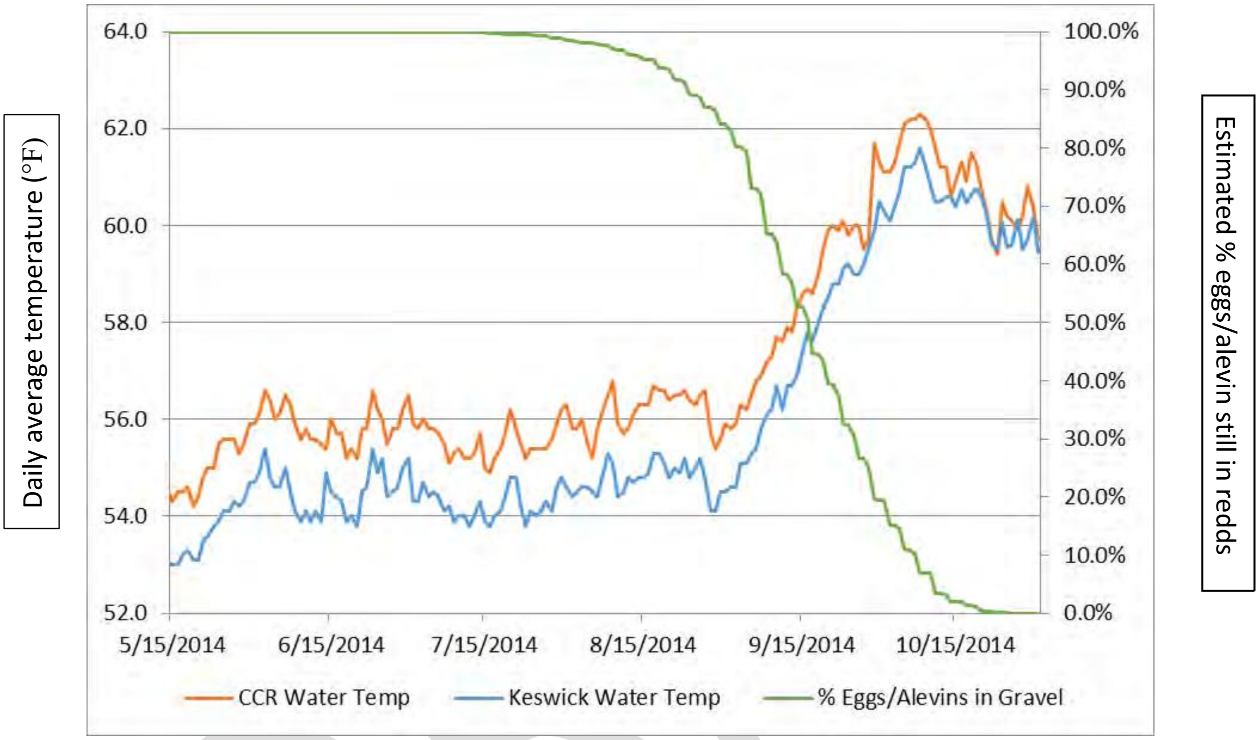

Figure 10. Daily average temperatures at CCR and Keswick (KWK) for the 2014 temperature management season with the cumulative proportion of eggs and alevins in gravel overlaid in green. Data source: CDEC and CDFW 2014.

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Enclosure 4

National Marine Fisheries Service—Southwest Fisheries Science Center
Updated January 2017

Central Valley water modeling for ecosystem protection

This document describes a proposed framework of physical and biological models designed to evaluate the impacts of Central Valley water operations on aquatic ecosystems under past, current, and future climate conditions. The document includes background on the basic conceptual model, descriptions of the existing components and how they are used in management, and recommendations on how the remaining components can be implemented.

Background

Water enters the Central Valley basin in the form of snow and rain and moves from watersheds through rivers and the estuary to the ocean. Throughout this domain there are two processes that govern most of the thermal hydrodynamics at local scales: advection (the movement of heat downstream with the water), and heat exchange (heating and cooling of the water with the environment). There are two primary drivers of these processes: flow dynamics and atmospheric forcings. Flow dynamics determine the rate at which heat is advected downstream (when and how much water is moved), and the rate of heat exchange. Atmospheric forcings and hydrology determine the amount of water entering the system (precipitation, evaporation, infiltration and either rain fed runoff or snow accumulation and snow melt) and the rate of heat exchange (solar radiation, evaporative cooling). The hydrologic processes influencing advection and heat exchange are well-understood and predictable phenomena. Atmospheric forcing and water resources operations (reservoir operations, water diversions, etc.) and the interactions between them are more variable and complex, and have important management, socio-economic, and environmental consequences.

The flow dynamics in the Central Valley have been fundamentally altered by the Central Valley Project (CVP) and State Water Project (SWP); a series of dams, reservoirs, and canals that were built to store and move water throughout the state. These projects have also significantly changed the spatial distribution and the timing of the advection and heat exchange processes. Reservoirs within the system were built to store water, forcing a lag in the timing of the movement of the water downstream. An unintended consequence of water storages is the associated alteration in the timing and magnitude of the advection of heat downstream. The statewide water budget model used for water management (CalSIM) was developed to inform water movement through actions such as reservoir operations and withdrawals, and does not have the capability to simulate heat and temperature processes.

The other key driver, atmospheric forcing, varies at multiple scales in the Central Valley, with daily to seasonal temperature and precipitation variation, seasonal to multi-year drought, and expectations for long-term increases in air temperatures. In

California, the majority of the water year's precipitation occurs in the winter months, but the water is released from storage reservoirs during the summer when the heat exchange is greatest. California is currently in a multi-year drought and air temperatures in 2014 and 2015 were the highest in recorded history.

While water temperatures do not directly impact the amount of water within the system, they can significantly influence water availability and distribution through restrictions driven by regulations such operating criteria based on ESA impacts. In 2015, for example, temperature compliance issues on the Sacramento River resulted in significant reductions in water delivery to Sacramento River Settlement contractors. Climate warming and the related increase in drought frequency and severity will likely make temperature management an even more important regulatory factor in the future. Thus there is a clear need for a comprehensive, basin-scale heat flow modeling framework. This framework can then be used to inform biological models for a better understanding of the ecosystem impacts of water management.

Proposed Framework – Physical Models

We propose to develop a coupled modeling framework to quantify the advection and heat exchange of water throughout the Central Valley basin, the San Francisco Bay/Delta, and the coastal ocean. There are five distinct zones that function under differing mechanisms and climate inputs that we refer to as process domains: watershed, reservoir, river, estuary, and ocean (Figure 1). The overall framework consists of a series of fine scale, process-based models that link each process domain through water flow (Q) and temperature (T) and are driven by outputs generated by climate models, for full regional coverage. The process-models are all mechanistic with heat budget components: VIC, a macroscale hydrologic model (watershed); CE-Qual-W2, a 2-D water quality and hydrodynamic model (reservoir); River Assessment for Forecasting Temperature (RAFT), a 1-D heat budget model (river); SCHISM (Semi-implicit Cross-scale Hydroscience Integrated System Model), a 3-D hydrodynamic model (estuary and coastal ocean).

Water enters the framework through the precipitation and atmospheric forcings from climate models. Heat is then advected (grey arrows) within and between domains (as a function of flow, Q, and temperature T), in the downstream direction only until the estuary, where tidal flow and diffusion become relevant. Heat exchange (black wavy lines) occurs within each domain, either adding heat, which is then advected downstream, or removing heat from the system through cooling. Heat can also be removed from the system through water withdrawals, such as in the estuary where a substantial proportion (up to 50%) of the water is exported for municipal and agricultural use. Examples of management options for each model are included (model subheadings). There is also the capacity to model the movement of contaminants or any scalar of interest (turbidity, dissolved oxygen, etc.) represented by C throughout and between domains.

The first three models, watershed-reservoir-river (grey layered boxes), would represent the Shasta watershed, Shasta Reservoir, and Sacramento River, and would be repeated to capture the multiple inputs into the estuary from the other major rivers. The project would be implemented in two stages: the first stage would include the development of linked process-modes for the Sacramento River (Shasta watershed, Shasta Reservoir, Sacramento River, Sacramento-San Joaquin Delta). The second stage (the full model) would incorporate the additional tributaries to the Sacramento (the Feather and American Rivers), and the San Joaquin River system (the Merced River, Tuolumne River, Stanislaus River and Mokelumne River).

Proposed Framework – Biological Models

The physical models will be used to inform biological models that range from ecosystem models to specific models of growth and energetics for individual species. The overall goal of these models is to evaluate the impacts of water operations on the aquatic ecosystems, taking into account other (non water management related) factors as much as possible. Examples include models of Chinook salmon embryo development and survival, and individual-based models of freshwater life stages, and stage structured models of the full salmon life cycle.

Current Status

The SWFSC and its collaborators have made significant progress on some components of this modeling framework, mostly on the Sacramento River domain.

The RAFT model

The River Assessment for Forecasting Temperature (RAFT) model is a one-dimensional heat budget model for the Sacramento River. RAFT takes the discharge temperature and flow from Keswick Dam and applies meteorological forcings from weather forecasts to predict the downstream temperatures for every kilometer of river at a sub-hourly timestep. RAFT has been run retrospectively to produce the temperature landscape for the entire river from 1990-2015. RAFT can be run in forecast mode for operations, where it predicts water temperatures 7 days out. RAFT can also be run in planning mode, where it takes output from various planning scenarios and predicts water temperatures for the entire temperature management season (February through October). One of the primary advantages of the RAFT model is that it allows for the detailed estimating of thermal exposure of salmon redds by location – which allows for calculating the egg development time and survival probability (described below).

Egg survival model

It has been well established that water temperatures play a large role in salmon egg survival. It is difficult to directly measure egg mortality in the field, so laboratory studies in controlled environments are used to develop a relationship between temperature and survival. However there is evidence that laboratory studies do not adequately represent conditions in the field. We therefore have developed a semi-mechanistic/statistical model of temperature-dependent survival of winter-run Chinook in the Sacramento River. Our modeling approach makes use of information from carcass surveys and the timing and distribution of redd locations taken from aerial surveys from 1996-2015. For each known redd we extract a temperature exposure profile that redd would have experienced from fertilization to emergence using the RAFT model. For each known redd, we then apply a temperature-dependent mortality model with daily time steps to calculate the probability of survival from fertilization to emergence. We then calculated predicted survival within a year by aggregating the survival of all redds within a year, and compare the predicted survival in a year to observed yearly survival from egg-to-fry (ETF) estimated by the US Fish and Wildlife serve from 1996-2015. Finally we estimate the parameters of our daily temperature-dependent mortality model by minimizing the deviations between predicted and observed survival across years.

One of the key findings from this work is that laboratory studies significantly underestimate the impact of temperature on salmon eggs by as much as 5°F (Figure 2). These results may have profound implications as to how we manage salmon throughout the Central Valley, as well as the rest of their range. The 56°F compliance temperature would result in ~75% survival based on fitting the model to laboratory data, but less than 15% survival based on fitting the model to field data. Application of this model to the past 20 years of temperature data on the Sacramento River indicates that using laboratory data would only predict temperature dependent mortality in the most extreme conditions of 2014, while field data would predict a range of mortality in most years (Figure 3). A manuscript on this work is currently in review in Ecology Letters.

Application of the coupled models - the survival landscape

Coupling the egg survival model with RAFT allows us to view the past, current, and future survival landscapes on the Sacramento River (Figure 4). The RAFT model provides the temperature landscape from the dam downstream over the time (Figure 4, panel A). The biological model predicts temperature dependent survival (Figure 4, panel B) over the same landscape, as well as total survival, which is the product of background survival (non temperature dependent, not shown) and temperature survival (Figure 4, panel C). The conditions in individual years can be viewed with respect to observed redd locations (Figure 5). By coupling RAFT and the egg survival model is it possible to generate temperature and survival forecasts for seasonal planning (Figures 6-8). These figures represent different proposed operational scenarios for 2016.

Individually Based Model - InSALMO

We have adapted the InSALMO model, an individual-based model of freshwater life stages (spawning through outmigration) of salmon (https://www.fws.gov/sacramento/fisheries/Instream-Flow/fisheries_instream-flow_inSalmo.htm) to the Sacramento River for winter run Chinook. Because many interacting ecological variables affect the success of restoration and water management actions, an individual based model (IBM) can allow researchers to account for all system variables deemed important, as well as their interactions. We use inSALMO, parameterized with literature, white and gray paper data, 2D HEC-RAS models, satellite imagery, and the RAFT model (Figure 9).

Recommendations for continued research

The river modeling components (as described above) are well developed and already used to inform management decisions. Following are brief descriptions of the remaining components.

Juvenile Growth

Understanding the factors affecting growth of Chinook salmon fry in the Sacramento River is needed to inform water management and habitat restoration practices. Bioenergetics modeling provides a useful tool for this purpose as it integrates the effects of temperature, flow and food availability. However, bioenergetics models are typically parameterized from laboratory studies that are unrepresentative of field conditions. For example, much of our understanding on how temperature affects growth is based on lab experiments where fish are maintained in tanks and hand-fed pellets where fish do not have to forage, avoid predators, or swim against a current. Currently, a lack of data on how abiotic (temperature and flow) and biotic (food availability) conditions affect feeding and growth rates of fry in realistic contexts (e.g. drift feeding) limits the predictive capabilities of bioenergetics models for Chinook salmon in the Sacramento River. We propose research to address this gap by studying the drift feeding behavior of Chinook salmon in natural contexts. Recent advances in high-resolution videography and computer vision have allowed for unprecedented rates of behavioral data collection. We plan to use such technology to generate high-resolution behavioral data from observational field studies and laboratory flume experiments to develop and test mechanistic models of salmon drift feeding, growth and survival.

Watershed

The watershed represents the resource "starting point" for the linked models. This involves implementation of the RBM10 stream temperature model in conjunction with the Variable Infiltration Capacity (VIC) model to a domain that includes the Sacramento River above Shasta Reservoir plus local inflows. The spatial resolution will be 1/16th degree, consistent with UCLA's California and Nevada Drought Monitoring System (http://www.hydro.ucla.edu/monitor_ca/index.html). Observations sources (USGS stream gauges plus USGS and/or other sources of stream temperature data) will be used to evaluate performance of the RBM10/VIC combination with respect both to stream temperature and discharge, and hence thermal loadings to Shasta Reservoir. The RBM10/VIC combination will also be used to model the major tributaries to the Sacramento River downstream of Shasta Reservoir, and via sensitivity testing with the RAFT stream temperature model to be applied to the managed reaches in conjunction with CE-Qual-W2; we will identify key lateral inflows, and use the VIC/RBM10 combination to predict lateral thermal loadings to the river.

Reservoir

The current monitoring and modeling of water quality in Shasta Reservoir, the largest and most important reservoir in the state, is inadequate. There is a need for expanded in-situ monitoring, including temperature, dissolved oxygen (DO), nutrient and biological profiling – phytoplankton and zooplankton enumeration and identification at multiple depths.

Estuary

The SCHIMS model will provide water temperatures, particle tracking, plus coupled with ecosystem models to evaluate food resources for rearing juvenile salmon. This processed based modeling approach will allow for the evaluation of future impacts, such as water withdrawals as proposed by California Water Fix.

Ocean

The SCHISM model domain includes the Gulf of Farallones, a key habitat area of juvenile salmon survival at early ocean entry. This hydrodynamic model has been coupled with CoSiNE, an ecosystem model that provides information about the water conditions, including temperature and density of salmon prey.

Summary

The full modeling framework will directly support both the management of endangered winter run Chinook salmon on the Sacramento River and future efforts to provide passage around Shasta Dam (watershed modeling will provide temperature and flow in proposed passage habitats). The framework will also have additional applications, such as California Water Fix and meeting Delta water quality standards, and support for ongoing NMFS life cycle modeling efforts.

Funding status

The watershed model (VIC), the reservoir model (CE-Qual-W2), and river model (RAFT) are funded through mid-2017. Funds have been allocated to purchase the equipment for the distributed temperature system (DTS) for monitoring Shasta Lake profiles, but there are no funds for the installation and deployment of the equipment. Funding for the ongoing biological modeling of temperature impacts and IBM efforts expires in mid 2017.

Modeling Framework

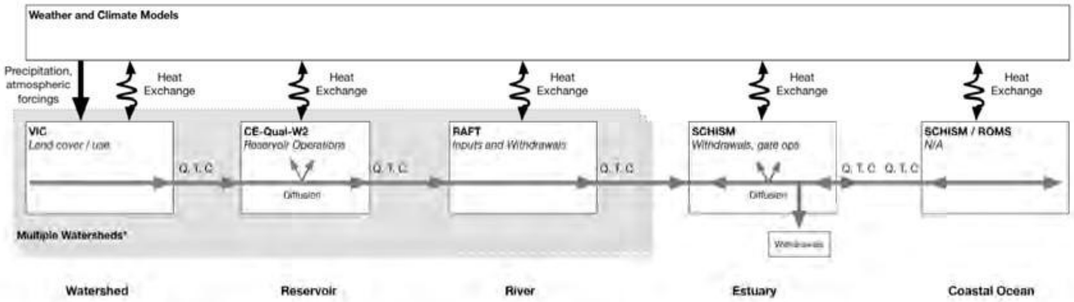


Figure 1. Model framework. The framework consists of five process domains: watershed, reservoir, river, estuary, and coastal ocean, each with a physical model (white boxes). Water enters the framework through the precipitation output from climate models. Heat is then advected (grey arrows) within and between domains (as a function of flow, Q, and temperature T), in the downstream direction only until the estuary, where tidal flow and diffusion become relevant. Heat exchange (black wavy lines) occurs within each domain, either adding heat, which is then advected downstream, or removing heat from the system through cooling. Heat can also be removed from the system through water withdrawals, such as in the estuary where a substantial proportion (up to 50%) of the water is exported for municipal and agricultural use.

Laboratory vs. Modeled Field Results

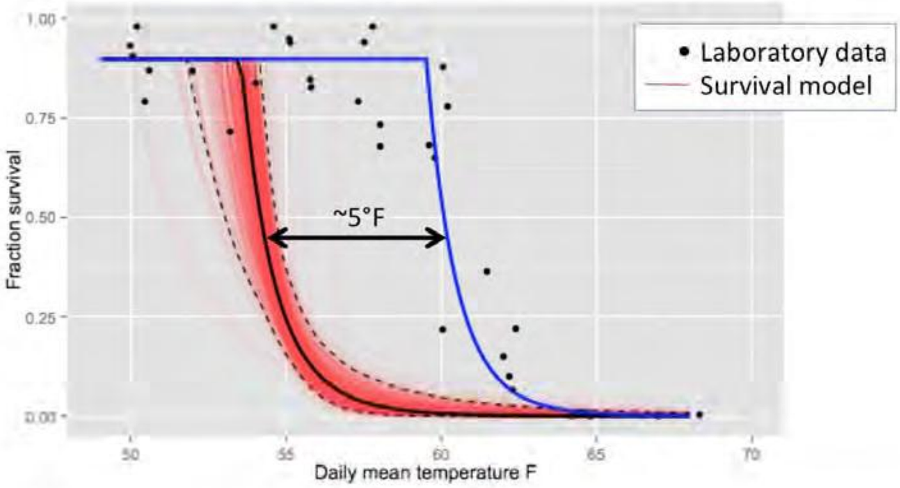


Figure 2. Daily mean temperature vs. survival for Chinook eggs in the laboratory (black dots) and modeled from field observations (red lines). There is a ~5°F difference between the lab results fitted to the model (blue line) and the mean model observed results (black line).

Lab vs. Field Results

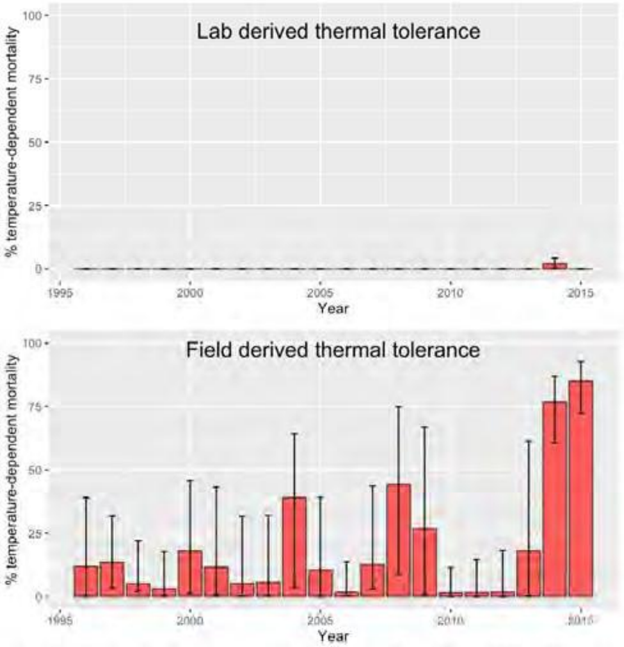
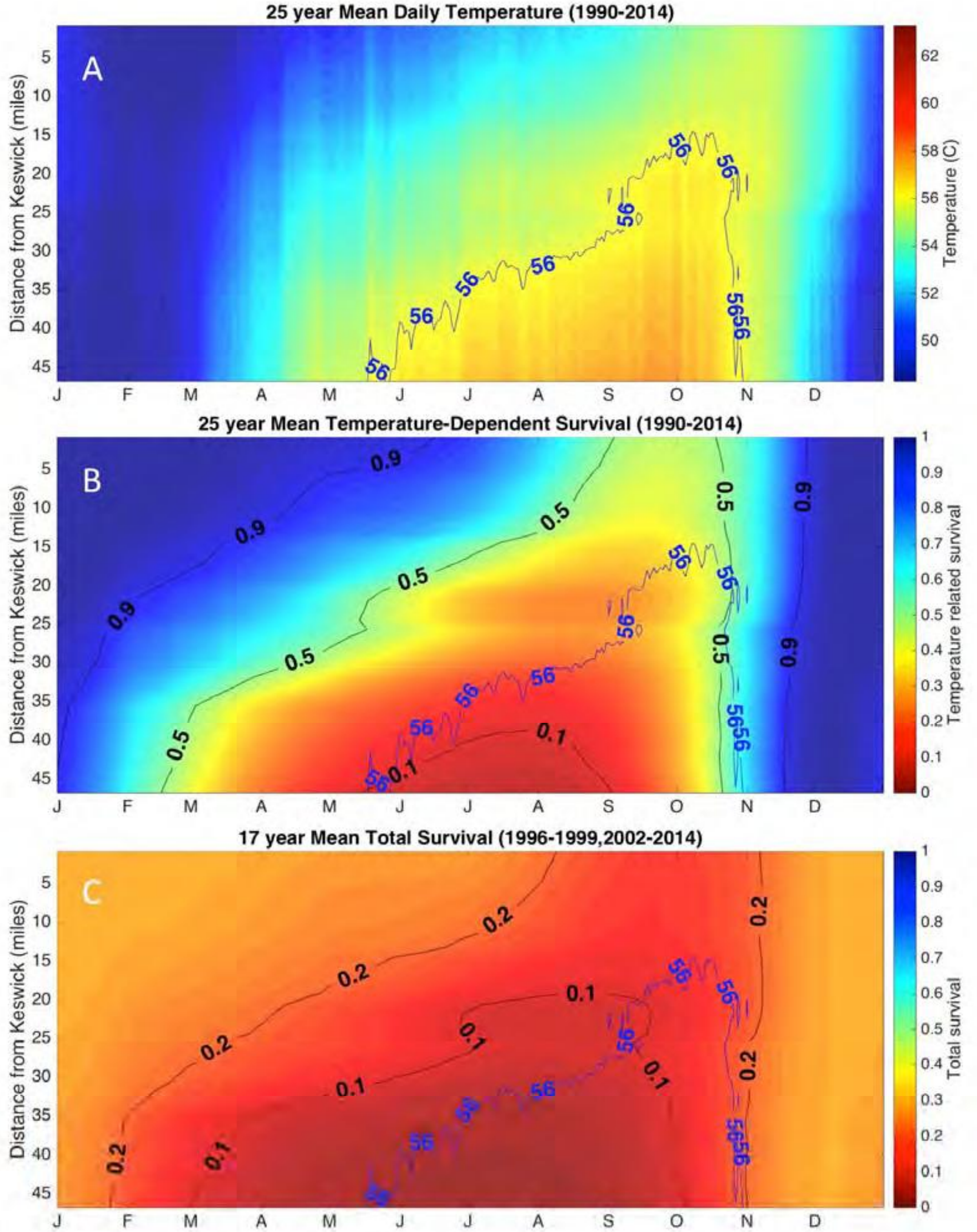


Figure 3. Monte Carlo methods (repeated sampling) on both field and lab data to generate a range of likely thermal tolerance parameters (1000 parameter sets) to predict mean temp-dependent mortality (95% CI) over the past 25 years. The lab fit does not predicts egg mortality except for 2014 when temperatures spiked. The field fit predicts some temperature dependent mortality in most years.


