April 2019

# Conservation Planning Foundation for Restoring Chinook Salmon (*Oncorhynchus Tshawytscha*) and *O. mykiss* in the Stanislaus River


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The Bay Institute: Jon Rosenfield and Alison Weber-Stover

California Department of Fish and Wildlife: Stephen Louie, John Shelton, and Tim Heyne

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## ABBREVIATIONS

| | |
|---|---|
| µg/L | micrograms per liter |
| 7DADM | 7-day average of daily maximum temperature |
| AFRP | Anadromous Fish Restoration Plan |
| BOD | biological oxygen demand |
| CDEC | California Data Exchange Center |
| CDFW | California Department of Fish and Wildlife |
| CFR | Code of Federal Regulations |
| cfs | cubic feet per second |
| CRR | cohort replacement rate |
| CVPIA | Central Valley Project Improvement Act |
| CVRWQCB | Central Valley Regional Water Quality Control Board |
| Delta | Sacramento-San Joaquin Delta |
| DO | dissolved oxygen |
| DRERIP | Delta Regional Ecosystem Restoration Implementation Plan |
| DWSC | Deep Water Ship Channel |
| EC25 | Effect concentration, affecting 25% of the test population |
| ELS | early-life stages |
| ESA | Endangered Species Act |
| ESHE | Emigrating Salmonid Habitat Estimation |
| Estuary | San Francisco Bay/Sacramento-San Joaquin Delta Estuary |
| ESU | evolutionarily significant unit |
| F&G | California Fish and Game |
| FL | fork length |
| ft | foot |
| $ft^2$ | square foot |
| ft/s | feet per second |
| HSI | habitat suitability index |
| in | inch |
| IULT | Incipient Upper Lethal Temperatures |
| $km^2$ | square kilometer |
| m | meter |
| $m^2$ | square meter |
| m/s | meter per second |
| maf | million acre-feet |
| mg/L | milligram per liter |

| | |
|---|---|
| $mg/m^2$ | milligrams per square meter |
| mm | millimeter |
| NMFS | National Marine Fisheries Service |
| OPP | Office of Pesticide Programs |
| PIT | passive integrated transponder |
| RBDD | Red Bluff Diversion Dam |
| report | *Conservation Planning Foundation for Restoring Chinook Salmon (Oncorhynchus tshawytscha) and O. mykiss in the Stanislaus River* |
| RM | river mile |
| RST | rotary screw trap |
| SAV | submerged aquatic vegetation |
| SJRRP | San Joaquin River Restoration Program |
| S.M.A.R.T. | Specific, Measurable, Achievable, Relevant to overarching goals, and Time bound |
| SEP | Scientific Evaluation Process |
| steelhead | California Central Valley Steelhead |
| SWRCB | State Water Resources Control Board |
| USBR | U.S. Bureau of Reclamation |
| USDOI | U.S. Department of the Interior |
| USEPA | U.S. Environmental Protection Agency |
| USFWS | U.S. Fish and Wildlife Service |
| VSP | viable salmonid population |
| WDOE | Washington State Department of Ecology |
| WQC Plan | Bay-Delta Water Quality Control Plan |
| YOY | young-of-the-year |

# Executive Summary

Salmon and steelhead populations in the San Joaquin River Basin were once some of the largest in California, with the river and its tributaries supporting fall-run and spring-run Chinook salmon (*Oncorhynchus tshawytscha*) and California Central Valley steelhead (*O. mykiss*). Over the past century, extensive water storage development and habitat degradation have led to significant declines in Chinook salmon and steelhead. Efforts have been made to reverse and restore the declining health of riverine and estuarine habitats in the Central Valley and their anadromous fish fauna. However, the San Joaquin River and its tributaries continue to suffer from declining fish populations, stream health, and overall watershed conditions.

Scientists from the California Department of Fish and Wildlife, U.S. Fish and Wildlife Service, U.S. Bureau of Reclamation, National Marine Fisheries Service, American Rivers, The Bay Institute, Trout Unlimited, and The Nature Conservancy formed a collaborative partnership to define a vision of conservation success (i.e., attainment of native salmonid population goals and objectives) for three of the Stanislaus River's native fish populations: fall-run Chinook salmon, spring-run Chinook salmon, and *O. mykiss* (both resident and migratory forms). They developed an approach called the Scientific Evaluation Process (SEP) to describe a vision of conservation success and articulate specific outcomes that are grounded in the best available science.

Key analyses included the development of objectives as a quantitative vision of a restored Stanislaus River for Chinook salmon and *O. mykiss* and the prioritization of current stressors to aid in conservation planning. Goals and objectives provide metrics to evaluate conservation success and provide a framework for adaptive management. Stressor prioritization guides the implementation of management actions to more efficiently reach stated outcomes.

## Goals and Objectives

### *Biological Objectives*

Quantitative Biological Objectives were developed for productivity, life history diversity, and genetic diversity. Biological Objectives for productivity were calculated by comparing current estimated survival rates throughout the salmonid life cycle with survival rates that would be needed in freshwater environments to achieve the population abundance goals. Biological Objectives included the following assumptions:

- Population abundance goals were guided by existing policy and plans.
- Ocean mortality estimates were constant into the future.
- Improvements in freshwater survival were applied equally to river and Sacramento-San Joaquin Delta environments.

Productivity objectives for juvenile fall-run and spring-run Chinook salmon were separated into three phases: 1) rebuilding (double current populations over 3 generations, or 9 years); 2) resiliency (double current populations over 1 generation, or 3 years); and 3) sustainability (productivity characteristic of Chinook salmon populations in other West Coast rivers).

Chinook salmon productivity objectives include the following:

- Rebuilding phase: total freshwater survival equal to 1.1% (egg to Caswell survival equaling 8% and Caswell to Vernalis survival equaling 68.2%)
- Resiliency phase: total freshwater survival equal to 2.2% (egg to Caswell survival equaling 10.7% and Caswell to Vernalis survival equaling 72.2%)
- Sustainability: total freshwater survival equal to 10% (egg to Caswell survival equaling 24.4% and Caswell to Vernalis survival equaling 82%)
- Adult survival, Caswell to spawning grounds greater than or equal to 90%

*O. mykiss* productivity objectives include the following:

- Minimum density of age-0 *O. mykiss* during the summer equals one per square meter on average, measured upstream of Oakdale
- Minimum average growth of both age-0 and age-1 *O. mykiss*, averaged over an entire season, equals 0.6 millimeter (mm) per day, measured upstream of Oakdale
- At least 90% of the smolts (Stages 4 and 5) observed should be 150 mm (5.9 inches) fork length (FL) or greater, measured at Caswell
- Naturally produced smolts (Stages 4 and 5) emigrating from the river each year shall increase to at least 165 per female spawner

Life history diversity among juvenile salmonids is increasingly recognized as vital to population growth rates and the stability of the population through time. Timing and quality of conditions in the San Francisco Bay Estuary and marine environments are highly variable; thus, a diverse portfolio of juveniles migrating at different times and at different sizes increases the chances that some fraction of each annual cohort will be able to capitalize on suitable conditions in pelagic environments.

Chinook salmon life history diversity objectives include the following:

- Fall-run fry should be detected every week from the last week of January through the second week of April in the Caswell rotary screw trap and comprise at least 20% of total outmigrants during this period in both wet and dry years.
- Fall-run parr should be detected every week from the first week of February through the last week of May at Caswell and comprise at least 20% of total outmigrants in wet years and 30% in drier years.

- Fall-run smolt should be detected every week from the third week of February through the first week of June at Caswell and comprise at least 10% of total outmigrants in wet years and 30% in drier years.
- Spring-run juveniles (fry, parr, and smolt) should be detected every week from the first week of January through the first week of April at Caswell. Minimum proportion targets by life stage are the same as for fall-run.

*O. mykiss* life history diversity objectives include the following:

- The proportion of age-0 juveniles with anadromous maternal origin in otoliths should be greater than 45%.
- Smolts (Stages 4 and 5; at least 150 mm FL) should be detected at least 4 months of each year at Caswell.
- Resident adult abundance should be 3 to 9 age-1+ fish per 100 square meters.

The prevalence of hatchery-origin fish returning to spawn in Central Valley rivers is a significant problem in managing wild stocks, and interbreeding among genetically distinct fall- and spring-run Chinook salmon poses numerous threats to both populations. Genetic diversity objectives for all runs include the following:

- Percentage of hatchery-origin spawners should be less than 20% of all spawners
- Percentage of fall-run eggs and juveniles should be less than 2% hatchery influence
- Percentage of spring-run eggs and juveniles should be less than 2% inter-run mating

### *Environmental Objectives*

Environmental Objectives represent the design criteria for the restored river. Essentially, these objectives are hypotheses about environmental conditions that are necessary to attain the Biological Objectives. Using the desired outcomes described above, as well as published literature and available models, the SEP Group defined a suite of environmental conditions that would support attainment of the Biological Objectives. The Environmental Objectives were established for each life stage of each focal population. Variables addressed include temperature, dissolved oxygen (DO), contaminant concentrations, physical habitat space (e.g., gravel for spawning and shallow habitat for rearing), and others. To the extent possible, Environmental Objectives are not expressed as volumes of flow required to produce these optimal conditions, although flow volumes could be determined to meet a suite of Environmental Objectives (e.g., depth and velocity of water to maintain desired temperatures or DO levels in spawning gravel).

## Stressors

Stressors are the obstacles to achieving the desired conditions (i.e., Environmental Objectives) necessary for the species to attain the target population conditions (i.e., Biological Objectives).

Identifying and ranking stressors supports conservation planning by providing the basis for prioritization of management actions such as habitat enhancement or temperature modification. For any given life history stage, progress towards the Biological Objectives can only be expected once the high priority stressors have been addressed and Environmental Objectives are largely achieved. The efficacy of conservation measures designed to reduce stressors should therefore be measured based on the extent that those measures advance or achieve Environmental Objectives or Biological Objectives.

The process for identifying and ranking stressors is as follows:

1. Identification of the range of stressors affecting each life history stage
2. Assignment of stressors for each life history stage to the current population and conditions and the target population and conditions
3. Scoring of stressors by life history stage for current and future conditions
4. Stressor ranking and prioritization across life history stages

The highest priority stressors for fall-run Chinook salmon include the following:

- Lack of suitable juvenile rearing habitat
- Lack of suitable juvenile migratory conditions
- Compression of the rearing and migration window
- Interactions with hatchery fish and other runs during spawning

The highest priority stressors for spring-run Chinook salmon include the following:

- Interactions with hatchery fish and other runs during spawning
- Inadequate egg development conditions
- Lack of suitable juvenile rearing habitat
- Lack of suitable juvenile migratory conditions

The highest priority stressors for *O. mykiss* include the following:

- Inadequate egg development conditions
- Lack of suitable juvenile rearing habitat
- Lack of suitable juvenile migratory conditions

## Management Implications

Native species in the Stanislaus River are impacted by changes to river flow, habitat alteration, and biological modification (e.g., non-native species and hatchery-origin fish). Most stressors can be addressed through water management, habitat creation or enhancement, or a combination. Flow and habitat are critical elements of river function and emergent themes necessary for river restoration. The SEP Group has not outlined specific actions necessary to alleviate stressors and meet

Environmental and Biological Objectives; however, modifications to current habitat and flow regimes will be necessary to achieve the Environmental and Biological Objectives for the Stanislaus River.

The next step to creating a comprehensive conservation strategy for salmonids in the Stanislaus River will be the design of a suite of specific Conservation Actions, including monitoring to evaluate the performance of actions individually and collectively. Actions should be evaluated based on their ability to alleviate priority stressors and attain the Biological and Environmental Objectives. Following the implementation of Conservation Actions, information developed through monitoring can be synthesized to evaluate an action’s effects and make modifications accordingly.

# Technical Summary

## Foreword

This technical summary summarizes the *Conservation Planning Foundation for Restoring Chinook Salmon (Oncorhynchus tshawytscha) and O. mykiss in the Stanislaus River* (report). It also highlights the key products—goals and objectives for restoring native salmonid populations and ranking and prioritizing barriers, or stressors, to the attainment of those goals and objectives—and conclusions developed through the Scientific Evaluation Process (SEP). Please refer to the report for more detailed information on the methods, rationale, and scientific justification for these products and cited literature.

## Introduction

Salmon and steelhead populations in the San Joaquin River basin were once some of the largest in California. Historically, the San Joaquin River and its tributaries supported both spring- and fall-runs of Chinook salmon (*Oncorhynchus tshawytscha*) and California Central Valley steelhead (steelhead). As recently as 1940, spring-run Chinook salmon were the most abundant Chinook run in the San Joaquin system, ascending and occupying the higher elevation streams fed by snowmelt. Yet, over the past century, extensive water storage development throughout the San Joaquin River watershed has resulted in a sizeable proportion of flow being diverted from river channels, degrading spawning and rearing habitats and blocking access to historical spawning and rearing reaches. This habitat degradation—due to damming, diversions, and levee construction—has led to significant declines in Chinook salmon and steelhead populations (Figures TS-1 and TS-2). Spring-run Chinook salmon were considered extirpated from the San Joaquin River basin for decades; however, recently, spring migrating Chinook salmon have been observed in the Stanislaus and Tuolumne rivers.

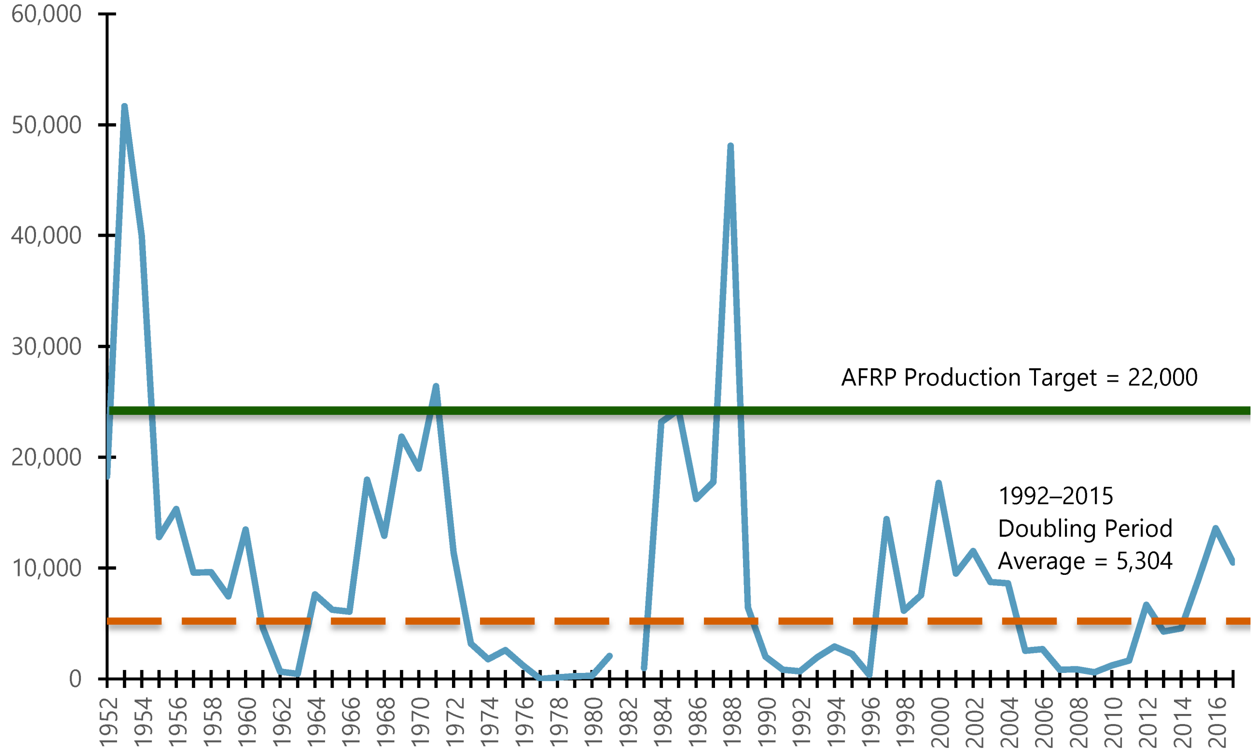



**Figure TS-1**
**Estimated Yearly Natural Production of Adult Fall-run Chinook Salmon**

Notes:
Fall-run Chinook salmon production estimates are well below AFRP production targets for the Stanislaus River from 1992 to 2015 (USFWS 2001). Figure is modified from USFWS Chinookprod doubling goal graphs available at https://www.fws.gov/lodi/anadromous_fish_restoration/documents/Doubling_goal_graphs_063016.pdf.

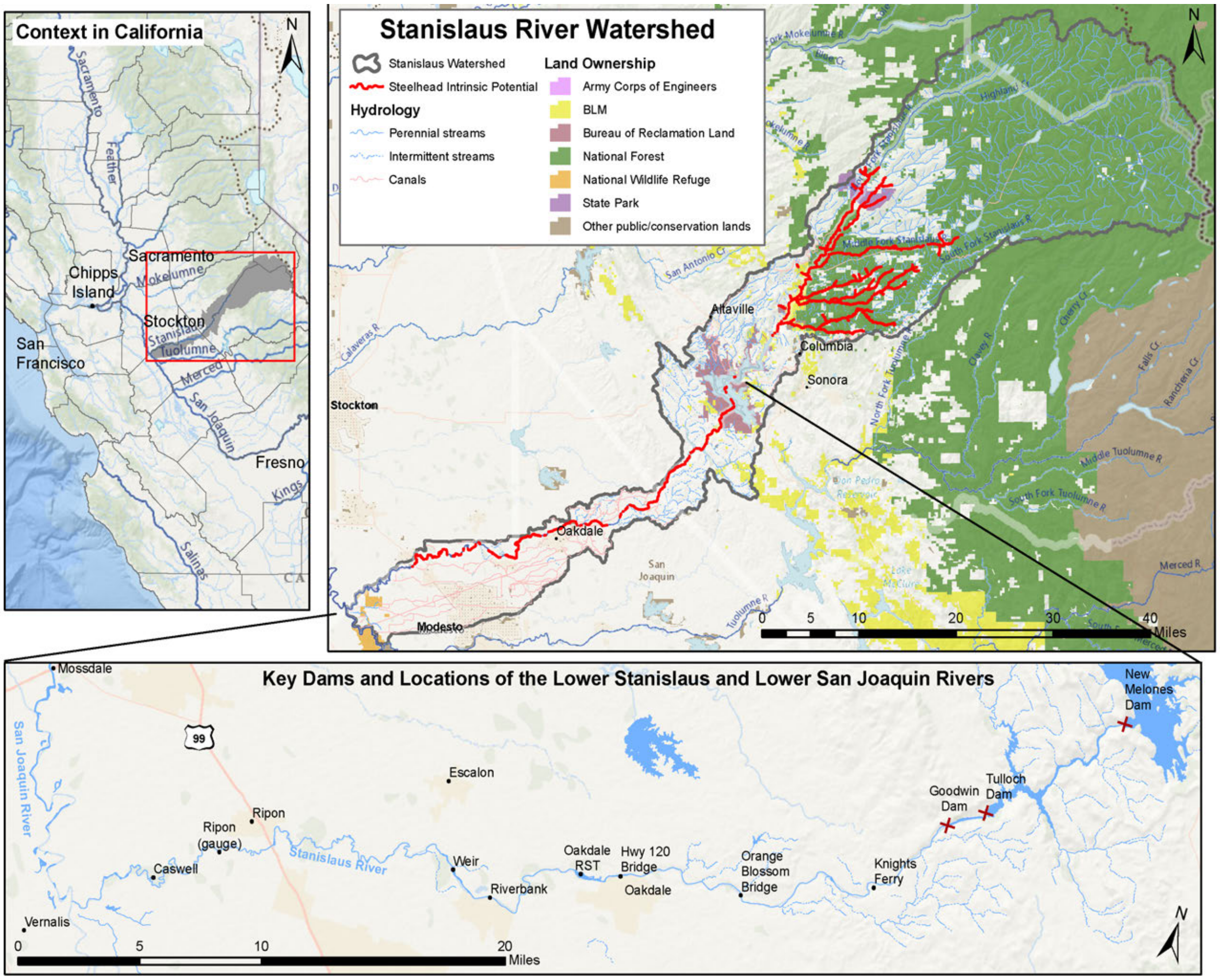



**Figure TS-2**
**Key Dams and Features of the Lower Stanislaus River**

Over the past few decades, efforts have been made to reverse and restore the declining health of riverine and estuarine habitats in the Central Valley, especially their anadromous fish fauna. Since 1988 with the adoption of Sections 6901 and 6902 of California Fish and Game Code (and arguably back to 1915 with Fish and Game Code Section 5937), numerous policies, laws, and regulations have called for the restoration of anadromous fish populations. However, the San Joaquin River and its tributaries continue to suffer from declining fish populations, stream health, and overall watershed conditions. This is partially attributable to the lack of a common vision of conservation success among resource agencies, conservation groups, and water districts, as demonstrated in the following examples:

- Many policies focus on Central Valley salmonid stocks and do not define desired outcomes for other stocks. For example, Central Valley spring-run Chinook salmon and steelhead distinct population segments were listed under the Federal Endangered Species Act (ESA) in 1999 and 1998, respectively.

- The National Marine Fisheries Service (NMFS) determined that listing of fall-run Chinook salmon under the ESA was not warranted, though the species was listed as a special concern in 2004.
- The doubling of anadromous salmonid populations is required under the State Water Resources Control Board (SWRCB) Bay-Delta Water Quality Control Plan (WQC Plan), the California Fish and Game Code Sections 6900-6924 (by year 2000), and the Central Valley Project Improvement Act (CVPIA; by year 2002). However, specific restoration targets for the San Joaquin watershed and its tributaries developed under the Anadromous Fish Restoration Plan (AFRP) in 2001 were designated for fall-run Chinook salmon, but not for spring-run Chinook salmon or steelhead (USFWS 2001).