25 year Mean Daily Temperature (1990-2014)

25 year Mean Temperature-Dependent Survival (1990-2014)

17 year Mean Total Survival (1996-1999,2002-2014)

Figure 4. Temperature and survival landscapes for the Sacramento River. (A) Mean daily temperatures over the past 25 years. The blue line represents the location of the 56°F compliance temperature. (B) Temperature dependent survival of eggs under the temperature conditions in panel A. Note the location of the 56°F line. (C) Total survival, which is the product of temperature dependent survival and background survival

Survival Landscape During the Drought

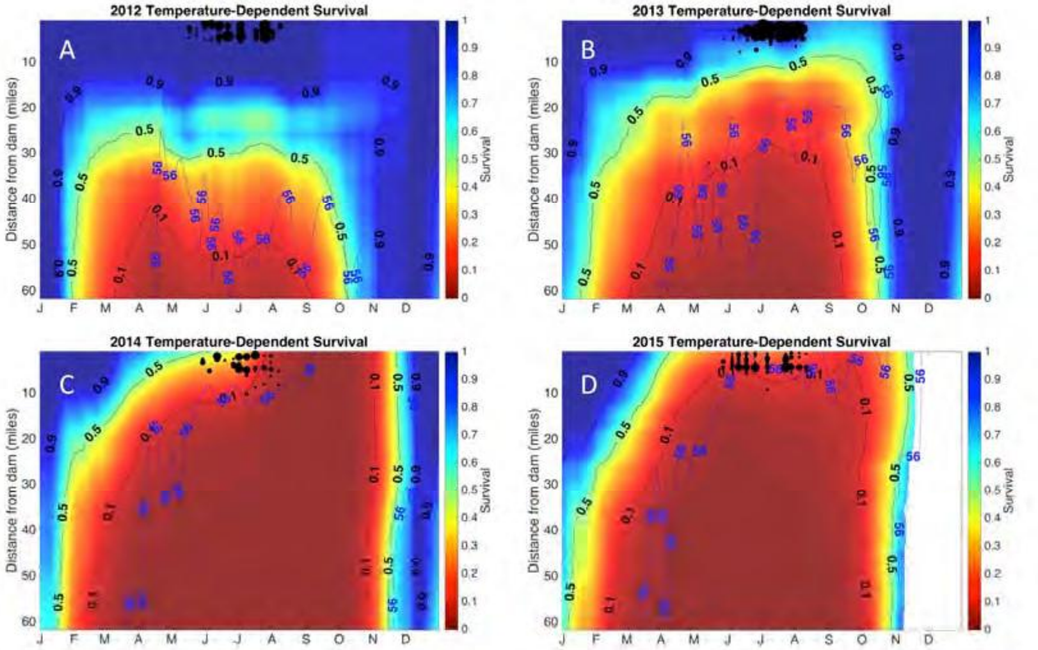


Figure 5. The survival landscape during multi-year drought conditions. (A) the first year of the drought there was still enough cold water to maintain habitat (annual temperature depend survival (TDS) = 100%). (B) Second year of the drought (TDS = 90%). (C) In 2014 temperature control was lost in September (TDS = 23%). (D) Despite attempts to maintain constant temperatures throughout the season mortality was high (TDS = 14%).

Temperature Scenarios for 2016

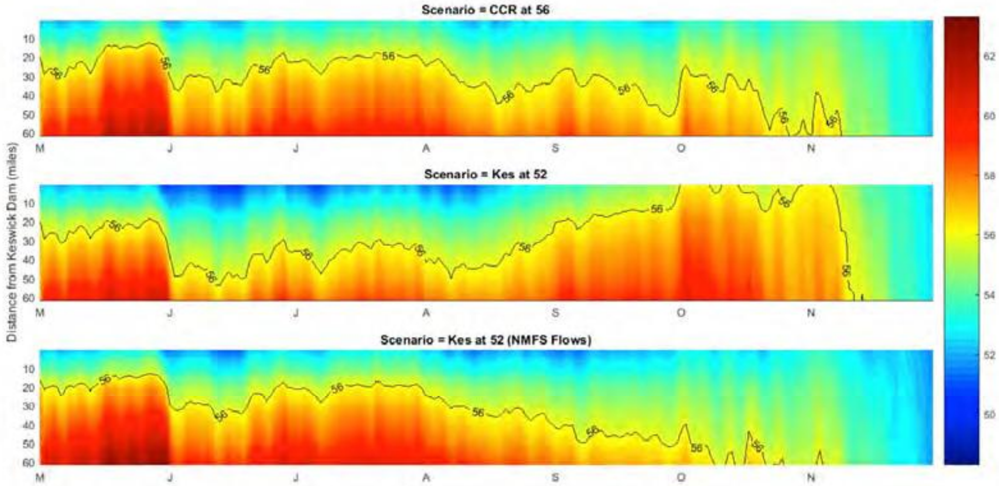


Figure 6. The temperature landscape under three possible operating scenarios for 2016.

Survival Landscape - Scenarios for 2016

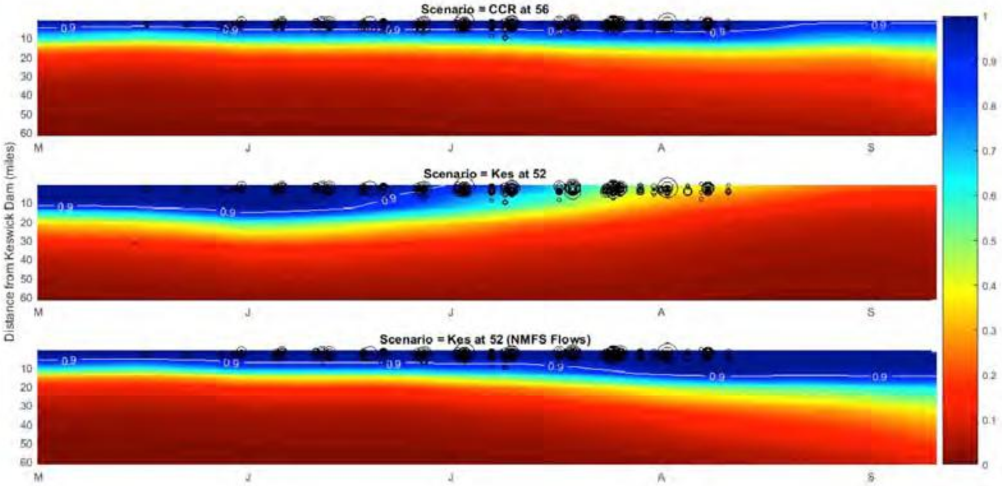


Figure 7. The survival landscape under three possible operating scenarios for 2016.

Survival Uncertainty - Scenarios for 2016

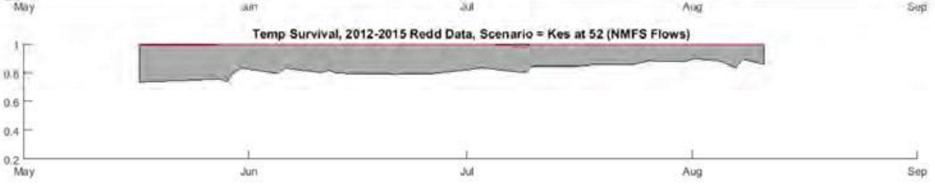


Figure 8. Survival probabilities and uncertainty under three possible operating scenarios for 2016. Mean (red line) and 90% confidence interval (grey area).

Individually Based Model: InSalmo

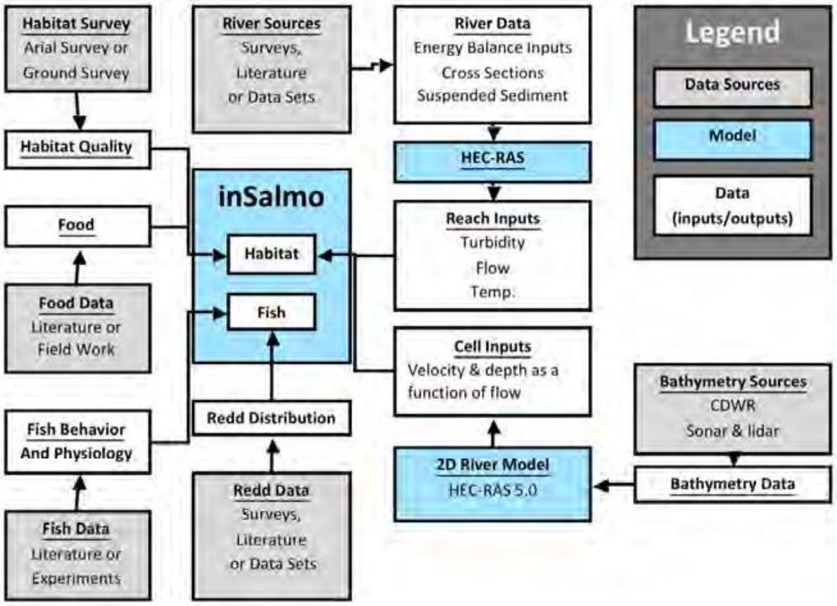


Figure 9. Concept map for InSalmo model applied to the Sacramento River for Winter run Chinook.

Shasta Temperature Profile

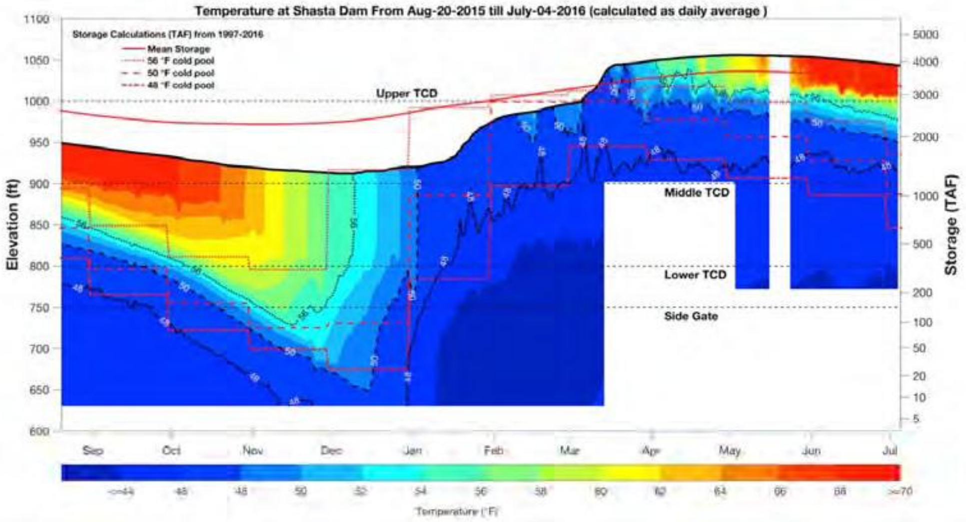
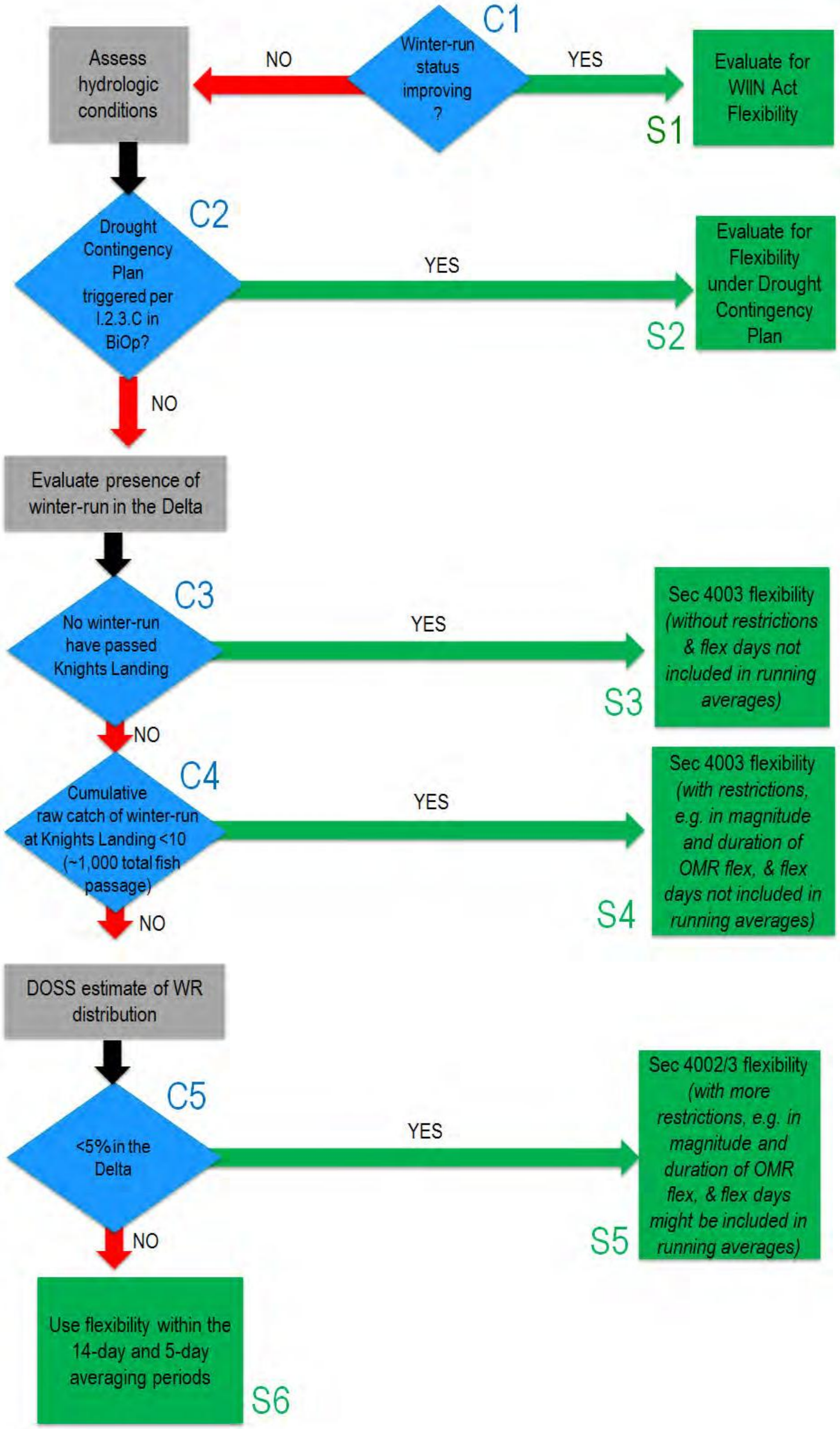


Figure 10. Temperature profile of Shasta Lake from mid-August to the present. Temperatures are recorded using a Distributed Temperature System (DTS), a fiber optical cable that measures temperature at very high resolution and precision (every 10cm at 1min intervals, with 0.1°C). White areas represent missing data.

Proposed NMFS flow chart for evaluating Sec 4003 WIIN Act Flexibility – 10/27/17 DRAFT



NMFS draft Technical Assistance on measures to minimize the potential effects to listed species of a WIIN Act section 4003 flex
Updated March 21, 2018

On March 19, 2018, the U.S. Bureau of Reclamation (Reclamation) shared a draft of the WIIN Act Operations Plan and Biological Review with representatives of the California Department of Water Resources, U.S. Fish and Wildlife Service, California Department of Fish and Wildlife, and NOAA's National Marine Fisheries Service (NMFS). NMFS has reviewed the operations plan and biological review, and agrees with the assessments in the summary tables for Sacramento River winter-run Chinook salmon, Central Valley spring-run Chinook salmon, and Central Valley steelhead that the proposed operations plan is expected to result in "Increased" risks of south Delta/central Delta entrainment and facility loss. For example, the narrative summary for Sacramento River winter-run Chinook salmon concludes that:

> "hydrodynamic modeling of the Proposed Operational suggest hydraulic alteration that may increase the risk of entrainment into the central Delta. Maintaining a short period of OMR flows more negative than -5,000 cfs may increase the risk of loss at the Central Valley Project (CVP)/State Water Project (SWP) fish collection facilities for any winter-run Chinook Salmon in the south Delta during and after the five days of increases [sic] export."

The Delta Operations for Salmonids and Sturgeon Technical Working Group (DOSS) met on March 20, 2018, and provided the following estimates of current fish distribution:

Location	Yet to Enter Delta (Upstream of Knights Landing)	In the Delta	Exited the Delta (Past Chipps Island)
Young-of-year (YOY) winter-run Chinook salmon	3-11%	47-66%	31-42%
Young-of-year (YOY) spring-run Chinook salmon	15-25%	75-85%	0%
Hatchery Produced BY17 Winter-run Chinook salmon	85-90%	10-15%	0%

DOSS stated that "OMR flows more negative than -5,000 cfs will create conditions that are not protective of listed salmonids in the southern Delta."

NMFS is taking the opportunity to provide technical assistance to Reclamation, and offers the following measures to minimize the potential effects to listed species of the proposed WIIN Act section 4003 flex:

1. Preferential pumping through the CVP

Current (March 20, 2018) and potential exports utilizing preferential pumping through the CVP:

Facility	Current Combined Exports (at OMR of -5,000 cfs	Potential Combined Exports (at OMR of -5,700[1])	Preferential pumping through the CVP to CVP capacity
CVP-Jones Pumping Plant	2,700 cfs	3,400 cfs	4,200 cfs
SWP-Banks Pumping Plant	3,900 cfs	3,900 cfs	3,100 cfs

Assuming that the split of entrainment into the CVP/SWP is similar to the split of exports at the CVP/SWP, preferential pumping through the CVP would reduce the potential risk of salmonid loss at the SWP since the loss associated with a salvage fish is much higher at the SWP than at the CVP. The following is an example of a simplified loss calculation based on the salvage of a single fish at the CVP and SWP.

Facility	# fish observed (30-minute count)	Expanded salvage (to 2 hours)	Multiplication factor used for rough loss estimate	# fish lost
CVP-Tracy Fish Collection Facility	1	4	0.68	2.72
SWP-Skinner Fish Protection Facility	1	4	4.33	17.33

2. Loss-based offramp from WIIN Act Section 4003 flex

NMFS assumes that recent conditions during March are reasonably representative of conditions during the 5-day flex period. The March 2018 loss to date (3/1/18-3/19/18) of non-adipose-clipped winter-run-sized Chinook salmon is 141, or 7.4 non-adipose-clipped winter-run-sized Chinook salmon per day. To minimize the risk of increasing loss rates during a WIIN Act flex, the following offramp could be adopted:

- If cumulative non-adipose-clipped winter-run-sized Chinook salmon loss over the 5-day duration of the flex period exceeds 37 fish (5 days x 7.4 fish/day), exports will be reduced to achieve daily OMR flows no more negative than -5,000 cfs.

3. **Frequency of WIIN Act section 4003 flex:** Any OMR flex pursuant to the WIIN Act section 4003 will be limited to one event per 14 days. If a loss-based offramp is not met during the flex period, NMFS may consider and offer additional technical assistance to Reclamation regarding another WIIN Act section 4003 flex within the 14-day period.

4. **OMR Flow Management RPA Action IV.2.3 – Loss-density triggers**: All action (e.g., loss-density) triggers and associated action responses (i.e., OMR limits of -3,500 cfs or -2,500

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[1] For simple calculation, assumption is that the change in OMR is equal to exports

cfs) in RPA Action IV.2.3 should remain in effect throughout the implementation of the WIIN Act section 4003 flex.