The lack of conservation success in the San Joaquin River and its major tributaries—the Stanislaus, Tuolumne, and Merced rivers—is widely recognized (e.g., proposed update of the WQC Plan, CVPIA progress toward doubling of anadromous fish, National Marine Fisheries Service (NMFS) Recovery Plan for salmon and steelhead). As a result, a large group of stakeholders convened the San Joaquin Tributary Settlement Process to explore potential resolutions to long-standing ecosystem and water management issues. Stakeholders participating in this process originally discussed a set of actions for the overall San Joaquin system. However, due to the size and complexities of the overall San Joaquin River basin and a lack of consensus regarding the key barriers to its successful conservation, the stakeholders realized that science-based methods should be used to establish desired outcomes—including goals, biological objectives, and environmental objectives—in each of three major tributaries to the San Joaquin River and the lower San Joaquin mainstem. As a follow-on step to developing goals and objectives, conservation proposals could then be evaluated in the context of those desired outcomes. The San Joaquin Tributary Settlement Process stakeholders decided to focus first on the Stanislaus River.

Scientists from the California Department of Fish and Wildlife (CDFW), U.S. Fish and Wildlife Service (USFWS), U.S. Bureau of Reclamation, NMFS, American Rivers, The Bay Institute, Trout Unlimited, and The Nature Conservancy participated in collaborative partnership called the SEP. The SEP Group focused on defining conservation success (i.e., attainment of native salmonid population goals and objectives) for three of the Stanislaus River's native fish populations: fall-run Chinook salmon, spring-run Chinook salmon, and *Oncorhynchus mykiss* (both resident and migratory forms).

The SEP Group's vision of conservation success expresses and harmonizes the regulatory policies (provided in the bullet list above) into science-based achievable goals and objectives. Their vision also does the following: 1) prioritizes barriers (stressors) to these goals and objectives that limit attainment of desired conditions; and 2) provides the framework for developing, evaluating, and implementing appropriate strategies for conservation and restoration. Without such a framework, science-based adaptive management cannot be applied to solve complex ecosystem and water management issues in the Stanislaus system. Development of the SEP vision also resulted in a common scientific foundation for restoring native species and habitats in the San Joaquin River basin and establishing a framework for addressing the SWRCB's update of the WQC Plan[1] and the Federal Energy Regulatory Commission relicensing proceedings.

## Purpose

The SEP's overarching purpose is to contribute to the technical foundation necessary to restore conditions in the lower San Joaquin River and its tributaries in order to support sustainable native fish populations and other living resources. The following actions will support this purpose:

- Articulating a clear, scientifically justified expression of policy guidance regarding the desired status of fall-run and spring-run Chinook salmon and *O. mykiss* (both resident [rainbow trout] and anadromous [steelhead] forms, where resident rainbow trout and steelhead used throughout the document distinguish a specific life-history type, respectively) in the Stanislaus River and larger San Joaquin River basin
- Providing well-documented and transparent technical guidance on the conditions necessary to attain that vision
- Providing a foundation for evaluating the effectiveness of proposed actions to achieve the conditions necessary to realize the vision

## Approach and Scope

This report translates policy guidance regarding desired ecological conditions in the rivers of California's Central Valley into its local expression on the Stanislaus River watershed. The products described in this report reflect biological conditions on the Stanislaus River that are consistent with and supportive of river management and restoration policies for the Central Valley as a whole. Desired outcomes for river restoration and fisheries management were informed by and interpreted through three filters—policy scope, biological scope, and geographical scope—to provide a tangible set of desired outcomes that were used to define quantitative metrics determined to be representative of a restored river ecosystem. As a result, the SEP Group's products do not simply serve one law (e.g., ESA), nor do they merely state CVPIA goals for doubling of anadromous fish populations. Rather, the products describe conditions on the Stanislaus River that support outcomes that are in line with the range of relevant public policies regarding management of Central Valley fish populations and water quality.

[1] As called for under the state Porter-Cologne Water Quality Control Act and the federal Clean Water Act

## *Policy Scope*

The policy scope is described as the various laws, regulations, and policy targets that are relevant to ecological management and restoration of Central Valley salmonid populations and water quality. These laws, regulations, and policy targets often state desired outcomes in terms that require more complete and specific articulation to develop desired outcomes for the Stanislaus River. For example, while none of these laws, regulations, or policy targets describe the need to restore and maintain intra-population life history diversity among salmon, it is well established in the scientific literature that such diversity is essential to achieving any of the desired conditions that are specified in existing policies (e.g., fish in good condition or doubling of anadromous fish populations).

## *Biological Scope*

The biological scope incorporates all salmonids native to the Stanislaus River watershed, including fall-run Chinook salmon, spring-run Chinook salmon, and *O. mykiss*. Restoration of viable and fishable salmonid populations is a goal of the State of California and national public policies, and many components of the policy scope identify desired outcomes for at least one salmon population (or salmon populations in general). Considering the native salmonid populations, both individually and collectively, allowed the SEP Group to develop a unified vision for conservation of the river and synthesize policy imperatives that might otherwise lead to conflicting or counterproductive outcomes. Also, the wealth of available research and monitoring data on these species enabled identification of tangible goals and measurable objectives for salmonid restoration.

For each focal salmonid population, restoration and maintenance of self-sustaining, fishable populations require attaining adequate levels of the following viable salmonid population criteria (VSP criteria): abundance, productivity (population growth rates), life history, genetic diversity, and spatial distribution. Although VSP criteria point to outcomes that are independently measurable, they are interdependent (e.g., acceptable levels of life history and genetic diversity require suitable productivity and abundance in the long term). Different temporal and spatial scales are relevant for each VSP criterion. As a result, the emphasis on a particular VSP criterion changes as one considers different geographic scopes and time frames.

When thinking about conservation of the Stanislaus River system, there are some shortcomings to focusing on salmonids. For example, salmon are among the hardiest and most successful fish species in the watersheds they occupy; thus, ecosystem conditions that support conservation of these species may not be protective enough for other sensitive fish and aquatic species (many of which are also covered by elements of the policy scope). Nevertheless, the SEP Group expects that restoring watersheds for salmonids will provide ancillary benefits to other native species and desirable ecosystem processes.

## *Geographic Scope*

Goals and objectives for the VSP criteria were defined to the extent that they could be addressed in whole or in large part through actions taken within the Stanislaus River watershed. Many elements of the policy scope describe desired outcomes for salmonids of the Central Valley (or California) as a whole. For migratory species like salmon, such outcomes can only be attained if they are supported by environmental conditions across the geographies these fish traverse during their life cycles. For example, adverse conditions in any one habitat could affect the attainment of desired outcomes for abundance identified in elements of the policy scope. The SEP products articulate these larger policy targets in terms that can be managed by actions on the local scale. Accordingly, the SEP Group focused the planning effort on the San Joaquin watershed and the Stanislaus River, in particular, and described a specific set of conditions that are largely controlled locally and can be modified by local actions.

For the Stanislaus River-specific scope of this effort, the SEP Group described desired outcomes of the VSP criteria that could be controlled by in-river conditions. For example, abundance targets for anadromous populations (fall-run and spring-run Chinook salmon and *O. mykiss*) were not specifically defined at the river-specific scale because abundance is not completely controlled by conditions in the Stanislaus River or any one habitat that salmonids occupy during their life cycle. Also, for each focal salmon species, restoring a population in the Stanislaus River would improve Central Valley salmonid viability simply by adding to or strengthening the larger Central Valley spawning population. As a result, no specific objectives for increasing spatial extent outside of the Stanislaus River were included. Rather, the report describes in detail the desired outcomes for the remaining VSP criteria such as productivity (stage-to-stage survival rates in freshwater), juvenile life history diversity (size at and timing of migration), and genetic interactions with other runs and hatchery fish in the Stanislaus River.

The SEP focus on improvements needed in the Stanislaus River and lower San Joaquin River segregates responsibility for achieving overall policy objectives into manageable units. As a result, responsibility for conservation success can be allocated to parties that can take conservation actions on the Stanislaus River. The Stanislaus River stakeholders are not responsible for the success or failure of restoration and management efforts in the Sacramento-San Joaquin Delta (Delta), San Francisco Bay, or the Pacific Ocean. Therefore, this approach separates the improvements needed on the Stanislaus River from those needed elsewhere and facilitates local action.

The SEP Group did not develop or evaluate conservation actions that could be taken on the Stanislaus River to improve conditions for native salmonid populations. Rather, the group focused on foundational elements needed to understand the nature and magnitude of challenges to restoring target populations. These elements are also essential to managing restoration activities in an adaptive management context. By developing goals and objectives and ranking and prioritizing the barriers (stressors) that prevent attainment of those goals and objectives, the SEP Group provides the design criteria for subsequent conservation planning and the benchmarks against which to prioritize, implement, and adjust conservation actions adaptively.

## Logic Chain

The report follows a structured approach to developing a framework of goals and objectives. This framework can be used to evaluate and prioritize conservation actions that are predicted to achieve measurable outcomes from the VSP criteria.

Some restoration programs do not adequately evaluate the effects of actions on their fundamental objective, in part because they do not express their objective in specific and measurable terms. To prevent this, the SEP Group initiated a logic chain approach to articulate the linkages between desired outcomes and the specific conditions that are hypothesized to lead to such outcomes. Articulating explicit, quantitative biological objectives provides a framework for the following:

1. Evaluating potential conservation measures
2. Measuring the success of conservation measures after implementation
3. Adjusting the conservation strategy through time to attain desired outcomes based on information gained from implementation and monitoring

In other words, this approach generates the basic building blocks for any subsequent adaptive management strategies.

The SEP Group addressed the following general questions to establish a logic chain for the development of Stanislaus-specific Biological and Environmental Objectives for Chinook salmon and *O. mykiss* and for identifying, ranking, and prioritizing stressors that prevent attainment of goals and objectives (Figure TS-3):

- What is the problem?
  - Define a **Problem Statement**, which is a concise declaration of the ecological issues that require attention.
- What outcome(s) will solve the problem?
  - Determine **Central Valley Goals** that present a vision for species-specific restoration actions across the Central Valley landscape. State desired outcomes that will solve the issue(s) identified in the problem statement.
- What does solving the problem and attaining the goal look like?
  - Develop **Central Valley Objectives** that provide a clear standard for measuring progress toward desired outcomes in the larger context of the Central Valley.

- What can efforts in the Stanislaus River contribute to the attainment of Central Valley Objectives?
  - Describe **Watershed-Specific Goals** that specify the watershed contribution to Central Valley Goals and Objectives. Watershed-Specific Goals can be attained within a watershed or geographic unit, regardless of actions taken outside the watershed or geographic unit.
- What is the suite of biological outcomes that characterize success?
  - Define the specific biological outcomes that characterize success in the geographic area and for the species of interest. **Biological Objectives** are the metrics towards which all conservation actions and adjustments to those actions are directed and will be evaluated.
- What is the suite of physical and ecosystem conditions that characterize success?
  - Develop **Environmental Objectives** that define the physical, chemical, and biological conditions that are hypothesized to be necessary to achieve the Biological Objectives. Environmental Objectives quantify the conditions that best available science indicates will lead to attainment of Biological Objectives.
- What are the barriers to achieving the Biological and Environmental Objectives?
  - Define the **Stressors** that must be alleviated to attain the Biological and Environmental Objectives. Prioritize stressors according to the magnitude and certainty of their effect(s) on Biological and Environmental Objectives.