Fisheries Management and Ecology

Fisheries Management and Ecology, 2014

Response of juvenile Chinook salmon to managed flow: lessons learned from a population at the southern extent of their range in North America

S. C. ZEUG, K. SELLHEIM & C. WATRY,

Cramer Fish Sciences, Auburn, CA, USA

J. D. WIKERT

U.S. Fish and Wildlife Service, Lodi, CA, USA

J. MERZ

Cramer Fish Sciences, Auburn, CA, USA

Abstract Fourteen years (1996–2009) of juvenile Chinook salmon, *Oncorhynchus tschawytscha* (Walbaum), migration data on the regulated Stanislaus River, California, USA were used to evaluate how survival, migration strategy and fish size respond to flow regime, temperature and spawner density. An information theoretic approach was used to select the best approximating models for each of four demographic metrics. Greater cumulative discharge and variance in discharge during the migration period resulted in higher survival indices and a larger proportion of juveniles migrating as pre-smolts. The size of pre-smolt migrants was positively associated with spawner density, whereas smolt migrant size was negatively associated with temperature and positively associated with discharge. Monte Carlo techniques indicated high certainty in relationships between flow and survival, but relationships with juvenile size were less certain and additional research is needed to elucidate causal relationships. Flow is an integral part of the habitat template many aquatic species are adapted to, and mismatches between flow and life history traits can reduce the success of migration and the diversity of migratory life history strategies. The analyses presented here can be used to assist in the development of flow schedules to support the persistence of salmon in the Stanislaus River and provide implications for populations in other regulated rivers with limited and variable water supply.

KEYWORDS: California, life history, Monte Carlo, river regulation, screw trap, survival.

Introduction

Pacific salmon, *Oncorhynchus* spp., stock abundances exhibit large temporal fluctuations that, in part, are determined by co-varying environmental parameters that characterise regional climatic conditions. This is not surprising given the profound effect freshwater flow has upon the physical, chemical and biological processes in streams, estuaries and associated coastal waters (Albright 1983; Junk *et al.* 1989; Wilcock *et al.* 1996). The freshwater hydrograph influences water temperature and quality, creation and maintenance of channel complexity, seasonal activation of floodplain habitats, regulation of primary productivity and stimulation of migration in aquatic species (Dingle 1996; Poff *et al.* 1997; Ahearn *et al.* 2006). Particulate organic and inorganic matter, as well as juvenile salmon, are carried seaward by freshwater flow and incorporated into coastal marine food chains. In turn, conditions within coastal waters influence the health, survival and reproductive success of adult salmon returning to natal streams, causing a biological feedback on long-term health and success of salmon stocks (Mantua *et al.* 1997; Greene *et al.* 2005).

Correspondence: Steven Zeug, Cramer Fish Sciences, 13300 New Airport Road Suite 102, Auburn, CA 95602, USA (e-mail: stevez@fishsciences.net)

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Salmon streams throughout the northern hemisphere have undergone dramatic and long-term anthropogenic changes including damming, mining, levee construction, hydropower generation and floodplain disconnection. Such effects have altered hydrologic, sediment and temperature regimes and impacted the native flora and fauna of these systems (Merritt & Cooper 2000; Trush *et al.* 2000; Vinson 2001). The associated decline of salmon populations that support valuable commercial and recreational fisheries has triggered efforts to design flow regimes for regulated rivers that provide conditions suitable to support self-sustaining populations. Yet, there remains a lack of information regarding the responses of different salmon life stages to specific environmental variables that can be used to inform flow strategies. Given the demands for large-scale water regulation and diversion within lotic ecosystems, effective resource management requires an understanding of how environmental conditions affect salmon (i.e. quantity, quality and migration strategy) during the freshwater portion of a given population's life cycle (Hoekstra *et al.* 2007; Nislow & Armstrong 2012).

It was hypothesised that juvenile salmon would demonstrate demographic responses to inter-annual variation in flow magnitude, flow variance and temperature. This hypothesis was tested by modeling how independent variables affected the proportion of juveniles transitioning from rearing to migration using an index of survival, the life stage when migration out of the natal stream was initiated and fish size. For this effort, 14 years of juvenile Chinook salmon migration data were collected at two locations on the Stanislaus River, California, USA, a highly regulated stream with an extant population of naturally reproducing Chinook salmon, *Oncorhynchus tschawytscha* (Walbaum). The monitoring sites included the downstream extent of identified Chinook salmon spawning habitat that was used to estimate fry abundance and the downstream extent of rearing used to estimate the abundance of Chinook salmon emigrating out of the natal stream. These analyses provide resource managers with essential information that can be used to better inform flow management for Chinook salmon in the Stanislaus River and provide implications for relationships between environmental drivers and Chinook salmon ecology in other regulated rivers.

Methods

Study site

The Stanislaus River drains approximately 2400 km^2 from the western slope of the central Sierra Nevada Mountains to its confluence with the San Joaquin River. The watershed has a Mediterranean climate with dry summers, and approximately 90% of the annual precipitation occurs between November and April. Historically, relatively low-magnitude flow pulses occurred from late autumn until early spring in response to rainfall in the lower watershed followed by a snow melt-driven pulse from spring through early summer. In the 20th century, more than 40 dams were constructed on the Stanislaus River for flood protection, power generation, irrigation and municipal water supply. Collectively, these dams have the capacity to store 240% of the average annual runoff in the catchment and have reduced the amount of habitat available to Chinook salmon by 53% (Yoshiyama *et al.* 2001). Goodwin Dam (GDW), located at river kilometre (rkm) 94, is currently the upstream migration barrier to adult Chinook salmon and demarks the upstream end of the lower Stanislaus River (Fig. 1). Most fall-run Chinook salmon spawning in the lower Stanislaus River (LSR) occurs in the 29-km reach below GDW (from GDW to ~rkm 66); however, spawning has been observed as far downstream as rkm 53.1.

New Melones Dam, completed in 1979, impounds a reservoir that accounts for approximately 85% of the total storage capacity in the system and is the primary instrument of flow regulation in conjunction with GDW that serves as a re-regulating facility for the larger reservoir. In the years since New Melones Dam operation began, the LSR (below GWD) has changed from a dynamic river system, characterised by depositional and scour features, to a relatively static and entrenched system (Kondolf & Batalla 2005). Annual mean daily discharge has been reduced from 48 to 23 m^3 s^{-1} with mean 30-day maximum discharge reduced from 137 to 38 m^3 s^{-1} (Brown & Bauer 2009). Vegetation encroachment into the active channel, as well as urban and agricultural development, has altered the natural river channel-floodplain connection and has led to the coarsening of bed material, particularly within spawning habitat between Goodwin Dam and Honolulu Bar (Fig. 1).

Fall-run Chinook salmon freshwater life stages and timing

Similar to many anadromous salmonids, California Central Valley fall-run Chinook salmon exhibit distinct life stages that occur during specific time periods (Merz *et al.* 2013). In general, adults migrate from the Pacific Ocean to natal streams between August and December and spawning is initiated shortly after (peak from early October to late November). Chinook salmon require relatively cool, clear, flowing streams with appropriate substrate for successful spawning (Zeug *et al.* 2013), incubation and emergence (Tappel & Bjornn 1983).

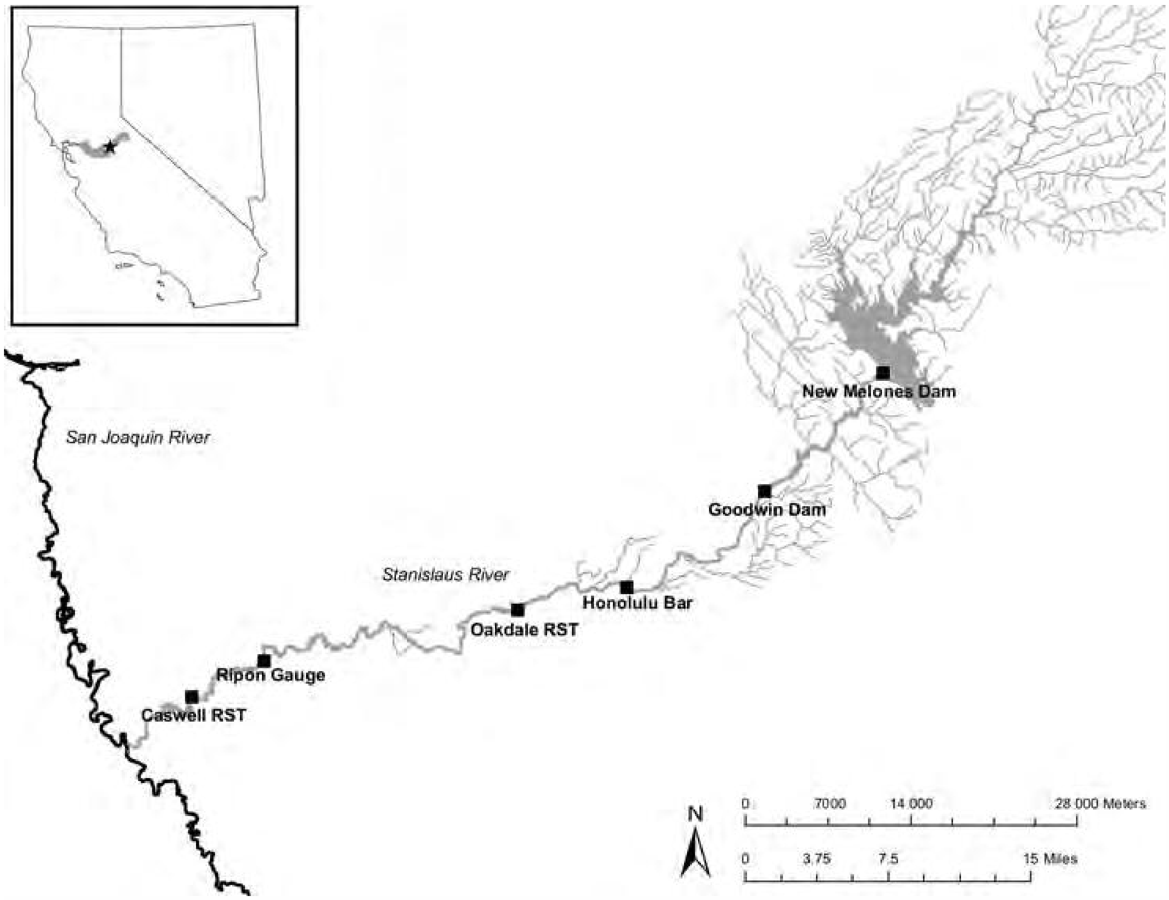

Figure 1. Location of the lower Stanislaus River, California and the location of rotary screw traps (RST) and other relevant features within the study area.

Incubation typically occurs from October through March, and emigration occurs from late December to early July.

Environmental variables

A suite of variables was measured to characterise LSR hydrologic and temperature regimes during the study period (Table 1). To facilitate comparisons of environmental conditions across years, a uniform range of days for each year was created to represent the juvenile rearing and emigration period. The beginning of the period was calculated as the day that 2.5% of cumulative juvenile Chinook salmon catch was observed for each year and averaged across years (mean = day of the year 17). The end date was calculated as the day that 97.5% of cumulative catch was observed for each year and averaged across years (mean = day of the year 147). These start and endpoints were assumed to represent conditions the majority of juveniles experienced as they reared and migrated downstream through the LSR.

Hydrologic variables included in the analysis were cumulative discharge during the rearing period and variance in discharge during the rearing period. Mean daily flow was obtained from the United States Geological Survey stream gauge on the Stanislaus River located near Ripon, CA (Fig. 1) and converted to total daily flow (m^3 day^{-1}). To calculate cumulative flow, total daily flow was summed for the rearing period (130 days) each year (Table 1). Variance in flow was calculated as the sample variance of the total daily flow (m^3 day^{-1}) during the 130-day rearing period. Flow variation provides a mechanism for habitat creation and activation (e.g. bar formation, floodplain inundation) and has been identified as a trigger for fish migration and overall changes in metabolism (Raymond 1968; Hvidsten *et al.* 1995; Baker & Morhardt 2001).

Table 1. Environmental variables and estimates of Chinook salmon spawner abundance in the Stanislaus River during 1996–2009

Year	Cumulative discharge × 10^8 (m^3)	Discharge variance × 10^9 (m^3)	Degree days	Spawner abundance
1996	6.12	6.02	1602	168
1997	10.66	6.39	1838	5588
1998	8.07	5.33	1489	3087
1999	7.02	4.61	1533	4349
2000	4.78	3.75	1710	8498
2001	2.22	1.01	1767	7033
2002	2.23	0.52	1696	7787
2003	2.02	0.29	1773	5902
2004	1.68	0.41	1847	4015
2005	1.89	1.05	1849	1427
2006	11.02	8.90	1449	1923
2007	3.27	0.56	1659	443
2008	2.34	0.83	1639	865
2009	1.62	0.47	1737	595

Degree-days were used to represent the overall water temperatures that juvenile Chinook salmon were exposed to during the rearing period each year. Temperature data were obtained from the United States Geological Survey gauge on the Stanislaus River located near Ripon, CA (11303000). Degree-days were calculated by summing the mean temperature for each day during the juvenile rearing period. The use of degree-days for calculating the temperature-dependent development of poikilotherms is widely accepted as a basis for building phenology and population dynamics models (Taylor & McPhail 1985; Roltsch *et al.* 1999), and accumulated thermal units (analogous to degree-days) have been shown to initiate physiological changes linked to outmigration behavior of juvenile Chinook salmon (Sykes & Shrimpton 2010).

In addition to the three physical parameters described above, the number of adult spawners was acquired for each study year. These data were used to account for potential density-dependent effects on the demographic metrics. Spawner numbers were estimated by annual carcass surveys performed by the California Department of Fish and Wildlife and obtained from their 'Grand Tab' data base file available at https://nrm.dfg.ca.gov/FileHandler.ashx?documentversionid=33911XXX.

Fish sampling

Rotary screw traps (2.4-m diameter cone; manufactured by E.G. Solutions, Corvallis, OR, USA), were operated at two locations from 1996 to 2009 to index survival between the traps and estimate the size and life stage of juvenile Chinook salmon emigrating from the system. Rotary screw traps (RSTs) are commonly used in the Pacific Northwest to monitor impacts of river management (e.g. habitat restoration, flow manipulation, dam management) on wild stocks (Volkhardt *et al.* 2007; Merz *et al.* 2013). Rotary screw traps are potentially powerful tools for validating assumptions regarding the effects of watershed restoration programs and land-use policies on fish populations (Solazzi *et al.* 2000; Johnson *et al.* 2005). These traps can also be used to assess survival between life stages, such as egg-to-smolt survival or parr-to-smolt overwinter survival (Solazzi *et al.* 2000; Johnson *et al.* 2005) and the effects of environmental parameters on migration timing and development (Sykes *et al.* 2009; Sykes & Shrimpton 2010).

The upstream RST was located at Oakdale (rkm 64.3; Fig. 1), which is immediately downstream from the majority of spawning habitat (hereafter referred to as the upstream trap). The upstream trap was assumed to provide a measure of juvenile Chinook salmon production from the spawning reach (Merz *et al.* 2013). The Caswell trap located at the lower extent of LSR rearing habitat (rkm 12.9) approximately 9 km from the San Joaquin River confluence (hereafter referred to as the downstream trap) was used to provide an estimate of out-migrating juveniles. Therefore, the lower trap provides a measure of size and survival of juvenile Chinook salmon exposed to the rearing reach just before exiting the LSR. Trap operations and configurations did not change among years at the upstream site where a single trap was operated. At the downstream site, two traps were operated in tandem for years 1996–2008; however, due to low flow and changes to site channel conditions, the trapping operation was relocated approximately 50 m downstream in 2009 to a site that would only accommodate a single trap.

Operation of LSR RSTs generally followed guidelines outlined in standard protocols [CAMP (Comprehensive Assessment & Monitoring Program] 1997; Volkhardt *et al.* 2007). Traps were deployed each year between mid-December and mid-January, and sampling was terminated when at least seven consecutive days of trapping resulted in zero catch. This typically occurred in June or July near the end of the Central Valley fall-run Chinook salmon emigration (Williams 2006). Traps were checked daily or multiple times per day depending on debris load. Trap cones were raised on days when sampling did not occur due to excess debris or dangerous conditions.

All Chinook salmon <200 mm fork length (FL) and not demonstrating secondary sexual characteristics (e.g. releasing milt, spawning coloration) were designated as juveniles. Chinook salmon in the LSR are considered 'ocean type' because they primarily emigrate from the system prior to their first winter and typically before July

(Clarke *et al.* 1994). However, there are at least two distinct migration strategies. Juveniles may emigrate from the LSR in winter or early spring prior to smoltification (fry and parr) and rear in the estuary or possibly other non-natal waters prior to ocean entry, or they may rear in the LSR and leave as smolts later in the spring (Limm & Marchetti 2009; Merz *et al.* 2013). To examine factors influencing interannual variation in out-migration strategy, juvenile Chinook salmon were sub-classified as pre-smolt and smolt life stages. Although specific life-stage designations (i.e. fry, parr or smolt) based on morphological characteristics were made in the field, there was considerable variability in the characteristics used to differentiate the life stages, depending on the year and personnel conducting the sampling. Therefore, a piecewise linear regression model for each year of data was used to provide a more objective temporal split between pre-smolt- and smolt-dominated migration periods. These models are commonly used to identify thresholds, or 'breakpoints', where the slope of a regression line changes (Betts *et al.* 2007; Muggeo 2008). First, fish lengths were plotted by date for each year and trap location to provide a visual representation of the pattern of change in fish size. Next, the segmented statistical package in R, which uses initial estimates of breakpoint(s) to iteratively fit a standard linear model to the data, was used to generate an estimated annual breakpoint value (Muggeo 2008). This value corresponded to a day for each year and was considered the 'smolt date' whereby all fish captured up to and including the smolt date were categorized as pre-smolts and all fish captured after the smolt date were categorised as smolts, regardless of previous life stage designation.

To derive accurate abundance estimates at each trap, it was first necessary to estimate RST efficiency for each site. Mark-recapture trials with juvenile Chinook salmon were performed to estimate trap efficiency at both sites. Experimental mark-recapture groups of both hatchery and natural-origin juveniles were used to estimate trap efficiencies at the upstream (n = 185) and downstream (n = 247) traps. Release group sizes ranged from 17 to 6737 depending on the availability of fish for the trial and were performed during periods of flow change and throughout the migration period to capture the range of efficiency variability. Fish were dye-marked using a photonic marking gun (MadaJet A1000, Carlstadt, NJ, USA) with dye on the caudal or anal fin. Releases occurred approximately 430 m upstream of the traps from the north bank at a narrow, deep area of the river. Fish releases occurred approximately 1 h after dark in small groups (5–10 individuals) to encourage mixing with natural (unmarked) Chinook salmon in the river, reduce schooling and mimic pulses in natural catch during nighttime migration. Marked fish were transported in a non-motorised boat and released across the channel at various points away from the bank. Traps were processed starting 1 h after completing release activities. Additional recaptures were recorded with the subsequent catch. To avoid pseudoreplication in efficiency analyses, data were pooled when multiple releases occurred on the same date. The maximum number of days post release that marked fish were collected ranged from 5 to 17 at the downstream trap and from 9 to 39 at the upstream trap.

Data analysis

Logistic regression was used to develop a predictive model of daily trap efficiencies. The dependent variable in these models was the binomial probability of capture. Independent variables included flow (log transformed), temperature, turbidity, fork length at release and year. A model was fit with an intercept (β_0), and then each explanatory variable was entered one at a time. The variable with the greatest explanatory power was then included in the model, and the remaining variables were again entered one at a time. The procedure was terminated when none of the remaining variables had a statistically significant effect on capture at $\alpha = 0.05$. The final model for the upstream trap included flow (negative relationship) and a year effect. The final model for the downstream trap included significant negative relationships with flow and fish fork length and a year effect.

Daily catch of migrating juvenile Chinook salmon for each trap was estimated as:

$$\hat{n} = \frac{c}{\hat{q}}$$

where c is the number of Chinook salmon captured each day and q is the estimated trap efficiency for that day from the logistic model. Error estimates for daily catch were calculated using the methods described in Appendix 1. During some years, there were periods when traps were not fished. A weighted average of all observed counts for the 5 days before and 5 days after the missing value were used to estimate a missing value of daily count (c) within a sampling period. The weights were equal to 1 through 5, where daily values that were 1 day before and after the missing day were weighted as 5, values that were two days before and after the missing day were weighted as 4, and so on. Annual catch estimates were generated by summing daily catch and error estimates (Fig. 2).

Three variables were estimated to describe the demographics of the juvenile Chinook salmon cohort in each

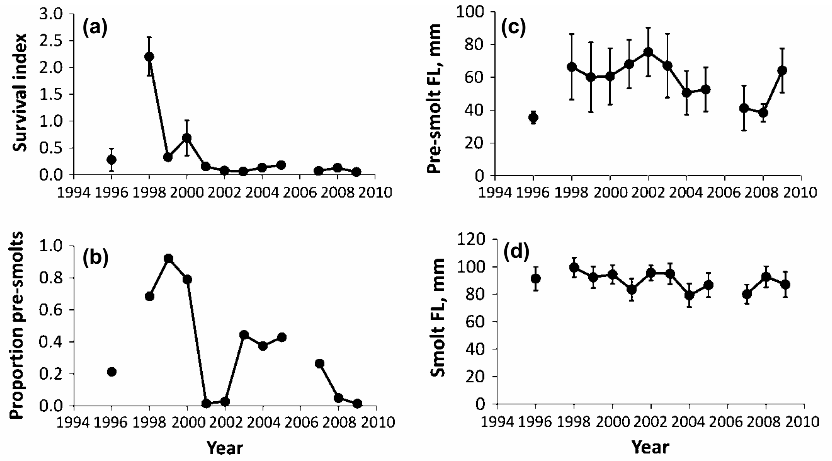

Figure 2. Demographic metrics (mean ± SD) of the Stanislaus River juvenile Chinook salmon population during 1996–2009. (a) Survival index. (b) Proportion of migrants classified as pre-smolts. (c) Mean fork length (FL) of pre-smolt migrants. (d) Mean FL of smolt migrants.

year. First, annual catch estimates at each trap were used to index survival between the two traps:

$$S_i = \frac{\widehat{P_D}}{\widehat{P_U}}$$

where S_i is the index of survival, $\widehat{P_D}$ is the estimated catch at the downstream trap and $\widehat{P_U}$ is the estimated catch at the upstream trap (Fig. 2). Second, migration strategy was estimated as the proportion of all juveniles that migrated out of the system as pre-smolts in each year. Third, the fork length of juvenile emigrants was estimated in each study year. Fish length was separated by pre-smolts and smolts because portions of the population migrate at each stage. Migration strategy and fish length were modeled using only data from the downstream trap because this location captured fish that were actively migrating out of the system.