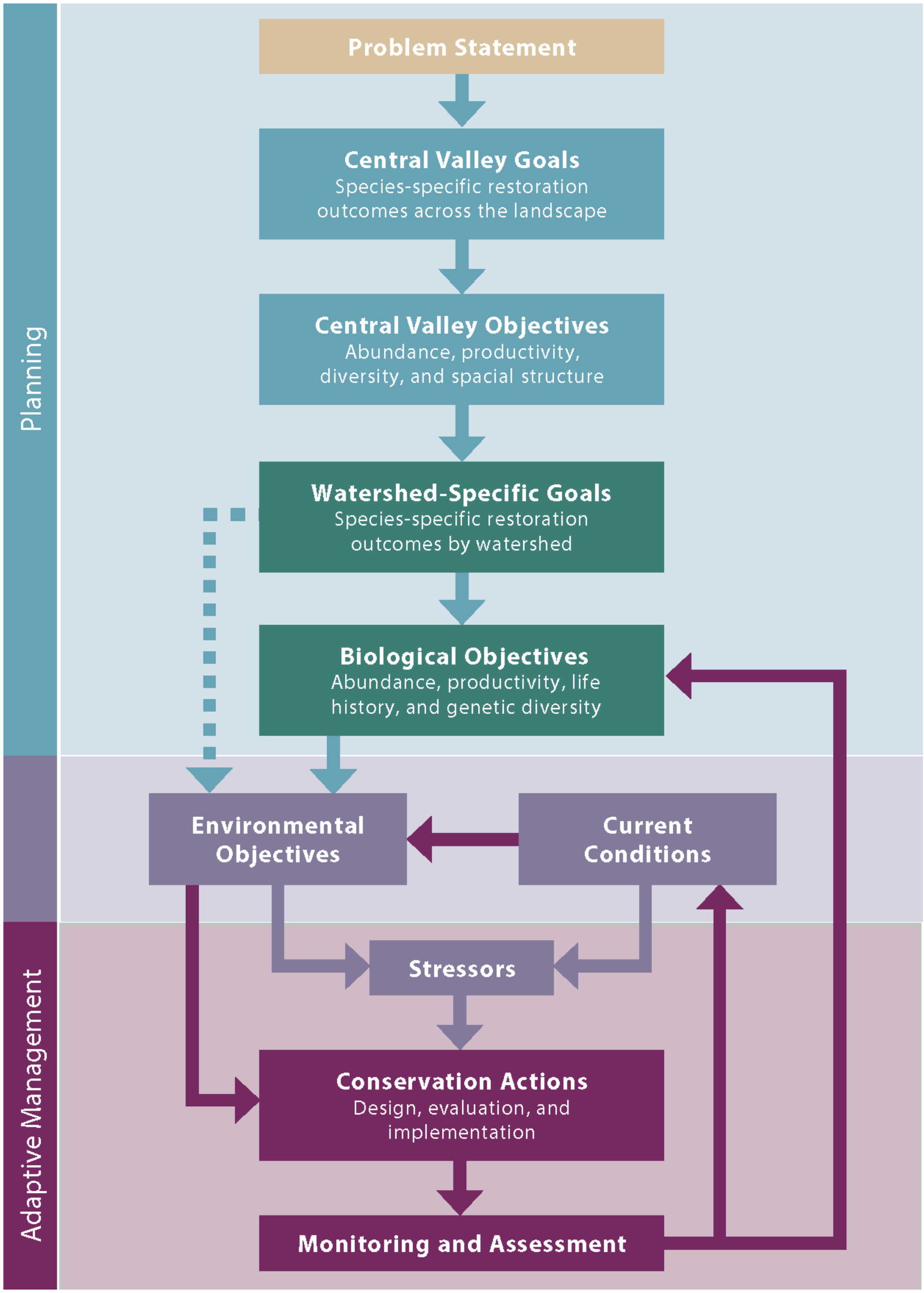



**Figure TS-3**
**Scientific Evaluation Process Logic Chain**

By prioritizing stressors without specifying conservation actions, the SEP allows for greater creativity and flexibility in the design of potential conservation actions and solutions to achieve Environmental Objectives. For example, Section 7 of the report, Environmental Objectives, specifies environmental conditions that are necessary to achieve life history stage-specific outcomes for each species. These conditions include metrics such as the spatial extent of spawning and rearing habitat, supportive water velocity ranges for high-quality habitat, and flow variability needed to provide cues for adult and juvenile migration. Attaining these conditions may be addressed through a set of flow prescriptions; however, it is possible that these conditions could also be met through habitat restoration, temperature management, fish passage, or some combination of actions.

Overall, the SEP approach provides the basis for learning-based management using adaptive decision making. The SEP products set the stage for generating and evaluating specific proposals for conservation actions and require that such proposals estimate outcomes in terms of Environmental and Biological Objectives. Such impact analyses, combined with analyses of costs to implement the strategy, allow for well-informed, transparent evaluations of trade-offs among proposed approaches.

## Structured and Collaborative Approach to Decision Making

Good decisions are defined by the process in which they were generated and by the degree to which they can integrate new information to minimize uncertainty and improve outcomes. The process of developing the SEP Group's objectives and stressor evaluations represents a significant advancement in the application of science to improve the understanding of conservation needs and challenges in the Stanislaus River and throughout the San Joaquin River basin.

The SEP Group produced a consistent and clear description of desired conditions that are embedded in different policies and a strong foundation for adaptive management to attain those outcomes. In addition, collaboration among the SEP participants resulted in the alignment of conceptual models related to attainable outcomes, system processes, and barriers to achievement of desired conditions. When the SEP began, participating organizations and agencies often had different definitions of restoration success for the Stanislaus River, and, in most cases, those desired outcomes were not well-articulated. Similarly, many of the participating scientists entered the SEP with their own internal (but unarticulated) conceptual models of the key problems and limits that prevented attainment of desired biological outcomes. The goals, objectives, and stressor rankings that emerged from this process represent a new scientific consensus around a vision of what the Stanislaus River can be expected to attain regarding salmonid restoration. The SEP also contextualized how this vision fits into the requirements of existing policy for the Central Valley as a whole and created a science-based, explicit, and agreed-upon conceptual model regarding the numerous barriers to attainment of the vision of success.

The SEP Group recognizes that adaptive management is a critical component of many resource management processes because decisions are always made with some degree of uncertainty. The SEP framework was designed to support an adaptive management framework that could improve decisions and outcomes over time. Managing adaptively requires navigating towards a vision of success that is specifically articulated and widely understood. Thus, the products contained in the report are essential to the practice of adaptive resource management in the Stanislaus River watershed. Indeed, they represent the first step in the adaptive management cycle. For example, the goals and objectives developed by the SEP—and the consensus that these outcomes represent the conditions required under a variety of policies—allow managers to evaluate and implement potential restoration solutions at the appropriate scale. The SEP's analysis of stressors provides a plan of action driven by scientific evidence on the importance of the stress and the appropriate sequence for actions. In other words, the stressor evaluation is expressed in terms of the need and opportunities for adaptive management.

What became clear from developing the vision of success articulated in the report is that there are no silver bullets for restoring populations of fall-run Chinook salmon, spring-run Chinook salmon, or *O. mykiss* on the Stanislaus River. The stressor evaluation presented in Section 8, which is based on comparisons of current conditions to the desired environmental conditions for salmonids as described by the best available science, reveals that a comprehensive conservation strategy is needed. This strategy must include a variety of actions to address multiple barriers to success that occur throughout the freshwater life cycle of target salmonid populations. The SEP Group's products provide the essential framework for designing an effective and efficient conservation strategy that can produce desired outcomes on the Stanislaus River (Watershed-Specific Goals) and ensure that this watershed can contribute to the attainment of larger laws and policies regarding salmonid restoration throughout the Central Valley (i.e., Central Valley Goals and Objectives). These products will support the prioritization of conservation activities (by allowing planners to make good decisions based on the best available science) and prevent limited resources from being misallocated to actions or monitoring that are not part of the critical path to successful outcomes.

In many ways, progress towards restoration has been stifled by policy goals that define success purely in terms of adult salmonid abundance. Because adult abundance results are difficult or impossible to guarantee as a result of modifications to any one environment occupied by anadromous salmon, defining desired outcomes in abundance terms can lead to paralysis because questions such as "where should conservation actions occur?" and "who should be responsible for implementing those actions?" remain unanswered. By focusing desired policy outcomes through the lens of a specific geography and the range of viability parameters that define population viability, the SEP produced the attainable definitions of local conditions that can support viable, healthy salmonid populations and an assessment of how local conditions currently impair such populations. As a result of this focus and specificity, the SEP products can facilitate local action and progress.

# Goals and Objectives

## *Central Valley*

Central Valley Goals for each salmonid population considered in the report include the following:

- Abundance: Increase population size.
- Productivity: Increase population growth rates and the ability to recover from years of poor recruitment.
- Spatial Extent: Increase the number of self-sustaining populations across the landscape.
- Genetic Diversity: Limit genetic influence from hatchery-produced fish and interbreeding of genetically distinct runs.
- Life History Diversity: Support a portfolio of life history types that are typical of each focal population.

Central Valley Goals are desired outcomes for Central Valley rivers and their salmonid populations as expressed in the numerous laws and policies that form the policy scope of this effort—they provide guidance and context for all other elements of the logic chain (Figure TS-3) developed herein. Where necessary, the desired outcomes of policies were further defined and articulated by the SEP Group as "VSP criteria." For example, many policies call for maintenance or restoration of salmonid populations that are "viable" or "in good condition"; these terms imply a need to achieve acceptable levels in all VSP criteria parameters.

In some cases, goals for restoration of rivers and salmonid populations in the Central Valley have been defined more specifically in the report with quantitative objectives. To the extent that they are Specific, Measurable, Achievable, Relevant to overarching goals, and Time bound (S.M.A.R.T.), Central Valley Objectives (Table TS-1) serve two essential functions in adaptive management: 1) they define goals in a manner that allows planners to scale restoration efforts to an appropriate level; and 2) they facilitate the measurement of progress toward desired outcomes. In other words, Central Valley Objectives allow for the effective and transparent evaluation of progress towards, or success in achieving, desired conditions through conservation actions (pre-implementation) and inform the need for adaptive management or additional conservation actions (post-implementation).