Prior to modeling the demographic metrics, a correlation analysis was performed on predictor variables to identify potential sources of multicollinearity. Correlations between all predictors were high (>0.70); thus, the full suite of predictor variables could not be included in the same statistical model without unacceptable variance inflation. Instead, four models were constructed (one for each demographic metric), and the strength of each predictor was evaluated using an information-theoretic approach.

For each of the four demographic metrics, the assumption of normality was tested with a Shapiro–Wilk test and auto correlation was tested with cross-correlation coefficients. When a parameter was identified as non-normal, an appropriate transformation was applied and the assumption of normality was retested. Four linear models were constructed for each demographic metric (16 total models) where the independent variables were: (1) cumulative discharge; (2) discharge variance; (3) degree days and (4) spawner abundance. Akaike's information criterion corrected for small sample size ($\mathrm{AIC_c}$) was used to evaluate the weight of evidence for each predictor. The difference in $\mathrm{AIC_c}$ values between each candidate model and the best model was calculated ($\Delta\mathrm{AIC_c}$), and models with a value <2 were considered to have similar support in the data (Burnham & Anderson 2002). Model weights ($\mathrm{AIC_c}$ W) also were calculated. These values are interpreted as the probability of each model being the 'best' of the four evaluated. The R^2 values of models with $\Delta\mathrm{AIC_c}$ values <2 were used to evaluate overall model fit.

Finally, because estimates rather than observations were used as response variables in the linear models, Monte Carlo methods were used to reduce uncertainty in model estimates. One hundred re-samples of each response variable were performed for each year using a distribution informed by the sample mean and associated error. Abundance at each trap (used to calculate the survival index) was described by a negative binomial distribution, whereas a normal distribution was used for pre-smolt and smolt size. A predictor was considered to have good support in the data if the 95% confidence interval of its coefficient did not include zero.

Results

Survival

Indices for survival between the two traps ranged from 5% in 2009 to >200% in 1998 (Fig. 2). Fewer trap efficiency trials may have led to the survival index over 200% in 1998. As one of the survival estimates was >100%, the data were scaled so that the value for 1998 was 100% and the values for all other years were adjusted accordingly prior to use in statistical models. Following $\log_{10}$ transformation, the data were found to be normal ($W = 0.909$, $P = 0.209$) and no autocorrelation was detected ($r = 0.36$, $P = 0.338$). Model selection based on ΔAIC_c values revealed that cumulative discharge and discharge variance had similar support for predicting survival, whereas degree days and the number of spawners were relatively poor predictors (Table 2). Both models had good overall fit to the data with R^2 values of 0.68 and 0.67 for cumulative discharge and discharge variance, respectively (Fig. 3). The coefficient in both models was positive indicating that survival increased as cumulative discharge and discharge variance increased (Table 3). The Monte Carlo exercise revealed that 94% of models that included cumulative discharge and 89% of models that included discharge variance had coefficients with confidence intervals that did not include zero suggesting low uncertainty for these relationships.

Migration strategy

The proportion of juvenile Chinook salmon that migrated as pre-smolts ranged from >0.92 in 1999 to 0.01 in 2001 and 2009 with a mean of 0.35 (SD = 0.32). Autocorrelation was not detected in the data ($r = 0.54$, $P = 0.136$), and the assumption of normality was met ($W = 0.905$, $P = 0.183$). Cumulative discharge was the best predictor of migration strategy, and discharge variance also had support in the data. However, the ΔAIC_c value of 2.11 for discharge variance was >2.00 that was the cutoff for assuming a similar level of support as the best fit model. (Table 2). Overall fit was good for models of cumulative discharge and discharge variance with R^2 values of 0.43 and 0.33 respectively (Fig. 4). Similar to the survival models, the coefficients for both independent variables was positive indicating that more Chinook salmon juveniles migrated as pre-smolts when cumulative discharge and discharge variance were higher (Table 3). Monte Carlo estimates could not be generated for the migration strategy data because life stage-specific information was not consistently available from the efficiency tests to generate error estimates that could inform a distribution. All statistical analyses were performed with the program R (R Development Core Team 2012)

Table 2. Results of the model selection exercise for juvenile Chinook salmon demographic metrics (response variable). Models for each response variable are listed in order from the most to least likely

Response variable	Predictor	AIC_c	ΔAIC_c	AIC_c W
Survival index	Cumulative discharge	8.75	0.00	0.58
	Discharge variance	9.42	0.67	0.41
	Degree days	17.83	9.08	<0.01
	Spawner abundance	22.32	13.57	<0.01
Proportion of pre-smolt migrants	Cumulative discharge	5.73	0.00	0.68
	Discharge variance	7.84	2.11	0.24
	Degree days	11.09	5.36	0.05
	Spawner abundance	11.94	6.21	0.03
Pre-smolt size	Spawner abundance	−21.81	0.00	0.96
	Discharge variance	−13.53	8.28	0.02
	Degree days	−13.38	8.43	0.01
	Cumulative discharge	−13.25	8.56	0.01
Smolt size	Degree days	−47.03	0.00	0.42
	Cumulative discharge	−46.17	0.86	0.27
	Discharge variance	−45.89	1.14	0.24
	Spawner abundance	−43.47	3.56	0.07

Pre-smolt migrant size

Juvenile Chinook salmon that emigrated as pre-smolts averaged 63.5 mm FL across all years with the smallest and largest pre-smolt emigrants observed in 1996 and 2002 (35.5 and 75.4 mm respectively). The data were normal following $\log_{10}$ transformation ($W = 0.901$, $P = 0.163$), and autocorrelation was not significant ($r = 0.49$, $P = 0.182$). Spawner abundance was the only variable that accounted for size variation in pre-smolt migrants among years (Table 2). The R^2 value for this model was 0.51 indicating the model was a good fit to the data (Fig. 5). The size of pre-smolt migrants was greater in years with higher spawner abundance (Table 3). Models from the Monte Carlo exercise revealed only moderate certainty for the relationship with spawner density. Forty six percent of models yielded a coefficient with a confidence interval that did not include zero.

Smolt migrant size

Fork lengths of juveniles that emigrated as smolts averaged 86.8 mm across all years. The smallest smolt emigrants were observed in 2007 (80.1 mm) and the largest in 1998 (99.5 mm). Autocorrelation was not significant ($r = -0.170$, $P = 0.653$), and the logarithm-transformed data met the assumption of normality ($W = 0.933$, $P = 0.416$). Model selection indicated that three models were similarly supported predictors of smolt size (Table 2). The best model included degree days as the independent variable and competing models included cumulative discharge and discharge variance. All three competing models had moderately good fit with R^2 values of 0.31, 0.27 and 0.25 for degree days, cumulative discharge and discharge variance, respectively (Fig. 6). The coefficient for degree days was negative, whereas the coefficients for cumulative discharge and discharge variance were positive. The Monte Carlo exercise suggested high uncertainty in these relationships with ≤13% of models for any of the three predictors having

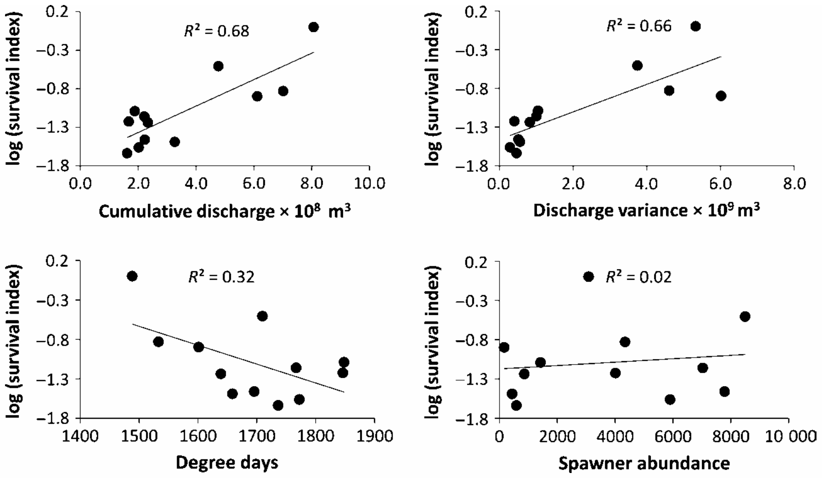

Figure 3. Relationships between the juvenile Chinook salmon survival index and four predictor variables.

Table 3. Coefficients and standard errors (in parentheses) for each predictor variable in linear models describing the four demographic metrics of juvenile Chinook salmon

Response variable	Cumulative discharge	Discharge variance	Degree days	Spawner abundance
Survival index	7.05×10^{-5} (1.52×10^{-5})	7.33×10^{-6} (1.64×10^{-6})	−0.002 (0.001)	2.16×10^{-5} (4.89×10^{-5})
Proportion of pre-smolt migrants	3.74×10^{-5} (1.34×10^{-5})	3.42×10^{-6} (1.54×10^{-6})	−0.001 (0.001)	2.48×10^{-5} (3.17×10^{-5})
Pre-smolt size	-1.28^{-6} (6.07×10^{-6})	-3.34×10^{-7} (6.32×10^{-7})	0.0001 (0.0002)	2.52×10^{-5} (7.78×10^{-6})
Smolt size	2.91×10^{-6} (1.54×10^{-6})	2.96×10^{-7} (1.64×10^{-7})	-1.57×10^{-4} (7.32×10^{-5})	2.87×10^{-6} (3.15×10^{-6})

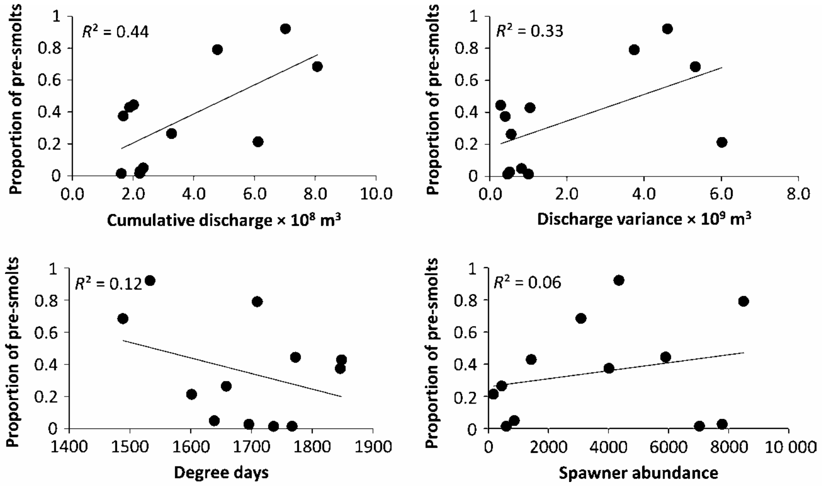

Figure 4. Relationships between the proportion of pre-smolt Chinook salmon migrants and four predictor variables.

coefficients with confidence intervals that did not include zero.

Discussion

The influence of flow regimes on the health of aquatic ecosystems has been widely recognised (Poff *et al.* 1997; Bunn & Arthington 2002). However, few studies have evaluated the demographic response of fish populations to flow regimes over multiple generations (Souchon *et al.* 2008). Analysis of 14 years of RST data on the LSR indicated that hydrology was a significant driver of several demographic characteristics of a Chinook salmon population. A strong positive response in survival, the

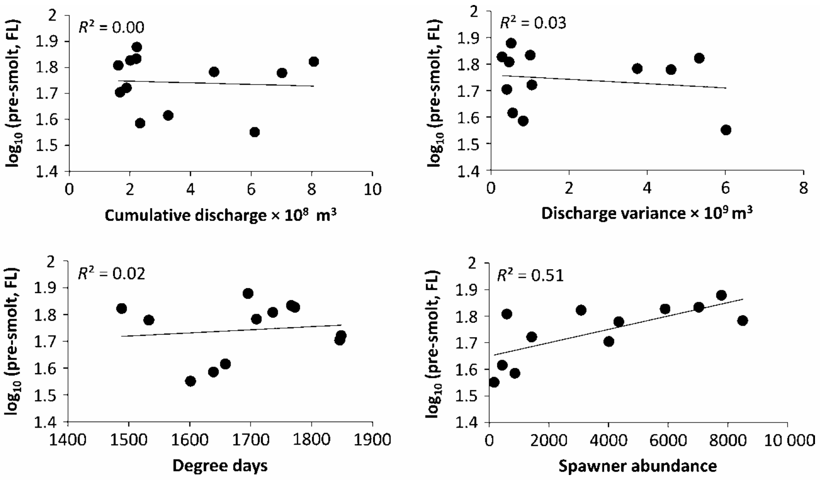

Figure 5. Relationships between the fork length (FL) of pre-smolt Chinook salmon migrants and four predictor variables.

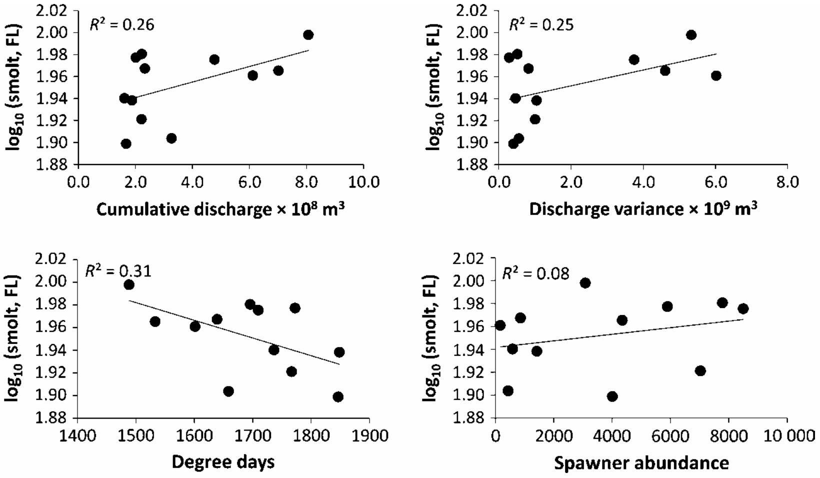

Figure 6. Relationships between the fork length (FL) of smolt Chinook salmon migrants and four predictor variables.

proportion of pre-smolt migrants and the size of smolts were observed when cumulative flow and flow variance were greater. Together, these data suggest that periods of high discharge in combination with high discharge variance are important for successful emigration as well as migrant size and the maintenance of diverse migration strategies.

Survival of migrating juveniles was higher when both cumulative discharge and discharge variance were greater. In a review of flow effects on salmonids, Nislow and Armstrong (2012) reported that reduced flow during the early emigration period was associated with lower growth and survival. Flow pulses provide fish access to seasonal habitats such as floodplains and side channels where food resources are often more abundant and predator densities lower (Junk *et al.* 1989; Bellmore *et al.* 2013). Chinook salmon rearing on California floodplains have been found to grow significantly faster than fish in the main channel (Sommer *et al.* 2001; Jeffres *et al.* 2008). Since the construction of New Melones Dam, the LSR has become increasingly incised resulting in greater disconnection from its floodplain because greater flows are now required for floodplain inundation (Kondolf *et al.* 2001). A lack of access to off-channel habitats in years with low discharge and discharge variance may partially explain why low survival indices were observed. Higher velocities within the main channel may also reduce exposure time of migrating juveniles to predation within a specific stream reach (Cavallo *et al.* 2013). While turbidity data were not available, increased turbidity during high flow events might also influence behavior and success of emigrating juveniles (Gregory & Levings 1998), and this should be investigated further.

The proportion of Chinook salmon juveniles migrating as pre-smolts also responded positively to higher cumulative discharge and discharge variance, supporting diversity in migration strategies (greater proportion of smolt migrants during lower discharge conditions, greater proportion of pre-smolt migrants during higher discharge conditions). It is unknown if LSR pre-smolt or smolt migrants survive better to later life stages; however, pre-smolt migrants from the Central Valley do survive and return as adults to spawn (Miller *et al.* 2010). The maintenance of multiple migration strategies can improve the persistence of salmon populations by spreading risk over space and time (Schindler *et al.* 2010). Reduction or elimination of the pre-smolt migration strategy by reducing cumulative discharge and discharge variance could have serious consequences for the LSR Chinook salmon population as risks associated with migration are increasingly concentrated into a relatively short time period (Carlson & Satterthwaite 2011).

The number of adult spawners was the only well supported predictor of pre-smolt size. Previous studies have found that marine-derived nutrients from spawner carcasses are incorporated into stream food webs that support juvenile salmon (Cederholm *et al.* 1999; Reimchen *et al.* 2002). Thus, increased spawner density may have increased productivity of invertebrate prey exploited by juvenile salmon or direct nutrient uptake from decomposing carcasses (Bilby *et al.* 1996). Alternatively, favorable ocean conditions that result in greater spawner returns may allow females to produce higher quality eggs that result in larger juveniles (Brooks *et al.* 1997; Heinimaa & Heinimaa 2004). However, caution should be used when interpreting this relationship. Negative density dependence may occur when spawner density exceeds the range observed during the years of this study. Thus, the relationship may not be linear across the range of potential spawner returns. Monte Carlo resamples of the data suggested there was only moderate certainty in this relationship. Additionally, both survival and the proportion of pre-smolt migrants could have stronger relationships with spawner density at levels above those observed during this study. The effects of quantity and quality of adult spawners on LSR juvenile offspring should also be evaluated further.

Juvenile size and water temperature at the time of Chinook salmon emigration can have a significant effect on ocean survival (Zeug & Cavallo 2013). Our results indicated that smolt size at emigration from the LSR had the strongest relationship with degree days. The Stanislaus River is located near the southern range limit of Chinook salmon spawning where temperatures can frequently exceed the optimum for the species (Myrick & Cech 2004; Williams 2006). Fish are strongly influenced by water temperature, which affects body temperature, growth rate, food consumption, food conversion and other physiological functions (Houlihan *et al.* 1993; Azevedo *et al.* 1998). The negative relationship between smolt size and temperature suggests that temperatures may get high enough to impede growth in certain years. Monte Carlo resamples indicated high uncertainty in all relationships with smolt size. However, the negative effects of altered flow regimes can be exacerbated by temperatures outside of the optimum for juvenile salmonids (Nislow & Armstrong 2012), and further investigation of this issue in the LSR is warranted.

Despite strong relationships between hydrology and early Chinook salmon ontogeny and survival within the LSR, several considerations should be recognised when interpreting these results. Although RSTs are a tool frequently used to monitor migratory fishes (primarily salmon), they only provide indirect evidence of survival in relation to environmental conditions. More direct evidence can be obtained with techniques such as biotelemetry; however, long term data sets obtained with these technologies are not yet available for analysis, nor does such technology presently lend itself to earlier stages of salmon (i.e. fry-sized fish). Additionally, RSTs may be limited during periods of high flows when debris loads compromise trap operations and field personnel safety. This could mean that RSTs underestimate the number of juvenile salmon emigrating during these periods. It is likely that this aspect of RSTs contributed to the 1998 results when a greater number of Chinook salmon was estimated at the downstream trap. Finally, information theoretic methods can only select the best models from a candidate set. There may be predictors not examined here that better explain the data (e.g. predation rate) but were not available for analysis. If data on other potential predictors are available in the future, their fit can be evaluated against the predictors examined here. Regardless of these issues, RSTs provide robust, long-term monitoring data sets that are required to evaluate population-level responses to changes in flow regime (Souchon *et al.* 2008; Poff & Zimmerman 2010), and model selection identified several strong relationships between juvenile Chinook salmon and flow regime.

Pacific salmon life history diversity differs significantly across streams with different hydrologic regimes (Beechie *et al.* 2006). Conservation of such diversity is a critical element of recovery efforts, and preserving and restoring life history diversity depends in part on environmental factors affecting their expression (Schindler *et al.* 2010). This study found significant responses from juvenile Chinook salmon demography to variation in the LSR hydrologic regime. Although many methods have been used to establish sufficient flows for fish (Jowett 1997), strategies that mimic aspects of the natural flow regime are more likely to be successful (Richter *et al.*

1997). Flow regimes are an integral part of the habitat template to which aquatic species are adapted (Townsend & Hildrew 1994; Lytle & Poff 2004), and mismatches between flow and species life history traits (e.g. migration strategy) can create bottlenecks for population persistence (Schiemer *et al.* 2003). Reduced flow variance and cumulative flow were associated with reduced survival and the proportion of pre-smolt migrants. Although the volume of water released in regulated streams is paramount to fisheries management, stream flows during biologically important times of the year appear equally important (Kiernan *et al.* 2012). Together, these data suggest that cumulative discharge, discharge variance and water temperature are important environmental drivers, and they all should be included in the development of regulated flows to support the persistence of Chinook salmon populations and diverse life history strategies. While this study focused on a single Pacific salmon race in a highly regulated system, the analyses demonstrated here can be employed wherever migratory species and environmental parameters are adequately monitored.