**Table TS-1**
**Central Valley Objectives Relevant to the Scientific Evaluation Process Scope**

| Relevant Goal | Target Population(s) | Policies or Recommendations | Objective |
|---|---|---|---|
| Abundance | Fall-run Chinook; Spring-run Chinook; Steelhead | CVPIA/AFRP, Fish and Game Code §6902, 2006 WQC Plan | Double natural production of anadromous fish as compared to their 1967 to 1991 average within 10 years. Specifically:<br>• 750,000 fall-run Chinook salmon per year from the Central Valley as a whole and 22,000 from the Stanislaus River<br>• 68,000 spring-run Chinook salmon per year from Central Valley rivers as a whole[a]<br>• 13,000 steelhead per year from Central Valley rivers as a whole |
| Abundance | Spring-run Chinook; Steelhead | ESA, Central Valley Salmonid Recovery Plan | Delisting of both species requires restoration of at least two populations in the Southern Sierra Diversity Group populations that are at low risk of extinction, which is defined, in part, as a census population size of greater than 2,500 (833 individuals, on average, for each of the three year classes in one generation) or an effective population size greater than 500.[b] |
| Productivity | Fall-run Chinook; Spring-run Chinook; Steelhead | CVPIA/AFRP, Fish and Game Code §6902, 2006 WQC Plan | Population growth rate sufficient to double populations within 10 years |
| Productivity | Spring-run Chinook; Steelhead | ESA, Central Valley Salmonid Recovery Plan | Restoration of viable populations at "low" risk of extinction is defined, in part, by failure to detect productivity declines among populations that meet other recovery criteria |
| Spatial Extent | Spring-run Chinook; Steelhead | ESA, Central Valley Salmonid Recovery Plan | Restore at least two viable populations of spring-run Chinook salmon and steelhead populations at low risk of extinction and multiple populations at no greater than moderate risk of extinction in the Southern Sierra Diversity Group |
| Genetic Diversity | Spring-run Chinook; Steelhead | ESA, Central Valley Salmonid Recovery Plan | Genetic introgression from different ESUs and/or hatchery populations must be no greater than "low" (e.g., less than 2%) |
| Genetic Diversity | Fall-run Chinook | HRSG 2012 | Proportion of hatchery-origin spawners less than 20% of adult spawners |

Notes:

a. Production targets for spring-run Chinook salmon and steelhead were not developed by the AFRP (USFWS 2001) for the Stanislaus River. However, natural production from the Stanislaus River would count towards Central Valley-wide Objectives.

b. Note that this objective, while specific and measurable, is not time bound.

### *Stanislaus River*

Watershed-Specific Goals for the Stanislaus River include the following:

- Abundance: Increase population size.
- Productivity: Increase population growth rates and ability to recover from years of poor recruitment. For Chinook salmon, population growth rates were targeted to increase in three stages to support the following:
  - Rebuilding: A population growth rate that supports increasing populations in a relatively short time period,
  - Resilience: A population growth rate that allows the population to rebound in a single generation after years with poor returns, and
  - Sustainability: Freshwater survival rates that are characteristic of salmon in human-modified rivers on the West Coast of North America.
- Genetic Diversity: Maintain genetic integrity of stocks by minimizing hatchery influence and introgression with other runs.
- Life History Diversity: Support the fullest expression of life history diversity (as seen within other Central Valley populations and in other rivers that support this phenotype).

Central Valley Goals and Objectives for salmonids are the aggregate of biological performance in all the waterbodies critical to Central Valley salmonids. Watershed-Specific Goals are the expression of local outcomes necessary to support attainment of Central Valley Goals and Objectives. Thus, while goals for the Stanislaus River are not detailed in the policies that define desired outcomes for the Central Valley at large, it is important to translate these Central Valley-wide outcomes into necessary component outcomes for each relevant waterbody in the Central Valley.

In the context of adaptive management, Watershed-Specific Goals provide context and direction for local management efforts. Because Watershed-Specific Goals expressions of existing policy, they will change only when and if the overarching policy (Central Valley Goals and Objectives) change.

There is no Watershed-Specific Goal that parallels the Central Valley Goals and Objectives regarding spatial extent (i.e., increase the number of self-sustaining populations across the landscape). This is because restoration of Stanislaus River populations of the focal species (i.e., attaining the other Watershed-Specific Goals for each population) will represent the local contribution to the Central Valley Goals and Objectives.

## Biological Objectives

A variety of Biological Objectives were identified for each focal species. These objectives relate to Watershed-Specific Goals for productivity, life history diversity, and genetic diversity of all focal species. Because abundance Biological Objectives were not developed for anadromous populations, Central Valley Objectives for abundance of the anadromous populations were used to guide Environmental Objectives related to habitat area (e.g., spawning habitat and juvenile rearing habitat). This reflects the understanding that, although conditions on the Stanislaus River are not solely responsible for anadromous fish cohort size, the habitat space available in the river system ultimately defines system-carrying capacity and that carrying capacity must be adequate to support Central Valley Objectives for abundance. Habitat space is the Stanislaus River’s “contribution” to the Central Valley Objectives for abundance as defined in the policy scope.

### *Productivity*

The **productivity** VSP attribute is composed of fecundity and stage-specific survival rates. The SEP Group’s Biological Objectives for focal anadromous populations focus on the production of juveniles per adult spawner. Annual estimates of juvenile population size are currently measured at various locations in the Stanislaus and lower San Joaquin rivers. Comparing these estimates to adult escapement estimates (which are measured at a counting weir and by redd and carcass surveys) reveals the overall annual productivity of the Stanislaus River for that population.

Biological Objectives for productivity of Stanislaus River salmonids are described in Tables TS-2 through TS-4. For Chinook salmon, productivity objectives tracked the three-staged Watershed-Specific Goals for productivity: rebuilding, resilience, and sustainability. Attaining these objectives means that adult-to-juvenile outmigrant survival will increase over a 24-year period. Although adult-to-juvenile outmigrant survival rates are mathematically independent of the number of adult spawners in a given year, the rates apply whether there are 100 spawners or 1,000 spawners. As the population of adults and juveniles reaches the system carrying capacity, actual juvenile survival rates may drop below the objective due to density-dependent mortality. As a result, the Biological Objectives for productivity are only to be measured in years when population abundance is substantially below carrying capacity—such conditions are expected to occur naturally, from time-to-time, regardless of the success of Stanislaus River restoration (e.g., due to poor ocean conditions).

**Table TS-2**
**Chinook Salmon Productivity Objectives**

| Objective[1] | | Productivity[1] | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Life History Stage | | Juvenile "Rebuilding" | | | Juvenile "Resiliency" | | | Juvenile "Sustainability" | | | Adult and Egg | | | |
| Description | Overview | Juvenile survival rate consistent with population growth rate of 2x over three generations (CRR=1.26) | | | Juvenile survival rate consistent with population resilience (CRR=2.5) | | | Juvenile survival rate in freshwater typical of Chinook salmon populations across the Pacific coast (10%) | | | Survival/reproductive success of adult migrants and indicators of egg development success | | | |
| | Achieved by When? | Year 10 | | | Year 15 | | | Year 24 | | | Year 9 | Year 9 | Varies (Year 9, 15, 24; see below) | Varies (Year 9, 15, 24; see below) |
| | Measure What? | Survival from/to | Survival from/to | Survival total | Survival from/to | Survival from/to | Survival total | Survival from/to | Survival from/to | Survival total | Survival from/to | Egg viability/ deposition | Egg/redd viability | Egg-emergence survival of surrogates |
| | Measured Where? | Spawning to Caswell [2] | Caswell to Vernalis [2] | Freshwater [3] | Spawning to Caswell [2] | Caswell to Vernalis [2] | Freshwater [3] | Spawning to Caswell [2] | Caswell to Vernalis [2] | Freshwater [4] | Caswell to spawning grounds at onset of spawning [5] | Spawning grounds | Spawning grounds | Spawning grounds |
| Fall-run and Spring-run | Wet Year | 12% | | | 15% | | | 35% | | | ≥ 90% | a) In hatchery hatching success = 95%; b) < 10% of female carcasses retain ≥ 10% of eggs | a) Environmental conditions consistent with in-hatchery development success: ≥ 80% (year 9); ≥ 85% (year 15); ≥ 90% (year 24) b) ≥ 90% redds remain intact through development period | Egg to fry survival (at Oakdale RST): ≥ 18% (year 9); ≥ 21% (year 15); ≥ 35% (year 24) |
| | Median Year | 8% | 68.2% | 1.11% | 10.7% | 72.2% | 2.2% | 24.4% | 82% | 10.0% | | | | |
| | Dry Year | 4% | | | 7% | | | 10% | | | | | | |

Notes:

1. Juvenile productivity and life history objectives refer only to those Chinook salmon that migrate before temperatures in the mainstem San Joaquin reach 25°C (77°F).
2. Survival objectives from Spawning to Caswell are premised on attainment of Caswell to Vernalis survival rate. If median Caswell to Vernalis survival rate is unattainable or exceeded, the Spawning to Caswell survival rate objective will be adjusted accordingly.
3. For reference purposes. Includes through-Delta survival. Conditions on the San Joaquin and its tributaries affect Delta survival; however, responsibility of San Joaquin tributaries for through-Delta survival outcomes is yet to be determined. Improvement in freshwater survival rates assumes river survival rates and Delta survival rates will improve proportionately from current levels.
4. For reference purposes. Assumes through-Delta survival of 50%. In this case, the improvement in river and Delta environments is no longer proportionate, as adherence to the proportionate improvement standard would require median survival of > 50% in the Delta. There was no consensus that survival rates of > 50% in the Delta could be achieved.
5. Currently, adult survival objectives are only developed for spring-run Chinook after they have migrated past Caswell. This reflects desired outcomes in the ability of spring-run to successfully "hold" in the river through the summer. Adult survival objectives may be developed (and potentially for fall-run and steelhead) in the mainstem San Joaquin; however, those objectives would be part of basin-wide planning and may require adult migration monitoring in the lower San Joaquin.

RST: rotary screw trap

**Table TS-3**
***O. mykiss* Productivity Objectives**

| Objective | | Productivity | |
|---|---|---|---|
| Life History Stage | | Juvenile Density | Juvenile Growth Rate |
| Description | Overview | Densities of *O. mykiss* that support desired frequency of anadromy in the population | Average individual growth rates that support desired frequency of anadromy in the population |
| | Achieved by When? | Year 15 | Year 15 |
| | Measure What? | Population density (parr/river $km^2$) | Average growth rate (mm/day) |
| | Measured Where? | Upstream of Oakdale, in reaches identified as having high quality *O. mykiss* holding habitat | Upstream of Oakdale, in reaches identified as having high quality *O. mykiss* holding habitat |
| ***O. mykiss*** | | The minimum density of age-0 *O. mykiss* during the summer equals $1/m^2$ on average | Minimum average growth of both age-0 and age-1 *O. mykiss*, averaged over an entire season, equals 0.60 mm/day |

Notes:
$km^2$: square kilometer
$m^2$: square meter
mm: millimeter

**Table TS-4**
**Steelhead Productivity Objectives**

<table>
<tr><th colspan="2">Objective</th><th colspan="8">Productivity</th></tr>
<tr><th colspan="2">Life History Stage</th><th colspan="2">Juvenile Smolt Size</th><th colspan="2">Juvenile Smolt Production</th><th colspan="3">Juvenile Smolt Survival</th><th>Adult</th></tr>
<tr><td rowspan="4">Description</td><td>Overview</td><td colspan="2">Proportion of smolts (Stages 4 and 5 in Table 16) observed should be of a size able to survive the ocean phase and return as anadromous adult</td><td colspan="2">Naturally produced smolts (Stages 4 and 5 in Table 16) per female spawner increase to levels consistent with other healthy steelhead populations</td><td colspan="3">Smolt survival – smolt (Stages 4 and 5 in Table 16) survival rate consistent with population resilience</td><td>Reproductive success of adult migrants and indicators of egg incubation success</td></tr>
<tr><td>Achieved by When?</td><td colspan="2">Year 15</td><td colspan="2">Year 15</td><td colspan="3">Year 15</td><td>Year 15</td></tr>
<tr><td>Measure What?</td><td colspan="2">FL</td><td colspan="2">Number of smolts per female spawner</td><td colspan="3">Survival through lower Stanislaus River</td><td>Egg-emergence survival of surrogates</td></tr>
<tr><td>Measured Where?</td><td colspan="2">Caswell (or other location prior to confluence with mainstem)</td><td colspan="2">Caswell (or other location prior to confluence with mainstem)</td><td>Lower end of gravel bedded reach</td><td></td><td>Delta entry</td><td>Spawning grounds</td></tr>
<tr><td colspan="2" rowspan="3">Steelhead</td><td>FL</td><td>150 mm (5.9 in)</td><td rowspan="2">3-year running average</td><td rowspan="2">Smolts per female spawner</td><td colspan="3" rowspan="3">> 90%</td><td rowspan="3">> 35%</td></tr>
<tr><td>Percentage</td><td>90%</td></tr>
<tr><td>Year type</td><td>All years</td><td>Minimum</td><td>165</td></tr>
</table>

Notes:
FL: fork length
in: inch

Biological Objectives for productivity were calculated by comparing current estimated survival rates throughout the salmonid life cycle and asking what survival rates would be needed in freshwater environments in order to achieve the Watershed-Specific Goals for population productivity. Ocean mortality estimates were considered to be constant into the future; many of the policies guiding river and salmon restoration in the Central Valley (the policy scope) do not authorize or anticipate further limitation of the ocean salmon fishery. In addition, changes to ocean survival rate would not affect the final stage of improvement in productivity ("sustainability") as the relevant survival objective applies only to the juvenile survival rate of salmon in freshwater environments.

Preliminary analyses of data collected by state and federal agencies revealed that the Watershed-Specific Goals for juvenile productivity of Stanislaus River salmon will be difficult or impossible to achieve without improving survival in both the riverine and tidal (Delta) portion of the salmon's freshwater environment. For example, "the sustainability" goal is characterized by survival rates that are typical of other Chinook salmon populations throughout the species' range; however, current survival rates in both the Delta and river environments are well below survival rates that characterize typical productivity of the entire freshwater environment (Table TS-5). Thus, even if there were no mortality in the Delta environment (survival equals 100%), survival in the river environment alone is well below that observed in freshwater for most other Chinook salmon populations.

**Table TS-5**
**Survival Rates in Freshwater Environments Necessary to Support Watershed-Specific Goal of Rebuilding the Stanislaus River Fall-run Chinook Salmon Population**

| Reach | Current | River Mile | Target Survival[3] | Target Survival[3] per River Mile |
|---|---|---|---|---|
| Eggs to Vernalis | 1.01% | 57 | 5.47% | 95.03% |
| Vernalis to Chipps Island | 3.75% | 72.5 | 20.31% | 97.83% |
| Chipps Island to Adult[1] | 5.40% | - | 5.40% | - |
| Adult to Spawner[1] | 60.24% | - | 60.24% | - |
| Recruits per Spawner[2] | 0.043 | - | 1.26 | - |

Notes:

1. Assumes no change from current estimated survival rates after juvenile salmon pass Chipps Island (the western edge of the Delta)
2. Recruits per spawner is calculated as the product of survival rates (e.g., Eggs to Vernalis × Vernalis to Chipps Island × Chipps Island to Adult × Adult to Spawner) × estimated population sex ratio (60% female spawners) × estimated average fecundity (5,813 eggs per spawner).
3. Target survival assumes an equal increase over current survival in Delta and riverine habitats. See the report for a calculation of survival in different riverine stretches.

Improvements in freshwater survival were applied to river and Delta environments proportionately to the current estimates of survival in these two environments. Juvenile salmon survival is currently estimated to be higher in the Delta than in the river; proportional improvement in survival rates maintained this asymmetry. This is consistent with the SEP Group's expectation that survival rates should increase as juveniles migrate downstream (e.g., because of the winnowing of weak or otherwise "unfit" individuals). However, proportionate improvement in survival rates eventually led to estimated Delta survival rates for juvenile salmon originating from the Stanislaus River that that the SEP Group considered to be unrealistically high. Many juvenile salmon emerging from the Stanislaus River are expected to complete freshwater rearing in the Delta (as opposed to salmon migrating from watersheds further upstream that will rear mainly in the river environment), and this extended residence in the Delta will likely cap potential survival improvements in the Delta. Thus, the final survival target for Stanislaus River juveniles in the Delta was capped at 50% median annual survival through the Delta. Juvenile survival required in the riverine environment was adjusted to produce overall freshwater survival identified in the final productivity-related Watershed-Specific Goal.

Adult-to-juvenile outmigrant productivity in the riverine environment is the product of spawning success of adults that return to the river, egg development success, and juvenile survival through the river system. These rates are controlled by conditions in the river system almost exclusively,[2] and, as a result, Biological Objectives for productivity of Stanislaus River salmonids may be attained through modifications of environmental conditions in the Stanislaus River and lower San Joaquin River. In addition to objectives for adult-to-juvenile survival rate, targets were established for adult survival, redd success, egg survival, and adult-fry production. These targets can be used to guide relative conservation efforts focused on improving conditions for each life history stage and, by monitoring these component rates, managers can determine where problems are occurring in the event that the overall adult-to-juvenile productivity objectives are not attained.

### *Life History Diversity*

Biological Objectives for life history diversity of Stanislaus River salmonids are described in Tables TS-6 through TS-9. Life history diversity among juvenile salmonids (commonly measured by the timing of and body size at migration) is increasingly recognized as vital to population growth rates (i.e., productivity) and stability of the population through time. Because the timing and quality of conditions in the San Francisco Bay Estuary and marine environments are highly variable, a diverse portfolio of juvenile sizes migrating at different times increases the chances that some fraction of each annual cohort will be able to capitalize on suitable conditions in pelagic environments.

[2] One nuance is that, for each individual female, maximum fecundity is determined by conditions experienced prior to river entry (e.g., in the marine environment). This potential fecundity may then be reduced by poor conditions encountered during the adult migration through freshwater.

**Table TS-6**
**Fall-run Chinook Salmon Timing of Migration Objectives**

| Size-Class | Caswell RST | | Mossdale[1] Trawl | |
|---|---|---|---|---|
| | Start Week | End Week | Start Week | End Week |
| Fry (smaller than 55 mm [2.2 in]) | Last of January | Second of April | N/A[2] | N/A[2] |
| Parr (larger than 55 mm [2.2 in], smaller than 75 mm [3 in]) | First of February | Last of May | Second of February | First of June |
| Smolt (larger than 75 mm [3 in]) | Third of February | First of June | February | June |

Notes:
1. Tributary contribution can be assigned (e.g., by otolith analyses).
2. Mossdale Trawl does not reliably detect fish smaller than 55 mm (2.2 in).

N/A: not applicable

**Table TS-7**
**Fall-run Chinook Salmon Size at Migratory Objectives**

| Size-Class | Wetter Years | Drier Years |
|---|---|---|
| Fry (smaller than 55 mm [2.2 in]) | 20% minimum | 20% minimum |
| Parr (larger than 55 mm [2.2 in], smaller than 75 mm [3 in]) | 20% minimum | 30% minimum |
| Smolt[1] (larger than 75 mm [3 in]) | 10% minimum | 20% minimum |

Note:
1. Includes only juveniles that migrate before daily mean temperatures greater than 25°C (77°F) at Mossdale

**Table TS-8**
**Chinook Salmon Biological Objectives – Life History Diversity Objectives**

| Objective | | Life History Diversity (Migration Timing) [1] | | | | Life History Diversity (Age-Class Distribution Minima) [1] | |
|---|---|---|---|---|---|---|---|
| Description | Overview | Support range of juvenile migration dates to maintain life history diversity | | | | Support range of sizes at juvenile migration dates to maintain life history diversity | |
| | Achieved by When? | Year 10 | Year 10 | Year 10 | Year 10 | Year 12 | Year 12 |
| | Measure What? | Detection every week no later than… | Detection every week through at least… | Detection every week no later than… | Detection every week through at least… | Minimum % juvenile migrants annually (wetter years) | Minimum % juvenile migrants annually (drier years) |
| | Measured Where? | Caswell RST | Caswell RST | Mossdale Trawl | Mossdale Trawl | Caswell RST | Caswell RST |
| Fall-run | Fry | Last week of January | Second week of April | N/A | N/A | 20% | 20% |
| | Parr | First week of February | Last week of May | Second week of February | First week of June | 20% | 30% |
| | Smolt | Third week of February | First week of June | Last week of February | Second week of June | 10% | 20% |
| Spring-run | Fry | First week of January | Second week of April | TBD | TBD | 20% | 20% |
| | Parr | | | | | 20% | 30% |
| | Smolt | | | | | 10% | 20% |
| | Yearling [2] | Detection in ≥ 50% weeks October to January | Detection in ≥ 50% weeks February to April | TBD | TBD | ≥ 1.5 yearlings per 1,000 female spawners | |

Notes:

1. Juvenile productivity and life history objectives refer only to those fish that migrate before temperatures in the mainstem San Joaquin reach 25°C (77°F).
2. The yearling life history strategy is associated with spring-running adults (fall-run adults may produce yearlings as well, but it is considered to be extremely rare). Production of some yearlings is expected whenever spring-run Chinook reproduce successfully; however, detection of yearlings is only required when sufficient numbers of spring-run salmon reproduce.

TBD: to be determined

**Table TS-9**
**Spring-run Chinook Salmon Timing of Migration Objectives at Caswell Rotary Screw Trap**

| Size/Life History Type | Frequency | Start | Fall-run Start | End (Both Runs) |
|---|---|---|---|---|
| Yearling (to be measured two calendar years following parent cohort return [escapement]) | a) Detection in at least 50% of weeks between the second week of October to January, and<br><br>b) 50% of weeks February to April (The division between time periods is intentional and meant to ensure that some yearlings migrate in each of the time periods) | October | No Applicable Objective | April |
| YOY (Fry, Parr, and Smolt)[1] | Every week | First week of January | Last week of January | First week of June |

Notes:

1. See Table TS-7 for definitions of fry, parr, and smolt size-classes.

YOY: young of the year

For Chinook salmon, life history diversity objectives took two forms: minimum standards for both the temporal distribution of migration and for the distribution of fish among three body size categories. Targets were not intended to be overly prescriptive in either of these categories, as life history diversity parameters should vary from year to year in response to environmental conditions. Rather, the life history diversity objectives were designed to identify minimum levels of diversity, below which the SEP Group would be concerned that the overall population was overly homogenous. It is worth noting that the existing fall-run Chinook salmon population on the Stanislaus River already meets many of the life history diversity Biological Objectives in many years (e.g., timing of juvenile migration), and other objectives, such as body size distribution, should be easily met following establishment of adequate rearing conditions on the Stanislaus River.

Life history diversity objectives for the Stanislaus River *O. mykiss* population were complicated by the extremely variable nature of *O. mykiss* life histories. Because factors like the proportion of anadromy (production of steelhead) are so dynamic within and among *O. mykiss* populations, there are few objective baselines against which to establish expectations for a healthy *O. mykiss* population. However, to support the attainment of Central Valley Objectives, life history diversity objectives were developed to ensure the expression of both resident and anadromous *O. mykiss* in the Stanislaus River (Table TS-10). Essentially, the Stanislaus River is expected to provide the environmental conditions to support the production of steelhead life histories by supporting the appropriate *O. mykiss* growth rates, smolt survival, resident densities, etc.