Acknowledgments

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Appendix (1) The following describes the methods used to estimate the variance and confidence intervals for total annual juvenile Chinook salmon catch. It begins with a description of the variance of a given daily catch estimate ($\hat{n}$), and then extends the formulas to the total annual catch. As noted in the methods, daily catch was estimated by:

$$\hat{n} = \frac{c}{\hat{q}}, \tag{1}$$

where c was the observed daily count of trapped juveniles and $\hat{q}$ was the estimated trap efficiency for that day. To simplify notation, $\hat{q}$ is expressed in terms of the daily 'expansion factor' denoted e, where:

$$\hat{e} = \frac{1}{\hat{q}}. \tag{2}$$

Thus, the daily catch estimate ($\hat{n}$) can be expressed as the following product:

$$\hat{n} = \hat{e}c. \tag{3}$$

There are two sources of variability in $\hat{n}$. First, there is error associated with the estimation of trap efficiency via logistic regression, which will be expressed as error in $\hat{e}$. Second, there is sampling error associated with the daily count (c), which is assumed to be a binomial variable. An estimate of the variance of $\hat{n}$ is given by Goodman (1960):

$$\hat{\sigma}^2\{\hat{n}\} = \hat{e}^2.\hat{\sigma}^2\{c\} + c^2.\hat{\sigma}^2\{\hat{e}\} - \hat{\sigma}^2\{\hat{e}\}.\hat{\sigma}^2\{c\} \tag{4}$$

To obtain a variance estimate for $\hat{e}$, it is fist expressed in terms of the back-transformation of the logit function (see equation (4)). Substituting equation 2 into equation 4 and rearranging yields:

$$\hat{e} = 1 + \exp[-(\hat{\beta}_0 + \hat{\beta}_1 x)] = 1 + \exp(-\hat{y}), \tag{5}$$

where $\hat{y}$ is the logit transform of the estimated trap efficiency $\hat{q}$ (see equation (3)). Given that the distribution of $\hat{y}$ is approximately normal, $\hat{e}$ is assumed to be lognormally distributed with an estimator of variance given by Gelman *et al.* (1995, p. 478):

$$\hat{\sigma}^2\{\hat{e}\} = \exp(-2\hat{y}) * \exp(\hat{\sigma}^2\{\hat{y}\}) * [\exp(\hat{\sigma}^2\{\hat{y}\}) - 1] \tag{6}$$

The variance of $\hat{y}$, which is a prediction from a linear regression, can be expressed in matrix notation as (Neter *et al.* 1990, p. 215):

$$\hat{\sigma}^2\{\hat{y}\} = \mathbf{X}'\mathbf{s^2}\{\mathbf{b}\}\mathbf{X}, \tag{7}$$

where **X** is a vector containing the daily values of the explanatory variables, **X'** denotes the transpose of **X**, and $\mathbf{s}^2$ $\{\mathbf{b}\}$ denotes the scaled estimate of the variance-covariance matrix for the logistic regression coefficients ($\hat{\beta}$). Specifically,

$$\mathbf{X} = \begin{bmatrix} 1 \\ x \end{bmatrix}, \mathbf{X}' = [1 \quad x], \mathbf{s}^2\{\mathbf{b}\} = \hat{\phi}\begin{bmatrix} \hat{\sigma}^2\{\hat{\beta}_0\} & \hat{\sigma}\{\hat{\beta}_0, \hat{\beta}_1\} \\ \hat{\sigma}\{\hat{\beta}_0, \hat{\beta}_1\} & \hat{\sigma}^2\{\hat{\beta}_1\} \end{bmatrix}. \tag{8}$$

Here, x is the daily value of log(flow). Note that the variance-covariance matrix for the logistic regression coefficients is multiplied (i.e. scaled) by the estimated dispersion parameter ($\hat{\phi}$) to account for extra-binomial variation. Equation 6 through equation 8 define the variance estimate for $\hat{e}$ required in equation 4. Also required in equation 4 is the variance of c, the observed daily count of trapped juveniles. Assuming that c follows a binomial distribution conditional on daily catch (n) and trap efficiency (q) (i.e. $c \sim \text{Bin}(n, q)$), the theoretical variance for c would equal $nq(1\text{-}q)$. However, a more reasonable and conservative approach is to assume that c is subject to the same extra-binomial variation estimated for the trap-efficiency tests. Extra-binomial variation would be expected due to unaccounted for factors affecting trap efficiency or characteristics of fish behavior, such as schooling. Thus, the variance of c is estimated as:

$$\hat{\sigma}^2 c = \hat{\phi}\hat{n}\hat{q}(1 - \hat{q}) \tag{9}$$

.

Equations A4 through A9 define the variance estimate for a given daily catch estimate ($\hat{n}$) given the estimated trap efficiency ($\hat{q}$) and trap count (c) for that day. The estimated total catch (N) of juveniles across days (i = 1, 2, 3, …, k) of the sampling season is the sum:

$$\hat{N} = \sum_{i=1}^{k} \hat{n}_i, \tag{10}$$

with associated variance (Mood *et al.* 1974, p. 179)

$$\hat{\sigma}^2\{\hat{N}\} = \sum_{i=1}^{k} \hat{\sigma}^2\{\hat{n}_i\} + 2\sum_{i=1}^{k-1} \sum_{j>i}^{k} \hat{\sigma}\{\hat{n}_i, \hat{n}_j\}. \tag{11}$$

The left side of equation 11 is sum of the variances of the daily catch estimates as defined by equation 4. The right side denotes the sum of the covariances among all pairs of daily catch estimates. These covariances arise from the fact that all daily catch estimates are based on predictions of q derived from the same logistic regression. Following from equations 3 and 5, the covariance of any two catch estimates can be approximated as follows:

$$\hat{\sigma}\{\hat{n}_i, \hat{n}_j\} = (c_i\hat{e}_i) * (c_j\hat{e}_j) * (\mathbf{X}'\mathbf{s^2}\{\mathbf{b}\}\mathbf{X}), \tag{12}$$

where

$$\mathbf{X} = \begin{bmatrix} 1 & x_i \\ 1 & x_j \end{bmatrix}, \mathbf{X}' = \begin{bmatrix} 1 & 1 \\ x_i & x_j \end{bmatrix}. \tag{13}$$

Again, $\mathbf{s}^2$ $\{\mathbf{b}\}$ denotes the scaled variance-covariance matrix for the logistic coefficients as in equation 8.

Approximate 95% confidence intervals for $\hat{\text{N}}$ assuming log normally distributed error is given by:

$$95\%LCI\{\hat{N}\} = \frac{\hat{N}}{c}, \text{ and } 95\%UCI\{\hat{N}\} = \hat{N} * c, \tag{14}$$

where

$$c = \exp(\text{Z}_{\alpha/2}) * \sqrt{\log_\text{e}(1 + (\hat{\sigma}\{\hat{\text{N}}\}/\hat{\text{N}})^2)} \tag{15}$$

NMFS Exhibit 7

Residence of Winter-Run Chinook Salmon in the Sacramento-San Joaquin Delta: The role of Sacramento River hydrology in driving juvenile abundance and migration patterns in the Delta

Submitted for the “Informational Proceeding to Develop Flow Criteria for the Delta Ecosystem Necessary to Protect Public Trust Resources”, scheduled to begin March 22, 2010

Residence of Juvenile Winter-Run Chinook Salmon in the Sacramento-San Joaquin Delta: Emigration Coincides with Pulse Flows and Floodplain Drainage

Rosalie del Rosario and Yvette Redler, National Marine Fisheries Service, Sacramento

Abstract

The Delta provides essential habitat for juvenile Sacramento River winter-run Chinook salmon as they rear and physiologically transform for ocean life. We identified patterns of juvenile migration entering and exiting the Delta by using monitoring data from the lower Sacramento River at Knights Landing and in the western Delta at Chipps Island. Average residence time in the Delta ranges from 2.5 to 3 months, and generally spans from November through April, with the majority of the population leaving in March. The onset of emigration to the Delta at Knights Landing is cued by upstream flows of 15,000 cfs at Wilkins Slough, and emigration from the Sacramento River to Chipps Island follows pulse flows of 20,000 cfs at Freeport. Smolts exit the Delta later in years when the Yolo Bypass floods. Understanding how flows affect residence of winter-run Chinook Salmon in the Delta is crucial to informing current water management decisions seeking to balance water demands and species conservation.

Introduction

Sacramento River winter-run Chinook salmon (*Oncorhynchus tshawytscha*) are endemic to California's Central Valley. Only one population of winter-run remains since their freshwater range has been limited from the upper Sacramento River below Keswick Dam to the Sacramento-San Joaquin Delta (Delta). The population's endangered status provides them protection under the federal Endangered Species Act, which affects natural resource uses in the Central Valley. Their sole route from freshwater to the ocean involves rearing and migrating through the Delta. Managing the Delta for this endangered species requires knowledge of when winter-run are in the Delta and how long they rear in the Delta.

Data Sources

Data on size, relative abundance, and residence time in the Delta were obtained for winter-run-sized fish from the following monitoring stations:

1. Knights Landing, rotary screw trap, 1996-2008, California Department of Fish and Game.
2. Sherwood Harbor, midwater and kodiak trawl survey, 1995-2008, U.S. Fish and Wildlife Service.
3. Chipps Island, midwater trawl survey,1995-2008, U.S. Fish and Wildlife Service.

Results and Discussion

1. Size and relative abundance show winter-run rear in the Delta.

Table 1. Mean Fork Length (mm) for juvenile Winter-run Chinook salmon in the Delta, 1995-2008

Color Key for Relative Abundance

High	Medium	Low	None /Rare

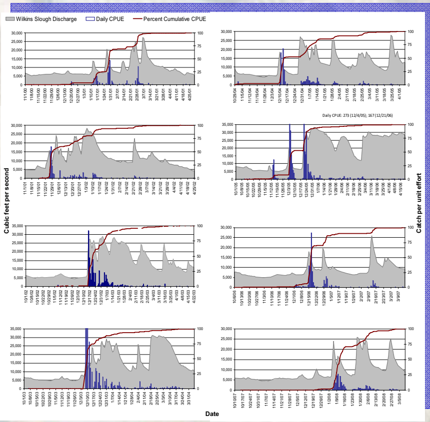
Monitoring Site	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Knights Landing (River Mile 89.5)	47	66	74	87	95	100	127					
Sacramento Trawl (River Mile 55)		66	74	91	101	104	114					
Chipps Island (River Mile 0)			90	106	113	110	117	140				

Winter-run smolts stay in the Delta an average of 2.5 to nearly 3 months. Early fry-sized (<70 mm) winter-run are detected in and north of the Delta starting in October followed by smolt-sized winter-run (>70 mm) starting December through April. These early fry migrants may be the first juveniles detected at Chipps Island in December where they are captured as smolts. The size distribution patterns as juveniles enter and exit the Delta suggest winter-run successfully rear and grow in the Delta. The monthly fork length distributions at the monitor sites indicate growth as the juveniles transit the Delta en route to the estuary. The large smolt-sized juveniles passing Knights Landing in April are likely the bulk of the May population caught at Chipps Island. Data from the monitoring sites clearly indicate rearing occurs in the Delta.

2. Upstream flows drive winter-run juvenile migration into the Delta.

The first autumn pulse flow exceeding 15,000 cfs triggers 50 percent of the population to enter the Delta on average four days following the event. The early migration pattern is abrupt as shown by the steep slope of cumulative catch per unit effort (Figure 1). The key management implication is that flows should be maintained to create sufficient rearing and migratory habitats in the Delta upon the abrupt entry of juveniles into the Delta triggered by pulse flow events.

Figure 1. Upstream flows of 15,000 cfs trigger winter-run juvenile emigration to Knights Landing, north of the Delta.



3. Floodplain inundation influences timing of Delta exit.

A secondary rearing and migratory route into the Delta becomes available to juvenile winter-run Chinook salmon in the Yolo Bypass during flood stage events in the Sacramento River. Chinook salmon rear in the Yolo Bypass floodplain each season it is inundated, and catch at the downstream end of the floodplain was greatest during the receding limb of the floodplain hydrograph (Sommer et al. 2005, North American Journal of Fisheries Management 25:1493-1504).

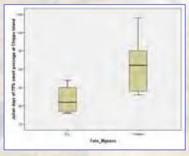


Figure 2. Smolts pass Chipps Island later in years when Yolo Bypass inundates (T-test, p = 0.03, n=4 for dry years; n=6 for flooded years).

In years when Yolo Bypass floodplain is inundated, smolts leave the Delta later. 75% of smolts exit the Delta nine days later when the Yolo Bypass is available as a rearing and migratory route. This emigration trend may support the theory that juvenile salmon take advantage of floodplain habitats to rear and that emigration coincides with drainage of the floodplain.

Table 2. Juvenile winter-run emigration to Chipps Island in the month of March.

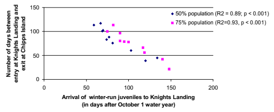
	Percent of total population exiting in March	Cumulative percent of population captured at Chipps Island by		March Freeport flows		March Rio Vista flows	
		March 1st	March 31st	Minimum (cfs)	Maximum (cfs)	Minimum (cfs)	Maximum (cfs)
1999	37	28	65	34,000	74,700	31,439	83,834
2000	56	19	75	27,100	81,100	22,416	132,056
2001	57	31	88	14,400	46,200	11,391	44,306
2002	36	29	65	17,379	28,806	13,847	24,245
2003	43	43	86	15,600	39,600	12,448	39,219
2004	78	18	96	20,400	71,300	18,068	145,426
2005	33	44	77	19,100	53,900	14,843	47,403
2006	37	9	46	57,596	71,500	60,138	154,051
2007	78	14	92	12,700	33,700	9,700	28,275
2008	45	42	87	9,260	28,000	7,108	25,747
mean	50	28	78	22,754	52,881	20,140	72,456
median	44	29	82	18,240	50,050	14,345	45,855

Sacramento-San Joaquin Delta

5. The earlier winter-run enter the Delta, the longer they stay.

Juvenile residence time in the Delta is a function of time of entry into the Delta, which is triggered by upstream Sacramento River flows. Given the consistency in timing of smolt exit from the Delta in March (Table 2, Figure 3), the earlier in the season juveniles enter the Delta, the longer their residence time in the Delta (Figure 4). In a Two-way ANOVA, residence time is significantly related to arrival time ($p < 0.001$) and flooding of the Yolo Bypass ($p = 0.10$).

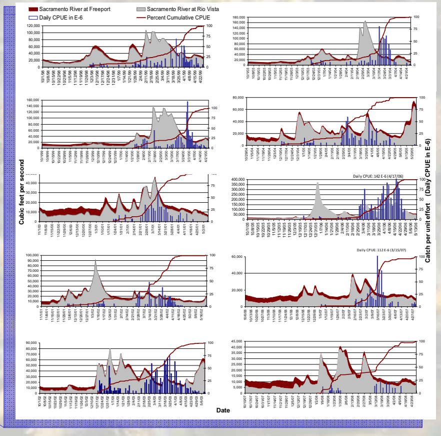
Figure 4. Residence time of winter-run juvenile population is inversely correlated with time of Delta entry.



4. Delta exit follows pulse flows, with majority leaving in March.

The first emigration to Chipps Island occurs on average 9 days following Sacramento River flow events exceeding 20,000 cfs, measured at Freeport (Figure 3). These early emigrants represent passage through the only available route along the lower Sacramento River and North Delta distributaries since the secondary route through Yolo Bypass becomes available upon inundation later in the season. In a typical year, 50 percent of the population leaves the Delta at Chipps Island during the month of March (Table 2). During this month, smolts migrating through the North Delta experience Sacramento River flow ranging from median flows of 18,240 cfs to 50,050 cfs, measured at Freeport.

Figure 3. Winter-run smolts exit the Delta at Chipps Island following upstream pulse flows.



Conclusions

1. Winter-run Chinook salmon rear in the Delta an average of 2.5 to 3 months starting in the late fall through early spring. Half of the population exit the Delta at Chipps Island between March 1 and 31.
2. Autumn upstream flows exceeding 15,000 cfs trigger a large portion of the emigrating juvenile population into the Delta on average four days after the event.
3. Emigrating smolts start leaving the Delta in the late winter on average nine days after pulse flows exceeding 20,000 cfs, measured at Freeport.
4. The early emigrating smolts leaving the Delta at Chipps Island have only the Sacramento River system available as their migratory route.
5. Residence time in the Delta is a function of when juveniles enter the Delta and flooding of the Yolo Bypass. Earlier arrival to the Delta yields longer residence time. Availability of floodplain rearing habitats provide for longer residence time.

These findings can help managers provide for rearing and migratory habitats in the Delta while winter-run Chinook salmon are present.

NMFS Exhibit 7

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Residence of Winter-Run Chinook Salmon in the Sacramento-San Joaquin Delta: The role of Sacramento River hydrology in driving juvenile abundance and migration patterns in the Delta

Rosalie B. del Rosario and Yvette J. Redler, National Marine Fisheries Service,
650 Capitol Mall, Suite 8-300, Sacramento, CA 95814

Pat Brandes, U.S. Fish and Wildlife Service,
4001 North Wilson Way, Stockton, CA 95205

ABSTRACT

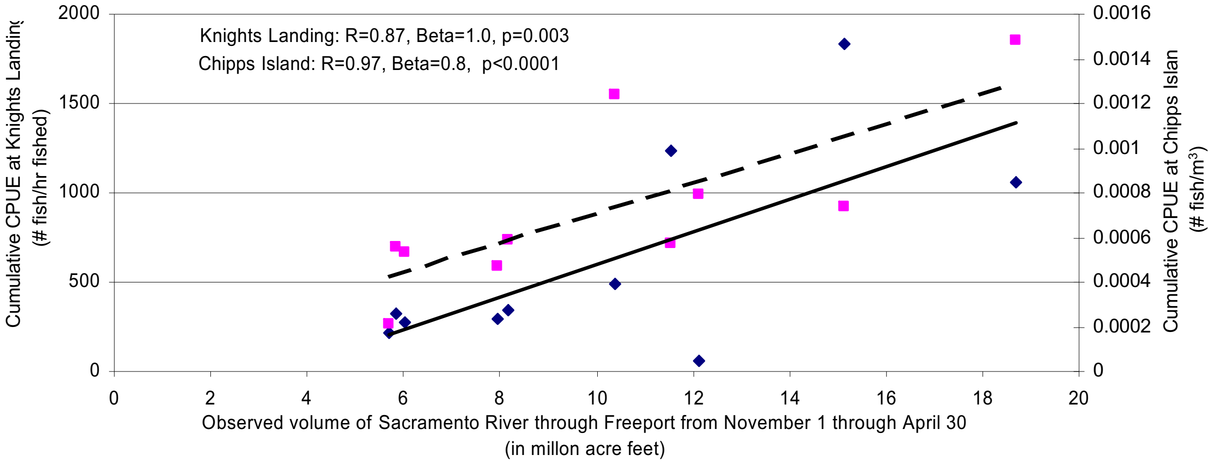
The Sacramento-San Joaquin Delta provides essential habitat for juvenile Sacramento River winter-run Chinook salmon as they rear and physiologically transform for ocean life. We identified patterns of juvenile abundance and migration entering and exiting the Delta by using monitoring data of winter-run sized fish based on assumed growth and size on date of catch criteria from the lower Sacramento River at Knights Landing and Sacramento and in the western Delta at Chipps Island.

Sacramento River hydrology drives both smolt abundance and emigration patterns in the Delta. The catch of winter run per unit effort is highly correlated with Sacramento River flows. Annual cumulative winter run smolt abundance entering the Delta at Knights Landing (measured as number of winter run per hour fished) and exiting at Chipps Island (measured as number of winter run per m^3) are each positively correlated with the cumulative volume of Sacramento River (measured at Freeport) during the emigration season; and neither abundance estimate is significantly correlated with annual spawner abundance (multiple regression, Knights Landing: $R^2=0.76$, $F=12.6$, $p=0.003$; Chipps Island: $R^2=0.93$, $F=53.7$, $p<0.0001$). Emigration patterns in the Delta are dependent on autumn and winter Sacramento River flow patterns. The first autumn pulse flow exceeding 15,000 cfs at Wilkins Slough triggers emigration of half the cumulative winter run catch at Knights Landing on average four days following the event, with the remaining population continuing to emigrate into the Delta during subsequent pulse flow events. The early emigrants leave the Delta at Chipps Island before spring on average 9 days following Sacramento River winter flow events exceeding 20,000 cfs, measured at Freeport.

Sacramento River hydrology also creates diversity in migratory routes and rearing habitats for winter run, when peak winter discharge allows for inundation of the Yolo Bypass floodplain. Patterns of winter run emigration from the floodplain are responsive to the floodplain's hydrograph, such that timing and frequency of floodplain drainage contributes to the temporal and size diversity of emigrants leaving at Chipps Island.

Sacramento River hydrology is related to average winter run residence time in the Delta, which is primarily a function of time of entry into the Delta. In a typical year, at least half of the cumulative catch at Chipps Island leaves the Delta during the month of March. Average residence time in the Delta ranges from 2.5 to 3 months, and generally spans from November through April.

Figure 1. Higher volume of flows during the winter run migration period results in greater abundance of winter run smolts entering the Delta at Knights Landing (diamonds, solid line) and subsequently exiting at Chipps Island (squares, dashed line), 1999-2008.



The hydrology of the Sacramento River drives winter-run smolt abundance and emigration patterns in the Delta. The annual cumulative winter run smolt abundance is highly dependent on the amount of flows in the Sacramento River, such that higher volume of water flowing in the river during the winter run emigration period results in greater abundance of winter run smolts both entering the Delta at Knights Landing (multiple regression, R^2=0.76, F=12.6, p=0.003), and subsequently exiting the Delta at Chipps Island (multiple regression, R^2=0.93, F=53.7, p<0.0001; Figure 1). This positive correlation between smolt abundance, expressed as annual cumulative CPUE at either sampling location, is not significantly correlated with annual spawner abundance (p>0.25).

Sacramento River flow data are from Interagency Ecological Program's Dayflow Sacramento station to represent flows at Freeport in the Sacramento River (http://www.water.ca.gov/dayflow/). The observed total volume of flow through Freeport during the winter run migratory period was calculated as the sum of mean daily flows from November 1 through April 30 of each year, and translated into million acre feet per emigration season.

RESEARCH ARTICLE

Reconstructing the Migratory Behavior and Long-Term Survivorship of Juvenile Chinook Salmon under Contrasting Hydrologic Regimes

Anna M. Sturrock[1¤*], **J. D. Wikert**[2], **Timothy Heyne**[3], **Carl Mesick**[2], **Alan E. Hubbard**[4], **Travis M. Hinkelman**[5], **Peter K. Weber**[6], **George E. Whitman**[7], **Justin J. Glessner**[8], **Rachel C. Johnson**[7,9]

1 Institute of Marine Sciences, University of California Santa Cruz, Santa Cruz, California, United States of America, **2** US Fish and Wildlife Service, Lodi, California, United States of America, **3** Tuolumne River Restoration Center, California Department of Fish and Wildlife, La Grange, California, United States of America, **4** School of Public Health, Division of Biostatistics, University of California, Berkeley, California, United States of America, **5** Cramer Fish Sciences, Auburn, California, United States of America, **6** Glenn T. Seaborg Institute, Lawrence Livermore National Laboratory, Livermore, California, United States of America, **7** Department of Animal Sciences, University of California Davis, Davis, California, United States of America, **8** UC Davis Interdisciplinary Center for Plasma Mass Spectrometry, Department of Geology, University of California Davis, Davis, California, United States of America, **9** National Marine Fisheries Service, Southwest Fisheries Science Center, Santa Cruz, California, United States of America

¤ Current address: Department of Environmental Science, Policy & Management, University of California, Berkeley, California, United States of America
* a.sturrock@berkeley.edu

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Abstract

The loss of genetic and life history diversity has been documented across many taxonomic groups, and is considered a leading cause of increased extinction risk. Juvenile salmon leave their natal rivers at different sizes, ages and times of the year, and it is thought that this life history variation contributes to their population sustainability, and is thus central to many recovery efforts. However, in order to preserve and restore diversity in life history traits, it is necessary to first understand how environmental factors affect their expression and success. We used otolith $^{87}Sr/^{86}Sr$ in adult Chinook salmon (*Oncorhynchus tshawytcha*) returning to the Stanislaus River in the California Central Valley (USA) to reconstruct the sizes at which they outmigrated as juveniles in a wetter (2000) and drier (2003) year. We compared rotary screw trap-derived estimates of outmigrant timing, abundance and size with those reconstructed in the adults from the same cohort. This allowed us to estimate the relative survival and contribution of migratory phenotypes (fry, parr, smolts) to the adult spawning population under different flow regimes. Juvenile abundance and outmigration behavior varied with hydroclimatic regime, while downstream survival appeared to be driven by size- and time-selective mortality. Although fry survival is generally assumed to be negligible in this system, >20% of the adult spawners from outmigration year 2000 had outmigrated as fry. In both years, all three phenotypes contributed to the spawning population, however their relative proportions differed, reflecting greater fry contributions in the wetter year (23% vs. 10%) and greater smolt contributions in the drier year (13% vs. 44%). These data demonstrate that the expression and success of migratory phenotypes vary with hydrologic regime, emphasizing the importance of maintaining diversity in a changing climate.

Introduction

Life history diversity is often cited as a crucial component of population resilience, based on theoretical and empirical evidence that asynchrony in local population dynamics reduces long-term variance and extinction risk at both regional and metapopulation scales [1]. Pacific salmon are recognized for their complex life histories, having evolved alongside the shifting topography of the Pacific Rim [2]. In the California Central Valley (CCV), four runs of imperilled Chinook salmon (*Oncorhynchus tshawytscha*) coexist, exhibiting asynchronous spatial and temporal distributions that allow them to exploit a range of ecological niches [3,4]. The maintenance of multiple and diverse salmon stocks that fluctuate independently of each other has been shown to convey a stabilizing 'portfolio effect' to the overall the stock-complex [5,6]. Such 'risk spreading' can also act at finer scales [7,8], such as within-population variation in the timing of juvenile emigration. Preserving and restoring life history diversity remains an integral goal of many salmonid conservation programs [9], yet baseline monitoring data with which to detect and respond to changes in trait expression are scarce and difficult to relate directly to population abundance.

The expression and success of certain traits can be largely driven by hydroclimatic conditions experienced during critical periods of development [10]. CCV Chinook salmon are at the southern margin of their species range, and are subjected to highly variable patterns in precipitation and ocean conditions [4,11]. It is also a highly modified system, with >70% of spawning habitat lost or degraded as a result of mining activities, dam construction, and water diversions [4,12]. The majority of salmon rivers in the CCV experience regulated flows according to 'water year type' (WYT). Optimization of reservoir releases presents considerable challenges, given often limited availability and multiple uses of the water resource, inability to predict annual precipitation, and uncertainty surrounding the direct and indirect effects of flow on salmon survival [13]. Such challenges are particularly critical for the more southerly San Joaquin basin, whose salmon populations fluctuate considerably with river flows experienced during juvenile rearing (Fig 1).

Juvenile Chinook salmon exhibit significant variation in the size, timing and age at which they outmigrate from their natal rivers [3,14]. Selection for one strategy over another may vary as a function of freshwater and/or marine conditions [10,15]. In the CCV, fall-run juveniles typically rear in freshwater for one to four months before smoltification prompts downstream migration toward the ocean [16]. In this system, contributions of the smaller fry and parr outmigrants to the adult population are often assumed to be negligible, as survival tends to correlate with body size [17,18] and there is little evidence for downstream rearing in the San Francisco estuary [19]. However, this has never been explicitly tested for smaller size classes. Indeed, salmon fry are frequently observed rearing in tidal marsh and estuarine habitats in other systems [3], and have been observed in non-natal habitats in the CCV, such as the mainstem Sacramento and San Joaquin Rivers, freshwater delta, and estuary [20]. Juvenile salmon that enter the ocean at a larger size and have faster freshwater growth have demonstrated a survival advantage when faced with poor ocean conditions [18]. Yet intermediate size classes can be better represented in the adult population [21,22], and size-selective mortality can be moderated by a variety of other processes [23]. In a regulated system such as the CCV, identifying the relationships between observable traits, hydroclimatic regime and survival would be invaluable for reducing uncertainty and predicting how populations may respond to climate change and management actions related to water operations.

Quantifying the relative contribution of fry, parr and smolt outmigrants to the adult population has, until now, been largely limited by the methodological challenges associated with reconstructing early life history movements of the adults. Mark-recapture studies using acoustic and coded wire tags (CWT) have provided empirical indices of juvenile survival through stretches of the Sacramento-San Joaquin River Delta (hereafter, “the Delta”) [24,25], but are hindered by low rates of return and tend to utilize hatchery fish that may exhibit different rearing behavior and sea-readiness to their wild counterparts [26]. Furthermore, ‘fry pulses’ tend to be dominated by individuals <45mm FL, which are difficult to mark externally without causing damage or behavioral modifications. No study to date has tracked habitat use of individual salmon over an entire lifecycle to estimate the relative success of juvenile outmigration phenotypes under different flow conditions. Previous studies have tended to rely on correlations between environmental conditions (e.g. flow) experienced during outmigration and the abundance of returns (Fig 1) [27]. Recent advances in techniques using chemical markers recorded in biomineralised tissues provide rare opportunity to retrospectively “geolocate” individual fish in time and space [28]. Given their incremental growth and metabolically inert

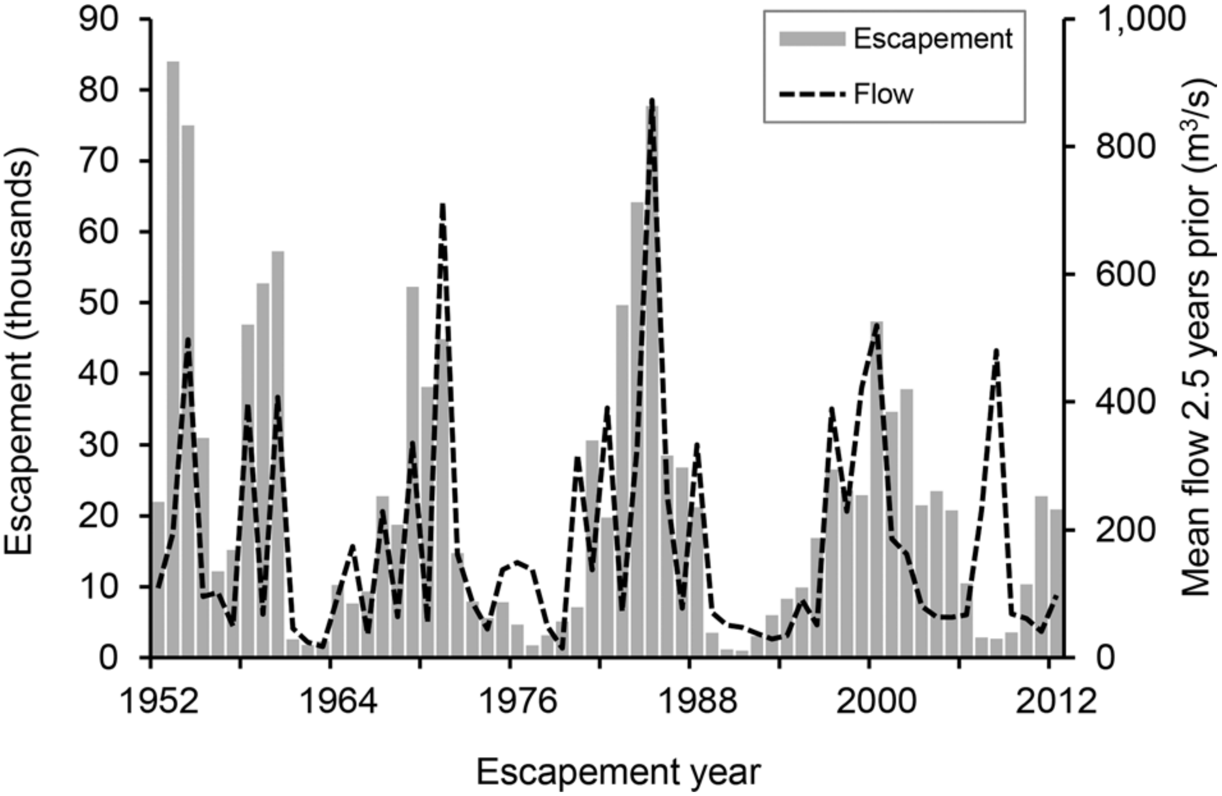

Fig 1. Relationship between adult salmon returns to the San Joaquin basin and the river flows experienced as juveniles. Fall-run Chinook salmon returns (‘escapement’) to the San Joaquin basin from 1952 to 2011 (CDFW GrandTab, www.CalFish.org) relative to mean flows at Vernalis (USGS gauge 11303500, http://waterdata.usgs.gov/nwis) for the January to June outmigration period they experienced 2.5 years previous. Note that adult abundance estimates have not been corrected for age distributions (we assumed that all adults returned at age 3), inter-annual variation in harvest rates or out-of-basin straying. The large deviation in 2007 reflected poor returns that were attributed to poor ocean conditions [96] and resulted in the closure of the fishery. Adapted from [97].

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nature, otoliths ('ear stones') represent a unique natural tag for reconstructing movement patterns of individual fish [29]. The technique relies on differences in the physicochemical environment producing distinct and reproducible "fingerprints" in the otolith. In the CCV, strontium isotopes ($^{87}Sr/^{86}Sr$) are ideal markers because the water composition varies among many of the rivers and is faithfully recorded in the otoliths of Chinook salmon [30–32]. Changes in otolith $^{87}Sr/^{86}Sr$ values can be used to reconstruct time- and age-resolved movements as salmon migrate through the freshwater and estuarine environments [33]. Furthermore, otolith size is significantly related to body size [34,35], allowing back-calculation of individual fork length (FL) at specific life history events [36].

Here, we document metrics of juvenile life history diversity (phenology, size, and abundance) of fall-run Chinook salmon as they outmigrated from the Stanislaus River during an 'above normal' (2000) and 'below normal' (2003) WYT. We used otolith $^{87}Sr/^{86}Sr$ and radius measurements to reconstruct the size at which returning (i.e. "successful") adults from the same cohort had outmigrated, then combined juvenile and adult datasets to estimate the relative contribution and survival of fry, parr and smolt outmigrants. Our main objectives were to determine (1) if a particular phenotype contributed disproportionately to the adult spawning population, (2) whether this could be attributed to selective mortality, and (3) if patterns in phenotype expression and success varied under contrasting flow regimes.

Study Area

The Stanislaus River (hereafter, "the Stanislaus") is the northernmost tributary of the San Joaquin River, draining 4,627 km^3 on the western slope of the Sierra Nevada (Fig 2) [37]. The basin has a Mediterranean climate and receives the majority of its annual rainfall between November and April. Contrasting with the Sacramento watershed in the north, the hydrology of the San Joaquin basin is primarily snowmelt driven [4]. There are over 40 dams in the Stanislaus, which collectively have a capacity of 240% of the average annual runoff [38]. Historically, the Stanislaus contained periodically-inundated floodplain habitat and supported spring- and fall-run Chinook salmon; however, spring-run salmon were extirpated by mining and dam construction, reducing habitat quality and preventing passage to higher elevation spawning grounds [4].

Materials and Methods

Ethics statement

This research was conducted in strict accordance with protocols evaluated and approved by the University of California, Santa Cruz Institutional Animal Care and Use Committee for this specific study (permit number BARNR1409). Otolith and scale samples were collected by California Department of Fish and Wildlife (CDFW) staff from adult salmon carcasses (i.e. already expired) as part of their annual carcass survey, permitted under the State legislative mandate to perform routine management actions. No tissue collections were taken from any state- or federally-listed endangered or protected species for this study.

Juvenile sampling and hydrologic regime

Typically, fall-run Chinook salmon return to the San Joaquin basin from September to early January, and their offspring outmigrate the following January to June [16,39]. Juveniles were sampled as they left the Stanislaus using rotary screw traps (RST) at Caswell Memorial State Park (Fig 2, N 37°42'7.533", W 121°10'44.882). Sampling was terminated when no juveniles had been captured for at least seven consecutive days in June or July [40]. Here, we focused on

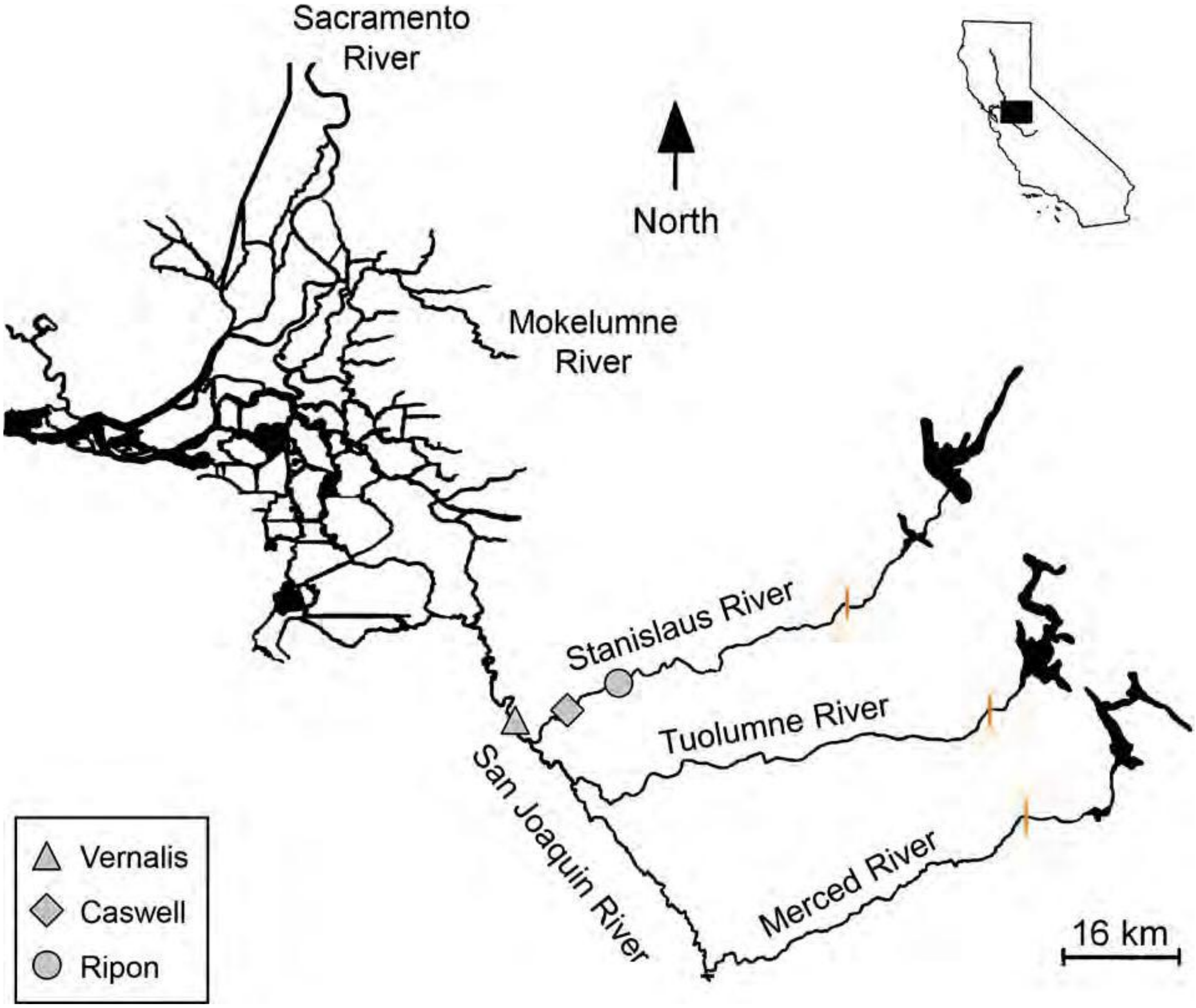

Fig 2. The San Joaquin basin of the Central Valley, California (inset). Map showing the major rivers in the San Joaquin basin, and the location of the rotary screw trap site at Caswell Memorial State Park and USGS gauges at Ripon and Vernalis. The upstream barriers to salmon migration in the three main tributaries are indicated by orange bars.

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an 'above normal' (2000) and 'below normal' (2003) WYT, and defined the outmigration period as January 1 to June 30, inclusive. When traps were checked, all fish were counted and up to 50 were randomly selected for fork length (FL) and weight measurements. Given potential subjectivity in visual staging criteria [41], we defined migratory phenotypes (fry, parr and smolt) by size: $\leq$55mm, $>$55 to $\leq$75mm, and $>$75mm FL, respectively (after [21]). Unmeasured fish were assigned to phenotype using the observed proportions in the measured fish for the same date. For each phenotype, we interpolated missing catch values with a triangular weighted mean [42].

Marked fish were periodically released to develop a statistical model of trap efficiency, which was used to expand counts of fry, parr and smolt-sized outmigrants. Trap efficiency was estimated using a GLM with a quasibinomial error distribution because of overdispersion in capture probabilities. We used the same efficiency model as [42], only using phenotype (fry, parr, smolt) to characterize fish size, rather than FL. We propagated uncertainty by deriving estimated expanded counts from repeated Monte Carlo draws (n = 2000) from the estimated sampling distribution of the estimated coefficients from the logistic efficiency model using R package mvtnorm [43]. Daily flow observations (USGS gauge no. 11303000 at Ripon, www.waterdata.usgs.gov/nwis) were used with the randomly-sampled model coefficients to simulate daily trap efficiency. Passage estimates were then simulated using daily catch and simulated trap efficiencies. We incorporated extra-binomial variation by generating simulated daily catch values from a beta-binomial distribution (based on the simulated efficiencies and passage estimates, as well as the dispersion estimated from the efficiency model). Finally, new daily passage estimates were calculated using simulated catch and trap efficiencies. Thus the final passage estimates incorporate both sampling error (catch) and estimation error (efficiency model). Annual passages estimates and confidence intervals (2.5% and 97.5% quantiles) were generated by summing daily passage estimates for the 6 month outmigration period (i.e. n = 2000 x 180 days).

Measured daily size-frequency distributions were applied directly to the expanded abundance estimates, then grouped into 2mm FL bins. We attempted to produce passage estimates by FL, but the distribution used in the uncertainty propagation procedure (see above) is asymmetric at low catches, resulting in zero-inflation and the median of the resampled distribution often being lower than the observed raw catch.

Turbidity was measured at Caswell using a LaMott turbidity meter [40]; mean daily flow and maximum daily temperature were measured at Ripon (gauge details above). Daily passage estimates, turbidity, flow and temperature were $\log_{10}$ transformed, then averaged for the 6-month outmigration period and compared among years by ANOVA, adjusting for temporal autocorrelation using the Durbin-Watson (DW) test [44]. Pearson's chi-squared test was used to identify differences in the proportion of phenotypes among years. Fry, parr and smolt phenology was summarized using three metrics associated with their date of passage past the trap: the range, interquartile range (IQR), and median (or "peak") outmigration date. Phenotype "migratory periods" were defined as the maximum IQR for both years combined.

Adult sampling and cohort reconstruction

To track outmigration cohorts 2000 and 2003 into the adult escapement, sagittal otoliths were extracted from Chinook salmon carcasses (aged 2–4 years, 45–112 cm FL) collected in the 2001–2006 CDFW Carcass Surveys (Table 1). Unmarked fish were sampled randomly, but in earlier years, known-hatchery fish with CWTs and clipped adipose fins ("adclipped") were preferentially sampled to assess the accuracy of age estimations. We utilized all otoliths collected from all unmarked fish, but included a subset of CWT fish from outmigration year 2000 (n = 27), which we analyzed blind to assess the accuracy of our natal assignments. Ages were estimated by counting scale annuli [45,46]. Each scale was aged by at least two independent readers and discrepancies resolved by additional reading(s).

Table 1. Adult sample sizes, age structure and collection periods.

	Outmigration cohort 2000 (wetter)			Outmigration cohort 2003 (drier)		
Age	N	%	Collection period	N	%	Collection period
2	6	7%	11/20/01–12/06/01	2	2%	11/08/04–11/12/04
3	80	87%	10/07/02–12/12/02	56	67%	11/02/05–12/15/05
4	6	7%	11/12/03–12/04/03	25	30%	11/15/06–12/06/06

Otoliths were analyzed from salmon carcasses belonging to adults that had outmigrated in 2000 and 2003, including 27 known-origin fish included as a blind test of our natal assignments.

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Otolith $^{87}Sr/^{86}Sr$ analyses

Otolith strontium isotope ratios ($^{87}Sr/^{86}Sr$) were measured along a standardized 90° transect [47] by multiple collection laser ablation inductively coupled plasma mass spectrometry (MC-LA-ICPMS; Nu plasma HR interfaced with a New Wave Research Nd:YAG 213 nm laser). Spot analyses were used to allow coupling of chemical data with discrete microstructural features, but otherwise preparation and analysis methods followed those of Barnett-Johnson et al. [32,48]. In brief, otoliths were rinsed 2–3 times with deionized water and cleaned of adhering tissue. Once dry, otoliths were mounted in Crystalbond resin and polished (600 grit, 1500 grit then 3 μm lapping film) until the primordia were exposed. Depending on sample thickness and instrument sensitivity, a 40–55μm laser beam diameter was used with a pulse rate of 10-20Hz, 3–7 J/cm^2 fluence, and a dwell time of 25–35 seconds, resulting in individual ablations roughly equivalent to 10–14 days of growth. Where individual ablations exhibited isotopic changes with depth (e.g. at habitat transition zones), only the start of the ablation was used (e.g. S1 Fig). Helium was used as the laser cell carrier gas (0.7–1.0 L/min) to improve sample transmission and was mixed with argon before reaching the plasma source. Krypton interference (^{86}Kr) was blank-subtracted by measuring background voltages for 30 s prior to each batch of analyses, and ^{87}Rb interferences were removed by monitoring ^{85}Rb. Isotope voltages were integrated over 0.2 s intervals then aggregated into 1 s blocks. Outliers (>2SD) were rejected. Marine carbonate standards ('UCD Vermeij Mollusk' and *O. tshawytscha* otoliths) were analyzed periodically to monitor instrument bias and drift, producing a mean mass-bias corrected $^{87}Sr/^{86}Sr$ ratio (normalized to $^{86}Sr/^{88}Sr = 0.1194$) within 1SD of the global marine value of 0.70918 (0.70922 ± 0.00008 2SD).