**Table TS-10**
***O. mykiss* Life History Diversity Objectives**

<table>
<tr><th colspan="2">Objective</th><th colspan="6">Life History Diversity (Anadromy)</th></tr>
<tr><th colspan="2">Life History Stage</th><th colspan="4">Juvenile</th><th colspan="2">Adult</th></tr>
<tr><td rowspan="4">Description</td><td>Overview</td><td colspan="2">Smolts produced per female spawner indicative of healthy spawner</td><td>Supports anadromy via a sufficient proportion of juveniles with anadromous O. mykiss mothers</td><td>Supports a range of outmigration dates for life history diversity</td><td>Support viable levels of both life history types</td><td>Support viable levels of both life history types</td></tr>
<tr><td>Achieved by When?</td><td colspan="2">Year 15</td><td>Year 15</td><td>Year 15</td><td>Year 15</td><td>Year 15</td></tr>
<tr><td>Measure What?</td><td colspan="2">Smolts per female spawner</td><td>Proportion of age-0 juveniles with anadromous maternal origin in otolith</td><td>Smolt (Stages 4 and 5; at least 150 mm [5.9 in] FL) detection</td><td>Proportion of adult O. mykiss</td><td>Resident adult abundance</td></tr>
<tr><td>Measured Where?</td><td colspan="2">Spawning reach</td><td>Age-0 O. mykiss collected in rearing areas</td><td>Caswell RST</td><td>Entire River</td><td>Reach just downstream of Goodwin Dam</td></tr>
<tr><td colspan="2" rowspan="3">O. mykiss</td><td colspan="4">This should be tracked on a brood year basis</td><td>N/A</td><td>Age 1+ fish superpopulation > 1,492 to 7,873</td></tr>
<tr><td>Annual hydrology > 50% exceedance</td><td>> 300</td><td rowspan="2">> 45%</td><td>Minimum of 4 months of the year</td><td>> 25% resident – summer</td><td rowspan="2">3 to 9 age 1+ resident fish per 100 m$^2$ (1,076 ft$^2$)</td></tr>
<tr><td>Annual hydrology ≤ 50% exceedance</td><td>> 150</td><td>N/A</td><td>> 20% anadromous – immigrating adults</td></tr>
</table>

Note:
ft$^2$: square feet

## *Genetic Diversity*

**Genetic diversity** objectives (Table TS-11) were intended to limit interbreeding between naturally spawned and hatchery-spawned individuals and among the different runs of Chinook salmon. Both phenomena are detrimental to the development of viable runs that are specifically adapted to local ecological conditions. Furthermore, both threats to genetic diversity are high-priority management problems in the Central Valley. The prevalence of hatchery-origin fish returning to spawn in Central Valley rivers is a significant problem in managing wild stocks, and interbreeding among genetically distinct fall-run and spring-run Chinook salmon poses numerous threats to both populations.

**Table TS-11**
**Genetic Diversity Objectives for Chinook Salmon**

| Objective | | Genetic | |
|---|---|---|---|
| Life History Stage | | Adult | Egg/Juvenile |
| Description | Overview | Maintain wild run genetic integrity | |
| | Achieved by When? | Year 9 | Whenever spring-running fish are present |
| | Measure What? | Percentage hatchery-origin spawners | Introgression |
| | Measured Where? | Spawning grounds | Spawning grounds |
| Fall-run | Wet | Proportion of hatchery-origin spawners < 20% of spawners | < 2% hatchery influence |
| | Median Year | | |
| | Dry | | |
| Spring-run | Wet | N/A | < 2% inter-run mating |
| | Median Year | | |
| | Dry | | |

## *Abundance*

**Abundance** objectives were developed for rainbow trout only because, like for Chinook salmon, the abundance of the anadromous form is not controlled solely by conditions in the freshwater environment (see Environmental Objectives below). Maintaining a viable population of rainbow trout is believed to be necessary to support the following:

- Increased frequency of the anadromous phenotype
- Resilience of *O. mykiss* populations to the prolonged natural occurrence of conditions that render anadromy a poor strategy
- Local recreational fisheries

The abundance objective for *O. mykiss* is in the term of parr density (i.e., one age-0 *O. mykiss* per square meter ($m^2$) during the summer in specified reaches) and adult rainbow trout abundance (i.e., 3 to 9 age-1+ fish per 100 $m^2$). Parr density and adult rainbow trout abundance, in conjunction with *O. mykiss* productivity objectives and associated Environmental Objectives, are believed to represent conditions in the Stanislaus River that will promote and protect the life history diversity of both resident and anadromous *O. mykiss*. The density and growth objectives for *O. mykiss* are described in Table TS-3, and *O. mykiss* abundance is provided in Table TS-10.

Biological Objectives define Watershed-Specific Goals in S.M.A.R.T. terms that define success. These tangible outcomes allow planners and managers to scale solutions appropriately, evaluate proposed actions against a clear baseline, and measure progress in a transparent fashion. Adaptive management requires such clear definitions of success and guidelines for implementing and adjusting actions through time.

The SEP Group made every effort to translate Watershed-Specific Goals into Biological Objectives that were S.M.A.R.T. Metrics related to each Biological Objective are either measured currently or are measurable using existing technology (Table TS-12). The Biological Objectives described in the report are considered achievable based on performance in other watersheds in the Central Valley or across the focal species' ranges.

Economic and political costs were not used in the evaluation of whether any Biological Objective would be successful for the following reasons:

- Such an evaluation would be speculative because a variety of solutions may be proposed to address any barrier to achieving the Biological Objectives.
- Evaluations of political and economic feasibility were beyond the scope of the SEP.

It should be noted that many Biological Objectives specified by the SEP Group are already attained in the Stanislaus River in many years. In these cases, the Biological Objectives serve as guidance that will help decision makers and managers to evaluate (and avoid) potential negative outcomes of future actions or trends.

The Biological Objectives may be modified if one of the following is true:

- Relevant Watershed-Specific Goals change; this would require changes in the larger policies that these goals represent.
- The specific outcomes are achievable, but not within the specified time bound; this would require a change in the time bound associated with the objective.
- Substantive evidence leads to the conclusion that the objectives are not physically or biologically achievable in the Stanislaus River; this would require revising the

Watershed-Specific Goal to be achievable and represent a meaningful contribution of the Stanislaus River to the relevant desired outcomes for the Central Valley at-large.

**Table TS-12**
**Current and Potential Monitoring that Could be Used to Measure Progress Towards Scientific Evaluation Process Biological Objectives**

| Biological Objective Type | Species | Life History Stage | Specific Objective | Relevant Current Monitoring (Monitoring Agency) | Relevant Monitoring Needed |
|---|---|---|---|---|---|
| Productivity | All | Egg | Egg-emergence to Oakdale RST Survival | Adult escapement at counting weir (USFWS weir – Tri-Dam funds);<br>Life history investigations, e.g., escapement and carcass surveys (CDFW);<br>Oakdale RST catch (Tri-Dam – currently not shared) | To be determined |
| Productivity | All | Egg | Viability | None | Requires incubation chamber (in hatchery or on site) measured by surrogates (e.g., egg trays) and/or as projected by monitoring of temperature, flow, sediment deposition, and scour |
| Productivity | All | Egg | Development success | None | Spawning surveys, redd mapping (superimposition), redd capping |
| Life History Diversity | Chinook salmon FR and SR | Adult migration | Migration timing | Adult escapement at counting weir (USFWS weir – Tri-Dam funds);<br>Life history investigations, e.g., escapement and carcass surveys (CDFW) | To be determined |
| Productivity | Chinook salmon FR and SR | Adult migration and spawning | Abundance | Adult escapement at counting weir (USFWS weir – Tri-Dam funds);<br>Life history investigations, e.g., escapement and carcass surveys (CDFW) | To be determined |
| Productivity | Chinook salmon FR and SR | Adult migration and holding | Survival | Adult escapement at counting weir (USFWS weir – Tri-Dam funds);<br>Life history investigations, e.g., escapement and carcass surveys (CDFW) | Include surveys for SR |
| Life History Diversity | Chinook salmon FR and SR | Adult migration and spawning | Spawning timing | Adult escapement at counting weir (USFWS weir – Tri-Dam funds);<br>Life history investigations, e.g., escapement and carcass surveys (CDFW) | Include surveys for SR |
| Productivity | Chinook salmon FR and SR | Adult migration and spawning | Prespawn mortality | Adult escapement at counting weir (USFWS weir – Tri-Dam funds);<br>Life history investigations (e.g., escapement and carcass surveys; CDFW) | Include surveys for SR |
| Productivity | Chinook salmon FR and SR | Juvenile emigration | In river (egg to delta) survival | Adult escapement at counting weir (USFWS weir – Tri-Dam funds);<br>Life history investigations, e.g., escapement and carcass surveys (CDFW);<br>Caswell RST catch (USFWS);<br>Mossdale trawl (CDFW) | Include surveys for SR;<br>Add or modify surveys at Mossdale to more accurately/frequently survey migrating salmonids, and smaller fish in particular;<br>Otolith microchemistry to distinguish juveniles from different natal streams in the lower San Joaquin |
| Genetic Diversity | Chinook salmon FR and SR | Adult migration and spawning | Percentage of hatchery-origin spawners | Adult escapement at counting weir (USFWS weir – Tri-Dam funds);<br>Life history investigations, e.g., escapement and carcass surveys (CDFW) | Include surveys for SR |
| Genetic Diversity | Chinook salmon FR and SR | Juvenile emigration | Percent introgression (SR and FR) | None | Genetic testing of outmigrating juveniles |
| Life History Diversity | Chinook salmon FR and SR | Juvenile emigration | Size, timing, and proportion of migrants; number of yearlings | Caswell RST catch (USFWS) | Include surveys for SR;<br>Add or modify surveys at Mossdale to more accurately/frequently survey migrating salmonids, and smaller fish in particular;<br>Otolith microchemistry to distinguish juveniles from different natal streams in the lower San Joaquin |
| Productivity | *O. mykiss* (steelhead) | Juvenile emigration | Smolt survival down the river and size and proportion of smolt migrants | None | Inclined-screen traps and video cameras, ARIS Didson cameras (imaging sonar system), or mark-resight estimates based on PIT tagging (some data from RST) |
| Productivity | *O. mykiss* (steelhead) | Juvenile emigration | Number of smolts (> 150 mm) per female spawner and total number of smolts per female spawner | Adult escapement at counting weir (USFWS weir – Tri-Dam funds);<br>Life history investigations, e.g., escapement and carcass surveys (CDFW);<br>Caswell RST catch (USFWS) | Inclined-screen traps and video cameras, ARIS Didson cameras (imaging sonar system), or mark-resight estimates based on PIT tagging (some data from RST) |
| Productivity | *O. mykiss* | Juvenile rearing | Parr density | Snorkel surveys (USBR) | Electrofishing or other appropriate sampling |
| Productivity | *O. mykiss* (steelhead) | Juvenile rearing | Number of smolts (> 150 mm) per female spawner and total number of smolts per female spawner | Adult escapement at counting weir (USFWS weir – Tri-Dam funds);<br>Life history investigations, e.g., escapement and carcass surveys (CDFW);<br>Caswell RST catch (USFWS) | Inclined-screen traps and video cameras, ARIS Didson cameras (imaging sonar system), or mark-resight estimates based on PIT tagging (some data from RST) |
| Productivity | *O. mykiss* | Juvenile rearing | Parr growth rates | None | Growth rates could either be measured by capturing, PIT tagging, and recaptured juvenile *O. mykiss* in the river or estimated by back calculating lengths at age from scales |

| Biological Objective Type | Species | Life History Stage | Specific Objective | Relevant Current Monitoring (Monitoring Agency) | Relevant Monitoring Needed |
|---|---|---|---|---|---|
| Life History Diversity | *O. mykiss* | Adults | Percentage of anadromous and resident adults | None | Resident: adult snorkel surveys or masks and recapture; Anadromous: weir counts, snorkel surveys, or redd surveys, otolith microchemistry |
| Life History Diversity | *O. mykiss* | Juvenile rearing | Proportion of anadromous mothers | None | Otolith microchemistry |
| Life History Diversity | *O. mykiss* (rainbow trout) | Adults | Minimum abundance of resident adults | None | Resident: adult snorkel surveys, mark and recapture, or electrofishing |
| Life History Diversity | *O. mykiss* (steelhead) | Juvenile emigration | Detection of emigrating smolts | Caswell RST catch (USFWS);<br>Oakdale RST catch (Tri-Dam – not currently shared);<br>Mossdale trawl (CDFW) | Modifications to Mossdale trawl (CDFW) to detect juvenile-size ranges |