Strontium isotopes to reconstruct natal origin and size at outmigration

The baseline of natal $^{87}Sr/^{86}Sr$ signatures described in [32] was updated and expanded upon to increase sample sizes and among-year representation, resulting in an 'isoscape' that encompassed all major CCV sources, with many sampled across multiple years and hydrologic regimes. Linear discriminant function analysis (LDFA) was used to predict the natal origin of the sampled adult spawners, assuming equal prior probabilities for all sites (S1 Text). Differences in natal $^{87}Sr/^{86}Sr$ values were tested between years and sites (S1 Text, S1 Table and S2 Fig), and the performance of the LDFA was assessed using known-origin reference samples (S2 Table). Adults in this study were considered strays (not produced in the Stanislaus) when their natal $^{87}Sr/^{86}Sr$ were closer to other sources in the isoscape, and were excluded from further analysis.

For adults that had successfully returned to the Stanislaus, we monitored the change in $^{87}Sr/^{86}Sr$ across the otolith to identify the point at which they had outmigrated as juveniles. The Stanislaus has a significantly lower isotopic value (0.70660 ± 0.00008 SD) than the mainstem San Joaquin River immediately downstream from it (0.70716 ± 0.00013 SD), resulting in a clear increase and inflection point in otolith $^{87}Sr/^{86}Sr$ at natal exit (e.g. Fig 3B). If the inflection point was unclear, sequential spot analyses were analyzed by LDFA, and exit was defined as a >0.3 decrease in posterior probability of Stanislaus-assignment to a probability <0.5. Deviation from the mean $^{87}Sr/^{86}Sr$ Stanislaus value was assumed to reflect considerable time spent in non-natal water, as (1) the Stanislaus $^{87}Sr/^{86}Sr$ signature shows minor variation in otoliths (S1 Table) and water samples collected immediately upstream of the confluence, (2) the RST location is 13.8rkm upstream of the confluence (Fig 2) and (3) the length of time integrated by each laser spot is ~12 days. Therefore, the distance used to back-calculate exit size was from the otolith core to the last natal spot. To improve resolution and accuracy, additional ablations were performed around the transition zone, typically resulting in sub-weekly resolution.

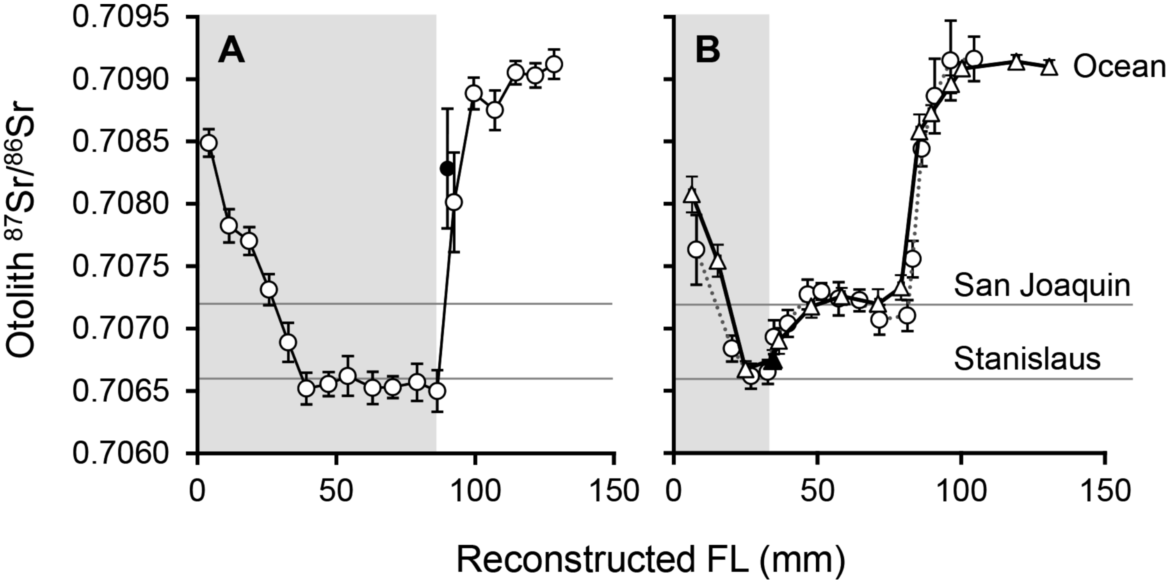

Fig 3. Otolith $^{87}Sr/^{86}Sr$ reconstructions of a smolt and fry outmigrant. Otolith $^{87}Sr/^{86}Sr$ profiles against back-calculated FL for two adult Chinook salmon that returned to the Stanislaus River having outmigrated as (A) a smolt and (B) a fry. The shaded box indicates the time spent rearing in the natal river. The fry outmigrant reared for several weeks downstream in the San Joaquin River before migrating out to the ocean, as indicated by both the left (triangles, solid line) and right (circles, dashed line) otolith (back-calculated FL = 33.3mm *vs*. 34.9mm). Mean $^{87}Sr/^{86}Sr$ signatures for the Stanislaus and San Joaquin Rivers, and modern-day ocean are displayed. Black filled symbols indicate 're-spots' carried out to improve sampling resolution. Error bars = 2SE.

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Reconstructed size at outmigration in the returning adults

The relationship between otolith radius (OR) and FL was first calibrated using juveniles collected from multiple sites in the CCV (S3 Table). All individuals belonged to the same Evolutionarily Significant Unit, which is critical for producing unbiased back-calculation models [49]. As there was no difference in the OR of paired otoliths from single individuals (n = 30, $\bar{x}\triangle$ = 2.5μm, 95% CI = -5.6–10.6μm), left and right otoliths were used interchangeably. OR was measured along the same 90° transect used for isotope analyses, using a Leica DM1000 microscope and Image Pro Plus (7.0.1).

Reconstructed sizes were grouped into 2mm FL bins and categorized as fry, parr or smolt outmigrants based on the criteria of [21]. Size-frequency distributions were compared between the juvenile and adult samples to identify trends indicative of size-selective mortality. The error around the OR-FL calibration line was used to estimate 95% CI around the proportions of fry, parr and smolt outmigrants using random resampling (n = 5000) of the residuals. This allowed us to derive the relative contribution of each phenotype to the adult spawning population.

Survival of juvenile migratory phenotypes

To generate survival indices, we normalized the contribution of each phenotype to the adult population by their abundance within each outmigration cohort based on RST sampling. To estimate spawner abundance ("natural escapement"), we removed adclipped strays from total escapement estimates (GrandTab, available at www.calfish.org) using river- and year-specific tag recovery rates (S4 Table), then separated cohorts using annual age distributions [50] and removed unmarked strays using our otolith natal assignments (see results and S4 Table). We evaluated the use of spawner abundance *vs*. "adult production" (after [51]). While production accounts for different harvest rates among years [52], the two metrics produced similar trends in survival ($r^2 = 0.98$), and we found that escapement, which includes harvest, bycatch and natural mortality between outmigration and spawning, to be more intuitive to interpret.

The otolith-derived proportions (±95% CI) of phenotype i in the escapement (β_i) were applied to our natural escapement estimates (E_n) to estimate the number of fry, parr and smolt spawners (E_i), then E_i was compared with the number of outmigrants of phenotype i (J_i) to estimate their relative survival (S_i):

$$E_i = E_n\beta_i \qquad S_i = E_i/J_i$$

To estimate 95% CI for S_i we combined error in β_i and J_i using the delta method. The 95% CI for S_i depends on the estimate and its standard error (SE): $\hat{S}_i,\ SE(\hat{S}_i)$. Assuming independence of β_i and J_i, we estimated variance as $SE(\log(\hat{S}_i)) \cong \sqrt{\left(\frac{1}{\hat{J}_i}\right)^2 SE^2(\hat{J}_i) + \left(\frac{1}{\hat{\beta}_i}\right)^2 SE^2(\hat{\beta}_i)}$. From this, we derived 95% CI for S_i as $\left(e^{\log(\hat{S}_i)-1.96\times SE(\log(\hat{S}_i))}, e^{\log(\hat{S}_i)+1.96\times SE(\log(\hat{S}_i))}\right)$. Note that uncertainties in adult escapement were not incorporated into these confidence intervals; however, the RST-expansions used to estimate J_i were deemed likely to introduce the largest amount of error.

Results

Juvenile outmigration relative to hydrologic regime

Mean flow and turbidity for the 6 month outmigration period were higher in 2000 than 2003 (DW-adjusted $F_{1,\,361} = 7.52$, $p = 0.006$ and $F_{1,\,257} = 14.53$, $p = 0.0002$, respectively) (Fig 4). In the drier year (2003) the river was warmer during the smolt migratory period (Apr 15-May 18: DW-adjusted $F_{1,\,60} = 4.54$, $p = 0.037$) and peak daily temperatures first exceeded 15°C three weeks earlier (Fig 4).

Peak flows were about five times higher in 2000 than 2003, and accompanied by spikes in turbidity and juvenile migration (Fig 4). The number of outmigrants was an order of magnitude higher in 2000 (Table 2), reflecting significantly higher daily abundances of fry, parr and smolt outmigrants (DW adjusted $F_{1,\,161} = 11.23$, $p < 0.001$; $F_{1,\,196} = 47.99$, $p < 0.001$; $F_{1,\,199} = 6.45$, $p = 0.0118$, respectively). While fry dominated in both years, phenotype contributions differed significantly between years ($X^2 = 223{,}683$, $p < 0.001$), with parr approximately twice as abundant as smolts in 2000, but vice versa in 2003 (Table 2). One yearling (FL = 140mm) was

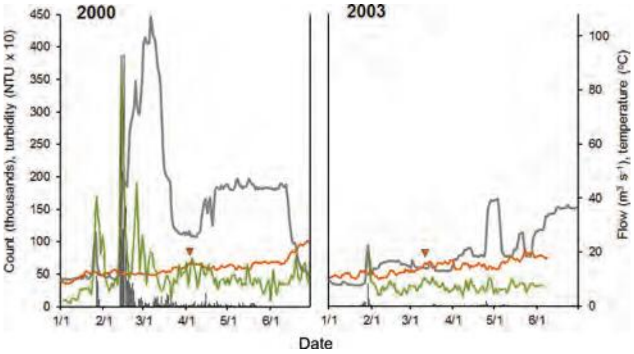

Fig 4. Daily abundance of juvenile salmon outmigrating in 2000 and 2003 relative to ambient environmental conditions. Juvenile salmon were sampled by rotary screw traps at Caswell as they outmigrated from the Stanislaus, and raw counts were expanded into daily abundance estimates (vertical bars) based on trap efficiency models. River flow (grey line) and maximum daily temperature (orange line) were measured at Ripon (data available at http://cdec.water.ca.gov/). Turbidity (green line) was measured at Caswell [40]. The first instance of temperatures reaching 15°C is indicated by an arrow on each plot.

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Table 2. Abundance and migration timing of juvenile migratory phenotypes.

Outmigration cohort	Migratory phenotype	N (95% CI)	Proportion of the sample	Duration of migratory period (range)	Duration of "peak" migratory period (interquartile range)	Peak migration date (median)
2000 (wetter)	Fry	1,837,656 (1,337,351–2,495,523)	0.85	115 d (Jan 2-Apr 25)	4 d (Feb 14-Feb 17)	Feb 16
	Parr	212,042 (141,238–310,174)	0.10	116 d (Feb 4-May 29)	29 d (Mar 18-Apr 15)	Apr 1
	Smolt	101,467 (70,181–145,793)	0.05	110 d (Mar 8-Jun 25)	34 d (Apr 15-May 18)	May 9
	TOTAL	2,151,165 (1,577,638–2,911,393)				
2003 (drier)	Fry	79,862 (59,795–103,916)	0.50	80 d (Jan 23-Apr 12)	4 d (Jan 27-Jan 30)	Jan 29
	Parr	25,729 (17,889–36,282)	0.16	118 d (Feb 5-June 2)	27 d (Mar 18-Apr 13)	Mar 21
	Smolt	55,465 (38,415–76,289)	0.34	107 (Feb 24-Jun 10)	21 d (Apr 18-May 8)	Apr 25
	TOTAL	161,056 (119,868–209,151)				

The abundance and proportions of fry, parr and smolt outmigrants sampled by rotary screw traps, and the timing of their outmigration from the Stanislaus River in 2000 and 2003.

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captured in the RST in 2000, but none in 2003, otherwise the size range of outmigrants was similar between years (25-115mm in 2000 *vs*. 27-115mm in 2003).

Phenology varied between phenotypes and years (Table 2 and Fig 5). In general, migratory windows were shorter and earlier in the drier year, with smolt outmigration ceasing 15 days earlier in 2003 than in 2000. The peak migratory periods were similar across years for fry and parr, the former exhibiting a compressed interquartile range (4 d) that was tightly correlated with the start of winter flow pulses (Fig 5).

Natal origin of unmarked adults

The unmarked adults from outmigration cohorts 2000 and 2003 comprised 18% and 51% hatchery strays, respectively, primarily from the Mokelumne, Merced, and Feather River

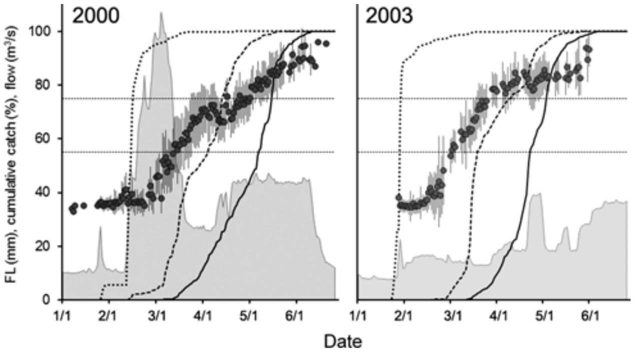

Fig 5. Size and phenology of juveniles outmigrants relative to river flow in 2000 and 2003. Mean (±SD) daily fork length (FL) of juvenile outmigrants, and cumulative percentage of fry (short dashed line), parr (long dashed line) and smolt (solid line) outmigrants relative to flow (filled area). Reference lines indicate the size categories used to define the migratory phenotypes: fry (≤55mm), parr (55-75mm) and smolts (>75mm).

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Table 3. Natal assignments of unmarked adults based on otolith $^{87}Sr/^{86}Sr$.

Natal source	Outmigration cohort 2000 (%)	Outmigration cohort 2003 (%)
Stanislaus River	82	49
Mokelumne River Hatchery	11	39
Merced River Hatchery	2	1
Feather River Hatchery	5	7
Nimbus Hatchery	2	2
Thermalito Rearing Annex [a]		1

Natal assignments of unmarked adults fish captured in the Stanislaus River between 2001 and 2006 that outmigrated in 2000 and 2003.

[a] Part of the Feather River Hatchery

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Hatcheries (Table 3). These individuals were removed from subsequent analyses, ensuring that size back-calculations were calculated only for Stanislaus-origin fish that had experienced the same outmigration conditions as the RST-sampled juveniles.

Back-calculation of size at outmigration

A strong, positive relationship was observed between OR and FL ($r^2 = 0.92$, n = 224, $p < 0.001$; FL = 0.171 (±0.003 SE) x OR—12.76 (±1.54 SE)), remaining linear across the full range of FLs reconstructed in the current study. This relationship was used to reconstruct FLs for individual $^{87}Sr/^{86}Sr$ profiles (e.g. Fig 3). The back-calculated size at which returning adults had outmigrated from the Stanislaus ranged from 31.3mm to 86.6mm in 2000, and 46.0mm to 90.5mm in 2003 (Fig 6). No yearlings were detected in the adult returns in either year.

To explore reproducibility of the method, paired left and right otoliths were analyzed from a subset of adults (n = 3 fry and n = 1 smolt outmigrant). All fish were assigned to the same migratory phenotype using either otolith, and the mean difference between back-calculated FLs was 2.3mm (e.g. Fig 3B).

Contribution and survival of juvenile migratory phenotypes

The relative abundance of the migratory phenotypes in the escapement differed significantly to the outmigrating juvenile population in both 2000 ($X^2 = 20{,}931$, $p<0.0001$) and 2003 ($X^2 = 1{,}381$, $p<0.0001$). The phenotype composition of the adult population also differed significantly between years ($X^2 = 749$, $p<0.0001$), reflecting higher fry contributions in the wetter year (23% in 2000 *vs.*10% in 2003) and higher smolt contributions in the drier year (44% in 2003 *vs.* 13% in 2000). Despite representing only 10–16% of the outmigrating juveniles (Table 2), parr were the most commonly observed phenotype in the surviving adult populations (46–64%, Table 4), although parr and smolt contributions to the escapement were near-identical in 2003 (46% vs. 44%, respectively). Conversely, fry outmigrants represented 10–23% of the adult escapement, despite representing 50–85% of the juvenile sample (Tables 2 & 4). The lowest survival was observed in individuals <45mm, particularly in 2003, when the smallest outmigrant in the adult sample had left the river at 46mm FL, while the smallest individual captured in the RST was 27mm FL (Fig 6). Conversely, in 2000, 11% of the adults had left at FLs ≤46mm (the smallest at 31.3mm), compared with 80% of the original juvenile population (the smallest at 25mm; Fig 6).

In both years, fry survival downstream of the Stanislaus (S_{fry}) was significantly lower than parr or smolt survival ($p<0.05$). S_{parr} was approximately double S_{smolt} in both years, but the confidence intervals were overlapping (Table 4). Generally, outmigrant survival downstream of

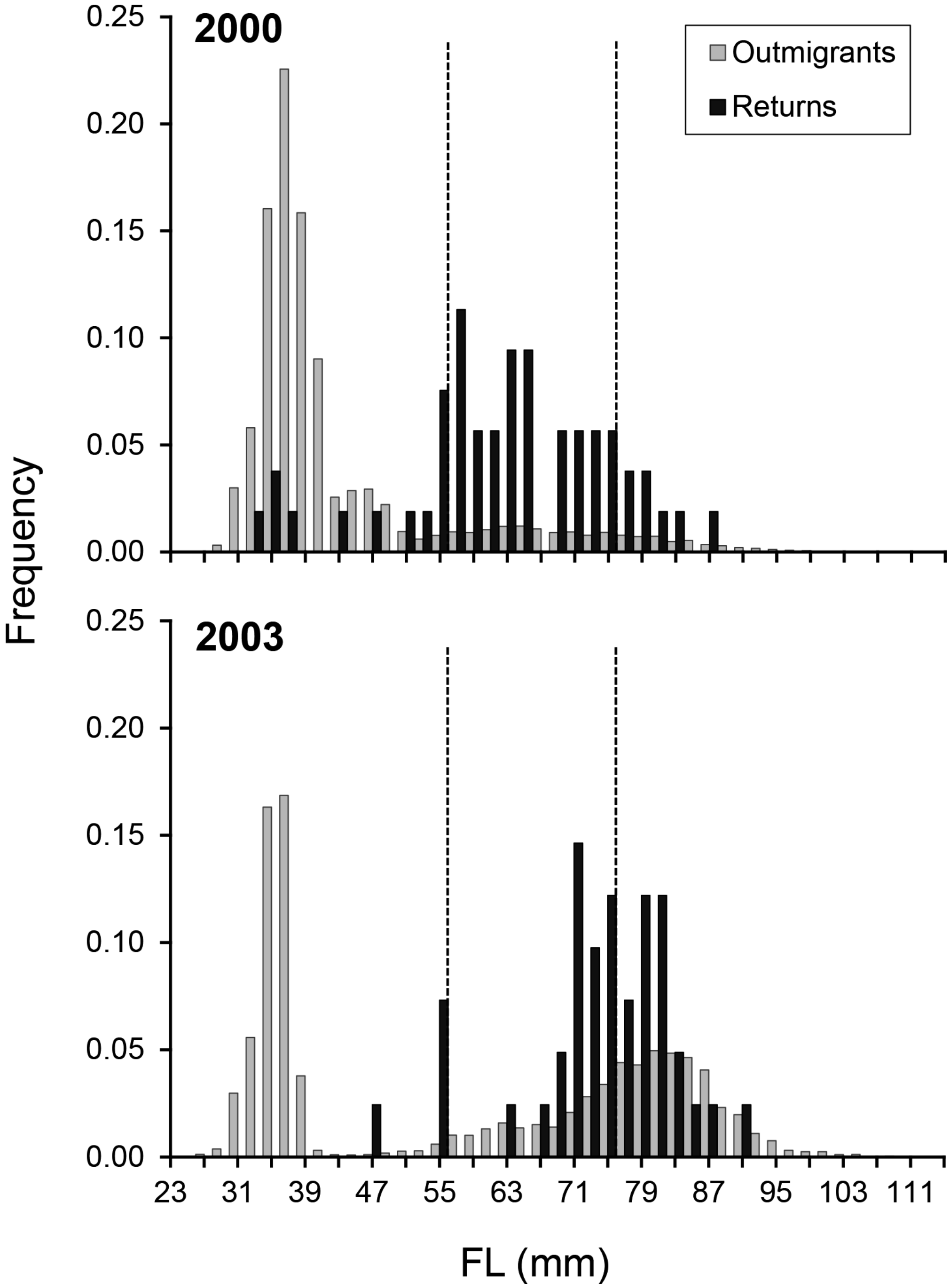

Fig 6. Size-at-outmigration of the juveniles and surviving adults that left freshwater in 2000 and 2003. Size-frequency distributions showing the fork length (FL) at which juveniles outmigrated from the Stanislaus River in 2000 and 2003 (grey bars) and the reconstructed size-at-outmigration of the returning (i.e. "successful") adults from the same cohort (black bars). FLs given in 2mm bins (where the x-axis represents ≤ that value, e.g. "55" = FL 53.01–55.0mm). Size classes used to categorize fry, parr and smolt outmigrants are indicated by dashed lines.

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the Stanislaus was slightly higher in the drier year (2003) than the wetter year (2000), but significant differences were not detected (Table 4).

Table 4. Contribution and survival of fry, parr and smolt outmigrants to the adult escapement.

Outmigration cohort	Phenotype	Contribution to the adult escapement (%) [a]	No. spawners produced [a]	Survival (%) [b]
2000 (wetter)	Fry	23 (19–36)	1,334 (1112–2113)	0.07 (0.04–0.12)
	Parr	64 (43–66)	3,781 (2557–3892)	1.78 (1.15–2.76)
	Smolt	13 (9.4–25)	778 (556–1446)	0.77 (0.39–1.52)
2003 (drier)	Fry	10 (2.4–12)	148 (37–186)	0.19 (0.1–0.33)
	Parr	46 (34–61)	705 (520–928)	2.74 (1.73–4.34)
	Smolt	44 (34–59)	668 (520–891)	1.2 (0.78–1.87)

[a] 95% CI in parentheses, derived from error around the FL back-calculation model.

[b] 95% CI in parentheses, derived from error around the FL back-calculation and RST efficiency models

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Discussion

In this study we document the expression of juvenile salmon migratory phenotypes under two contrasting flow regimes and provide new insights into their contribution to the adult spawning population and ultimate survival. We observed variable expression and survivorship of fry, parr and smolt life histories within and between years, yet all three phenotypes consistently contributed to the adult spawning population. This result challenges the common perception in the CCV, that smolt outmigrants are the dominant phenotype driving adult population abundance. Our key findings in the context of the salmon life cycle in order to link the datasets, methods, and processes examined in the study (Fig 7). Overall, the wetter year (2000) was characterized by higher numbers of juvenile outmigrants and adult returns, despite fewer adult spawners contributing to the cohort the previous fall. Using the number of parental spawners as a coarse proxy for juvenile production, these trends suggest higher in-river mortality in the drier year (2003). Given similar downstream (outmigration-to-return) survival rates, these data suggest that for the two focus years of the study, cohort strength was primarily determined within the natal river, prior to juvenile outmigration.

Juvenile outmigration behavior and phenotype expression

Juvenile outmigration timing in salmonids is inextricably linked to large-scale patterns in hydroclimatic regime and local-scale patterns in the magnitude, variation, and timing of flows [14,42]. In the Stanislaus, increases in flow were accompanied by pulses of outmigrants in both years, though greatly amplified during the turbid storm events of 2000. Correlations between fry migration, flow, and turbidity are commonly reported in the literature [14,53,54], and are suggested to have evolved as a result of reduced predation from visual piscivores [14,27,55,56]. The peak in migration in late January 2003 contained 85% of the year's total fry outmigrants and coincided with a managed water release that resulted in mean river flows of 28.4 $m^3 s^{-1}$ [57]. This pulse flow appeared to stimulate fry migration, but comprised relatively clear water (~8 NTU) and contained outmigrants almost entirely <40mm FL (Fig 5). In both years, the larger parr- and smolt-sized fish also appeared to respond to instream flows, exhibiting smaller migration pulses from March through May, coincident with both natural and managed flows (Fig 4) [58,59].

The date and periods of peak migration were generally earlier and shorter in 2003, particularly for smolts. While warmer conditions can result in faster growth rates [60], smoltification in juvenile Chinook salmon is significantly impaired at temperatures above 15°C [61] and this critical temperature was reached at Ripon three weeks earlier in 2003, prior to the onset of peak parr migration. As the reduction in juvenile abundance in 2003 occurred in spite of greater

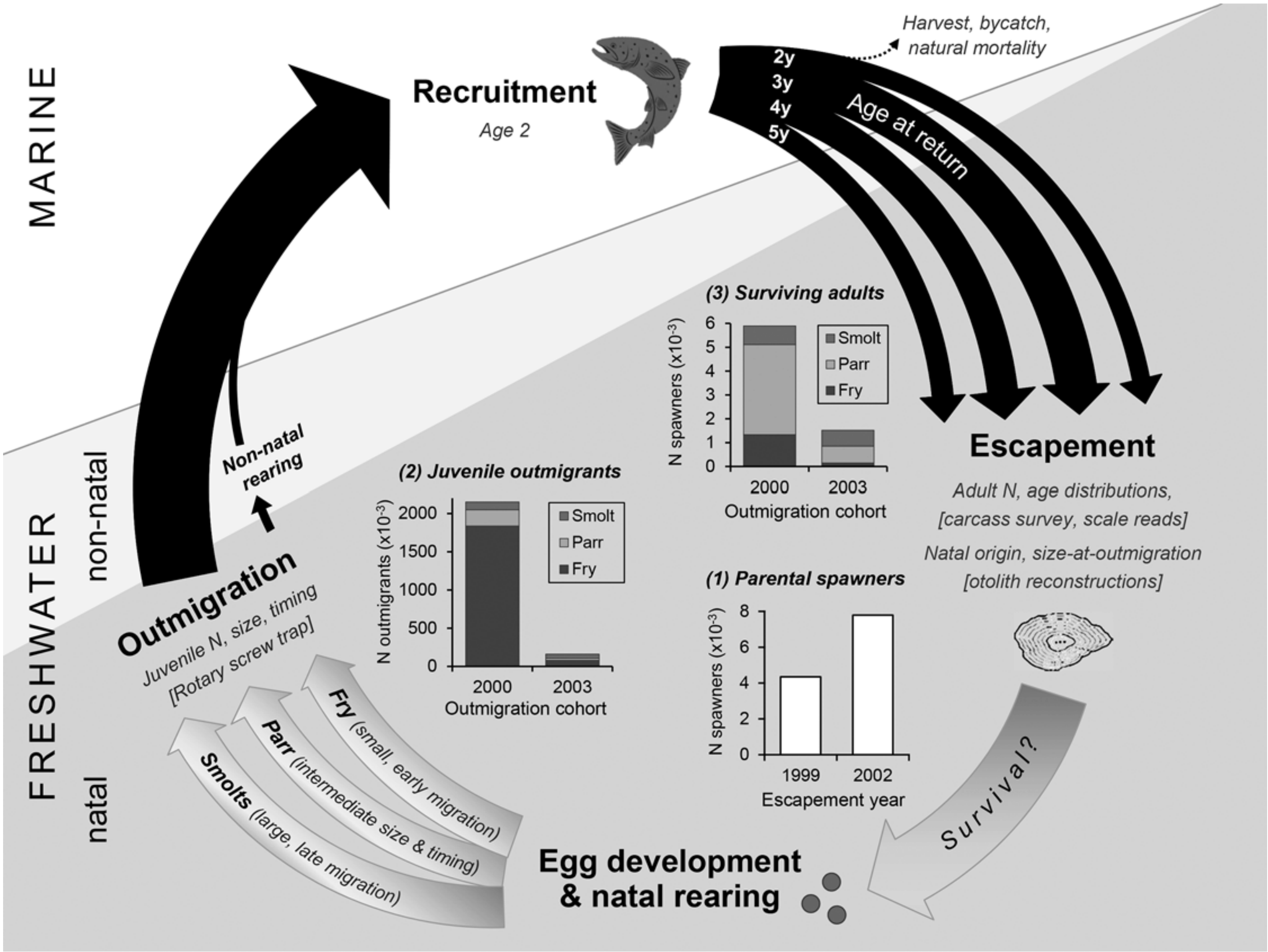

Fig 7. Schematic to conceptualize the data sources, methods and results presented in this study. This figure outlines the life cycle of fall-run Chinook salmon in the California Central Valley. Inset plot (1) demonstrates the abundance of parental spawners in the 1999 and 2002 escapement that contributed to the two focus years. Inset plots (2) and (3) illustrate the abundance and proportions of migratory phenotypes (fry, parr and smolts) observed in the juvenile sample (based on RST sampling) and in the adult escapement (based on otolith reconstructions), respectively. Arrow widths (not to scale) illustrate the typical proportions of 2, 3, 4 and 5 year olds observed in the adult escapement; note that age 5 fish tend to comprise <1% of the returns [50].

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numbers of parental spawners (Fig 7), we hypothesize that the truncation of migratory periods was driven by in-river mortality rather than altered migration timing or faster transitions between size classes. Juveniles tend to encounter less floodplain habitat, and increased predation rates and physiological stress in warmer, drier years [62], which likely resulted in a lower carrying capacity in the natal tributary [63] and increased density dependent mortality [64,65].

Survival of migratory phenotypes

Although lower flows and warmer temperatures in the Stanislaus may have contributed to the lower outmigrant production observed in 2003, our results suggest that after exiting the natal river, there was no significant difference in juvenile survival. Survival rates were, if anything, marginally higher in 2003, contradicting many tagging studies which find reduced salmon survival through the freshwater delta during low flow conditions [24,66–68]. This discrepancy is likely due to differences in the sampling design and the time period represented by the different indices. Tagging studies generally release larger hatchery fish in similar sized batches during the later months of the outmigration season, when warmer conditions likely increase their vulnerability to predation [62]. Conversely, our survival estimates were based on variable numbers of fish over a larger size spectrum and broader migratory window, incorporating mortality events in all habitats downstream of the natal river, including the mainstem river, delta, estuary and ocean. However, we assume that differences in our survival indices would be driven by selective mortality events occurring during outmigration and early ocean residence. In support of this, there was no relationship between back-calculated size at outmigration and return FL ($r^2 < 0.01$, $p > 0.05$), implying that size-selective mortality did not vary by phenotype in the adult fish. However, marine distributions of adult salmon can be non-random [69], and if driven by timing at ocean entry, the migratory phenotypes could have been subjected to different ocean processes and mortality rates even as adults.

Parr and smolt outmigrants. Life history theory predicts selection to favor different phenotypes under different hydrologic regimes, maintaining behavioral and phenotypic diversity [70]. Yet in the current study, parr consistently exhibited the greatest contribution to the adult population and the highest survival rates. Greater representation of intermediary-sized juveniles has also been observed in some years in the ocean fisheries of Chinook [21] and Atlantic salmon [22], contradicting the expected directionality of size-selective mortality. Generally, larger or faster-growing individuals within a population are thought to have a selective advantage as a result of greater feeding opportunities, lower vulnerability to predation and greater tolerance of environmental perturbations [71]. However, the strength of size-selection in juvenile CCV Chinook salmon can vary as a function of ocean productivity [18], highlighting the importance of maintaining life history diversity in outmigration strategies. Without large-scale field experiments, it is not possible to definitively ascertain why smolts were not the most successful phenotype, however the San Joaquin basin is at the southernmost reaches of the species distribution [3] and its salmon populations are exposed to high temperatures, poor water quality, and significant water diversions [72,73]. This frequently results in river conditions that could impair growth and smoltification, and increased vulnerability to predation and disease [62], particularly at the end of the season when smolt-sized fish are most prevalent. Thus, the survival advantage of parr is likely attributable to both size and migration timing, analogous to the marine-orientated "critical size and period hypothesis" proposed by Beamish and Mahnken [74]. Furthermore, current flow practices in the San Joaquin basin include managed releases in April and May, intended to improve the survival of smolts [75]. These managed flows typically occur after most parr have left their natal tributaries, potentially selecting for this phenotype by providing downstream benefits as they migrate through (or rear in) the San Joaquin River and freshwater Delta.

Fry outmigrants. Little is known about the factors driving fry behavior or survival, yet the numbers that outmigrated during the wetter year (2000) were orders of magnitude higher, when they also contributed more than double the number of adult survivors (23% in 2000 *vs.* 10% in 2003). While fry consistently exhibited lower survival rates than their conspecifics (Table 4), reflecting the typical direction for size-selective mortality [71], the fact that any survived to contribute to the adult population, let alone contributing >20% of the adult returns, is a significant finding. Based on these data, their sheer abundance during high flow conditions at least partially helps to explain the increases in returns following wet outmigration conditions in the San Joaquin watershed (Fig 1). Early-migrating fry and parr may represent a significant portion of the population that can access favorable downstream rearing habitats in high flow years and survive to contribute to the adult population. Indeed, our otolith reconstructions indicated that all of the smallest (≤46mm FL) fry outmigrants in the surviving adult population (n = 4 in 2000, n = 1 in 2003) had spent several weeks rearing in the San Joaquin mainstem prior to leaving freshwater (e.g. Fig 3B). These data corroborate the extended transit times of CWT-tagged fish released in the San Joaquin basin and freshwater Delta in wetter years (averages of 16 d in 2000 vs. 6 d in 2003), although their mean size also differed (81mm vs. 87mm, respectively) [58]. Fry are observed in downstream freshwater and estuarine habitats in the CCV [20,76], and were probably more common when the Delta was a large tidal wetland [14,24,53]. This study confirms that these individuals can survive and contribute meaningfully to adult returns.

Currently there are no genetic data to support or refute a heritable component to early outmigration behavior, but it could otherwise meet the criteria of an adaptive trait, given that its expression is associated with "differential survival" and there is evidence for "a mechanism of selection" [77]. There is still some debate as to whether fry pulses during high flow events represent displacement due to reduced swimming ability or a deliberate behavior that might be considered a 'strategy' [3,14]. While catastrophic floods undoubtedly result in riverbed scouring and some fry displacement, not all individuals outmigrate during these events. Conversely, some fry migration is observed during periods with no pulse flows [78]. Given the frequency with which this phenotype is reported and the considerable rearing potential of downstream habitats, it is conceivable that fry dispersal is a heritable strategy, representing a 'migratory contingent' within the population [79,80]. Indeed, their consistent contribution to the adult population (observed here and in [21]) conclusively demonstrates that fry migration can be successful. If, however, early outmigration is purely an expression of phenotypic plasticity, it is likely that multiple factors are involved in stimulating the behavioral switch, including hydrology, intraspecific interactions [3] and density dependent mechanisms [65,81–83]. Irrespective of the underlying mechanisms, quantifying the relative success of migratory phenotypes across a broader range of hydrologic regimes is fundamental to understanding how environmental conditions and water operations contribute to salmon population dynamics.

Otolith strontium isotopes and sources of uncertainty

One of the most significant advances of the current study was the pairing of RST sampling with otolith reconstructions. This process enabled us to compare fish size at a specific time and location across life stages, and provided a unique method for generating survival estimates into adulthood. CWT studies and acoustic telemetry have provided valuable insights into survival through particular stretches of the CCV [25,75], but tend to focus on larger fish and provide no information about the long-term success of particular traits. In addition, acoustic tags have focused on understanding flow-survival relationships for smolts, which are physiologically ready for seaward migration and likely use the mainstem rivers, delta, and estuary differently than fry or parr, which may exhibit prolonged rearing. Otolith $^{87}Sr/^{86}Sr$ ratios are an ideal natural tag as they vary among many of the rivers in the CCV, resulting in high classification scores for natal assignments (S1 and S2 Tables) [30,32,84]. Sr isotopes also represent a unique and sensitive marker for reconstructing downstream movements and non-natal rearing patterns in the freshwater system (e.g. Fig 3B). While seasonal variation in $^{87}Sr/^{86}Sr$ values have been reported in certain systems [85] and interannual variations were detected for some sites (S1 Table), these were minor compared with most of the geographic differences, with the majority of sites exhibiting classification scores >70% even when pooled across years (S2 Table). Importantly, the Stanislaus exhibited a stable and distinct isotopic signature; with 96% of juveniles correctly classified using jack-knife resampling (S2 Table). Identification of natal origin represents a significant advantage of using otolith Sr isotopes over element concentrations. This was critical for pairing RST- and otolith-derived datasets and providing confidence that our size reconstructions were not skewed by hatchery smolts.

A high occurrence of straying of fall-run Chinook salmon occurs between the San Joaquin and Sacramento basins [86–88], potentially due to the relative outflows during the return migration as well as hatchery release practices [89]. However the extent to which hatchery fish are functioning to sustain the San Joaquin salmon populations has gone largely undetected until recently [86,87]. In the current study, hatchery strays represented 18–51% of the unmarked fish, reducing the number of samples available to inform outmigration strategies of wild fish and increasing analytical costs. However, the removal of strays was vital to ensure that FL reconstructions were only performed on individuals that had experienced the same conditions as the RST-sampled juveniles. The implementation of 100% visual identification of hatchery fish [90] would increase the feasibility and efficiency of future life history diversity studies in this system.

We attempted to reduce and account for sources of uncertainty, but the low number of focus years and sample sizes, and the potential for error propagation limit the strength of our inferences. With greater representation of 2 and 4 year olds in our adult sample, a more sophisticated analysis using age-specific natal assignments could have been carried out. While no yearlings were detected in the surviving adults, their rarity in the RST-sampled outmigrant population indicate that larger sample sizes would be required to ascertain the success of this strategy with any confidence. Similarly, our approach for assigning natal origin based on otolith chemistry following yolk sac absorption means that individuals that outmigrated as yolk sac fry could have been misclassified as strays. However, yolk sac fry are rarely observed in the outmigrant population (0.1% of the 2001–2011 RST catch at Caswell), so this was deemed unlikely to significantly influence our results.

Management implications

The complex biophysical properties of freshwater systems have led to the evolution of dynamic habitat mosaics [91] and diverse salmon life histories and distributions. The observed life history diversity likely provides within-population buffering, an as yet understudied component of the portfolio effect [5,6]. These data add to the mounting evidence that managing and conserving life history diversity is necessary to support resilient salmon populations, particularly in the face of climate change and projected human population growth [9,10]. Diversity in phenotypic traits is thought to produce a more stable population complex by decoupling population dynamics and buffering variance [6]. However, population resilience does not necessarily immediately translate into population abundance. In a highly regulated system such as the CCV, there is debate as to whether environmental unpredictability dictates a need to manage salmon stocks for diversity and resilience, or whether our understanding of (and control over) the relevant processes is sufficient to manage purely for abundance. Such topics are complicated by socio-economic and ecological trade-offs, however, by improving our understanding of how juvenile life history strategies are expressed and respond to different flow regimes, we may be able to optimize both. Currently, the portfolio effect for CCV salmon stocks is weak and deteriorating [92] and San Joaquin populations face serious future challenges, given predicted 25–40% reductions in snowmelt by 2050 [93]. CCV salmon exhibit diverse outmigration timings that have evolved over geological time scales in response to the unpredictable hydroclimatic conditions characteristic of the region [11]. Yet modern-day water and hatchery management practices tend to constrain outmigration timing. For example, alterations to the natural hydrograph, such as suppression of winter pulse flows, likely to truncate migratory windows, reduce the variability in outmigration timing, and significantly suppress the fry life history type. Such simplification and truncation of life history diversity could significantly reduce the resiliency of the stock-complex and exacerbate the risk of a temporal mismatch with favorable ocean conditions [94]. Indeed, the only clear deviation from the flow-driven relationship in Fig 1 was attributed to juveniles entering the ocean during a suboptimal period and resulted in the closure of the fishery in 2008. Perhaps with more diverse, resilient stocks, the consequences would have been less extreme. Largely without direct empirical support, hatchery and flow management practices tend to focus on optimizing the success of the largest, smolt-sized juveniles that are assumed to contribute the most to adult returns [14,21,24]. Here, we found that all phenotypes contributed to the reproductive adult population, with smolts comprising less than half of the surviving adults following two contrasting flow regimes. Without otolith reconstruction data for additional years, species, and watersheds, the broader inferences one can make regarding the influence of hydroclimatic regime on juvenile salmon survival are limited. However our data and a previous study [21] indicate that assumptions regarding size-selective mortality and smolt-focused management schemes need to be tested on a species, system and hydroclimatic basis.

This study has demonstrated the value of a combined RST and otolith geochemistry study to reconstruct patterns in the expression and survival of salmon migratory phenotypes. The results show that under paired years of low and high flow conditions, parr outmigrants comprised a significant portion of the returning adult population, while fry made smaller, but substantial contributions. Future efforts should focus on reducing the error in juvenile production estimates in order to produce more meaningful survival estimates, and understanding the demographic role that fry and parr play in salmon population dynamics. Management actions that promoted the expression and survival of fry in natal and downstream rearing habitats could result in demographic and genetic benefits to the population. Recognition of the importance of hydrodynamic regime and life history diversity should provide guidance to system managers when reassessing goals and future management strategies [5,95]. It is also important that management actions consider carefully-designed monitoring programs to detect changes in stock abundance and life history diversity at appropriate temporal and spatial scales.

Supporting Information

S1 Text. Testing the performance of the Sr isoscape.
(DOCX)

S1 Fig. Time-resolved plot of a single spot ablation at a habitat transition. This plot (macro developed by C. Donohoe) shows how the isotopic composition of the otolith can change with sample depth (equivalent to analysis time). Typically we would use ~20 seconds of data per spot (A), but in cases like this we would use only the surface material (B) to avoid signal attenuation and to ensure consistency between otolith ^{87}Sr/^{86}Sr, microstructure and distance analyses.
(DOCX)

S2 Fig. Median ^{87}Sr/^{86}Sr natal values for major sources of Chinook salmon in the California Central Valley. Values are based on juvenile otoliths and/or water samples. The mainstem San Joaquin River (SJR) isotopic signature is displayed, but was not included as a potential natal source. Boxes represent 25-75th percentiles, whiskers represent 5-95th percentiles. Site codes are defined in S1 Table. Isotopic signatures not significantly different ($p > 0.05$, Tukey's test) are joined by brackets. Mean ocean ^{87}Sr/^{86}Sr is indicated by a dashed line.
(TIF)

S1 Table. $^{87}Sr/^{86}Sr$ isoscape used to train the LDFA and assign unknown adult otoliths to natal location. Data based on known-origin otolith (O) and/or water (W) samples. Interannual differences were tested by ANOVA or Welch's Test when data exhibited unequal variance. Differences among sites are shown in S2 Fig Underlined years represent water samples collected Oct 1997 to Apr 1998 that were pooled into a single water year (1998).
(DOCX)

S2 Table. Natal assignments and correct classification scores of known-origin samples. Assignments based on $^{87}Sr/^{86}Sr$ values and jackknife resampling. Site codes are defined in S1 Table. Equal prior probabilities were given to all sites and sites are ordered by increasing mean $^{87}Sr/^{86}Sr$ value. The training dataset (n = 290) comprised both juvenile otoliths and water samples. Counts are for actual rows by predicted columns. Samples from the Stanislaus River (STA) are highlighted in bold, while groups of sites with statistically overlapping $^{87}Sr/^{86}Sr$ signatures ($p>0.05$, Tukey's test) are shown in italics and S2 Fig
(DOCX)

S3 Table. Reference samples used to calibrate the fork length back-calculation model.
(DOCX)

S4 Table. The number of adult spawners produced by the 2000 and 2003 outmigration cohorts ("natural escapement")
(DOCX)

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Author Contributions

Conceived and designed the experiments: RCJ JDW. Performed the experiments: AMS RCJ TH JJG PKW GEW. Analyzed the data: AMS RCJ TMH AEH CM. Contributed reagents/materials/analysis tools: TH. Wrote the paper: AMS RCJ.

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