Notes:
FR: fall-run
PIT: passive integrated transponder
SR: spring-run
USBR: U.S. Bureau of Reclamation

Political and economic considerations will come into play in the process of determining the best pathway to achieve Biological Objectives. However, political or economic considerations (while important) are not considered valid reasons for modifying Biological Objectives. Current evaluations of political or economic feasibility are unlikely to account for potentially innovative solutions to problems that arise as a result of changes in either restoration technology or the socioeconomic backdrop of the Stanislaus River watershed. The Biological Objectives are based in the best available scientific information on the outcomes that a functioning Stanislaus River ecosystem can support, given the directives provided by the policy scope. In cases where political or economic considerations are barriers to current attainment of Biological Objectives, it is preferable to make as much progress as possible towards full attainment and simply acknowledge that the Biological Objective in question has not been attained yet.

## Environmental Objectives

Environmental Objectives represent the design criteria for the restored river. They are, in a sense, hypotheses about what is required to attain the Biological Objectives. Using the desired outcomes described above as well as published literature and available models, the SEP Group defined a suite of environmental conditions that would support attainment of the Watershed-Specific Goals and Biological Objectives. Where possible, these were expressed in ranges that the literature indicated would represent "detrimental," "stressful," and "supportive" conditions for salmonids. Detrimental conditions for any one variable are those that will result in failure of the affected cohort to attain the Biological Objectives that are specific to that life history stage. Conversely, attainment of supportive environmental conditions across the suite of Environmental Objectives is consistent with attainment of the Biological Objectives (i.e., all the Biological Objectives are well within the known capacities of Chinook salmon and *O. mykiss* populations when environmental conditions are in the supportive range). Supportive conditions will not always occur for any one variable. The severity, duration, frequency, and number of other conditions that are stressful will determine whether a given population attains its Biological Objectives. Generally, the more conditions that are stressful and the longer or more frequently they are stressful, the less likely it is that Biological Objectives will be attained.

Environmental Objectives were established for each life history stage of each focal population. Variables addressed included temperature, dissolved oxygen (DO), contaminant concentrations, physical habitat space (e.g., gravel for spawning, shallow habitat for rearing), and others. To the extent possible, Environmental Objectives are not expressed as volumes of flow required to produce supportive conditions, although flow volumes can be determined to meet a particular suite of Environmental Objectives (e.g., depth and velocity of water to maintain desired temperatures or DO levels in spawning gravel).

The Environmental Objectives represent the hypothetical environmental conditions (based on best available science) that are necessary to attain the Biological Objectives in the Stanislaus River. It is possible that Biological Objectives can be attained even though the full suites of Environmental Objectives are not being met. This is grounded on the uncertainty around our scientific knowledge, natural variability, physical and biological interfaces, etc. As restoration proceeds on the Stanislaus River and the range of environmental conditions that approach their respective Environmental Objectives increases, the likelihood of attaining the Biological Objectives increases as well. When Biological Objectives are attained, the Environmental Objectives may be reassessed in an adaptive management context. Similarly, Environmental Objectives will need to be reassessed in the unlikely event that supportive conditions are attained for all Environmental Objectives, but the Biological Objectives are not attained.

## Stressors

Stressors (also known as limiting factors) are conditions (physical, biological, or ecological) within the system that limit or inhibit the attainment, existence, maintenance, or potential for desired conditions as characterized by the Biological and Environmental Objectives. Because different objectives are already being achieved to different degrees under existing conditions, identification of stressors is critical for highlighting components of desired conditions that are not being achieved and identifying the specific obstacles (i.e., stressor[s]) inhibiting desired conditions.

As a complement to the identification of stressors, ranking stressors enables the development of specific actions to achieve desired conditions by resolving stressors and facilitates the prioritization and sequencing of those actions to maximize benefits by addressing the most significant stressors first. In this way, when combined with the Biological and Environmental Objectives, the stressor analysis provides the basis for the following:

- Prioritizing conservation measures, including habitat enhancement actions and research, for maximum biological benefit
- Understanding the full range and extent of conservation measures necessary to support population recovery
- Setting expectations related to the extent of conservation measures required to see progress towards the Biological Objectives for a given life history stage by virtue of the extent of the stress to that life history stage that has been resolved

### *Stressor Identification, Ranking, and Prioritization*

The process for identifying and ranking stressors comprises the following four key steps:

1. **Identification of the range of stressors affecting each life history stage**. Potential stressors were identified based on expert opinion elicitation and reviews of published literature and available data related to current and projected future conditions. The identified stressors were

framed in terms of parameters specified in Environmental Objectives to characterize desired conditions (e.g., temperature and DO) and factors that are not specifically addressed in the objectives, but which affect the potential for the Biological or Environmental Objectives to be achieved (e.g., predation).

2. **Assignment of stressors for each life history stage** as relevant to the following three cases: 1) current population and conditions; 2) target population and conditions; or 3) both.
   - In the first case, the stressor affects the species or ecosystem under current conditions and/or at current species population levels.
   - In the second case, the stressor, although not currently impacting populations or ecosystem conditions, is predicted to become impactful once populations approach recovery; when ecosystem conditions progress towards desired conditions; or as a function of some other trend, transition, or tipping point occurring in the future.
   - In the third case, a stressor is currently having an impact on the species, and it is also expected that the magnitude or nature (e.g., scale and predictability) of that impact will change as populations increase, progress towards Environmental Objectives is made, or some other future condition occurs.
3. **Scoring of stressors by life history stage for current conditions and target of future conditions, as applicable**. Based on existing information, stressors were assigned a score of 1 to 4 points (1 being lowest and 4 being highest) in two categories—magnitude and certainty—using a scoring approach adapted from the Delta Regional Ecosystem Restoration Implementation Plan (DRERIP). Magnitude scores were based on the scale and severity of the impact to populations from the stressor. Certainty scores were based on the understanding of a stressor's related impact as a function of the available information base as well as the predictability of that impact. In combination, magnitude and certainty scores generate an overall score, guide stressor ranking, and provide indications about the appropriate stressor response.
4. **Stressor ranking and prioritization across life history stages**. Once scored, stressors for individual life history stages were combined for each of the three species (i.e., fall-run Chinook salmon, spring-run Chinook salmon, and *O. mykiss*). Stressors were then sorted and ranked based on their magnitude and certainty scores and assigned a stressor response type. In addition to the severity of the stress, a high magnitude score indicates the potential need for a major action, depending on certainty. A low magnitude score, depending on certainty, suggests either a need for monitoring to ensure the magnitude does not increase or research to confirm the low magnitude score and potentially inform adaptive management. In order to facilitate the application of the stressor analysis to the development and sequencing of conservation measures to alleviate stressors, the stressors were grouped and prioritized according to stressor responses in the following broad categories: Actions, Research, and Monitoring.

Stressor priorities are summarized across life history stages for fall-run Chinook salmon, spring-run Chinook salmon, and *O. mykiss*. All stressors identified in the analyses for the different species and life history stages are considered significant and in need of being addressed in order for Biological and Environmental Objectives to be achieved. However, the analyses specifically identify stressors with both a high magnitude and certainty as the highest priority for response in the form of conservation action(s) that will resolve the stressors and support attainment of the Environmental Objectives. The analysis further defines lower priority actions as those with a lower magnitude, but high degree, of certainty. Stressors with a high magnitude, but lower degree, of certainty are considered the highest priority for research, with other research priorities falling in below based on their relative magnitude scores. Low magnitude stressors are prioritized under baseline monitoring needs, where higher certainty indicates a priority for trend monitoring to ensure that the magnitude does not increase.

The report includes an analysis and summary of coarse scale stressors (e.g., lack of suitable rearing habitat) and single variable fine scale stressors (e.g., lack of suitable rearing habitat as a function of temperature) for each of the species over the near term and long term. The results are summarized in four matrices—1) coarse and 2) fine scale priorities for both 3) near-term and 4) long-term populations—and are presented for each of the three focal species (near term is provided in Figures TS-4, TS-5, and TS-6; long term is provided in Appendix D).

## *Results of Stressor Analysis*

The following matrices summarize a portion of the stressor prioritization results for each of the three focal species. For the purposes of this technical summary, only the highest and high priority coarse scale stressors for each of the three focal species are included to provide a sense of the most biologically pressing needs for action or research in the near term.

## Priority 1 (Highest)

### Actions and Associated Monitoring:

*Juvenile Rearing/Migration*

- **Lack of suitable rearing habitat**
- **Lack of suitable migratory conditions**
- **Compression of the rearing and migration window**

*Adult Spawning*

- **Interactions with hatchery fish and other runs**

## Priority 2 (High)

### Actions and Adaptive Management:

*Egg Development*

- **Inadequate development conditions**

*Juvenile Rearing/Migration*

- **Lack of suitable migratory cues**

### Research:

*Adult Migration*

- **Late access to river (relative to migration window) due to impassable or unsuitable conditions**

**Figure TS-4**

**Fall-run Chinook Salmon – Stressor Response Prioritization (Near Term/Coarse Scale)**

## Priority 1 (Highest)

### Actions and Associated Monitoring:

*Adult Spawning*

- Interactions with hatchery fish and other runs

*Egg Development*

- Inadequate development conditions

*Juvenile Rearing/Migration*

- Lack of suitable rearing habitat
- Lack of suitable migratory conditions

## Priority 2 (High)

### Actions and Associated Monitoring:

*Adult Holding*

- Lack of suitable habitat

### Actions and Adaptive Management:

*Juvenile Rearing/Migration*

- Lack of suitable migratory cues

### Research:

*Adult Holding*

- Loss of fecundity

*Adult Spawning*

- Compression of the spawning window

*Adult Migration*

- Negative sub-lethal effects (indirect; e.g., reduced fecundity or mortality via disease)

*Juvenile Rearing/Migration*

- Compression of the rearing and migration window

**Figure TS-5**

**Spring-run Chinook Salmon – Stressor Response Prioritization (Near Term/Coarse Scale)**

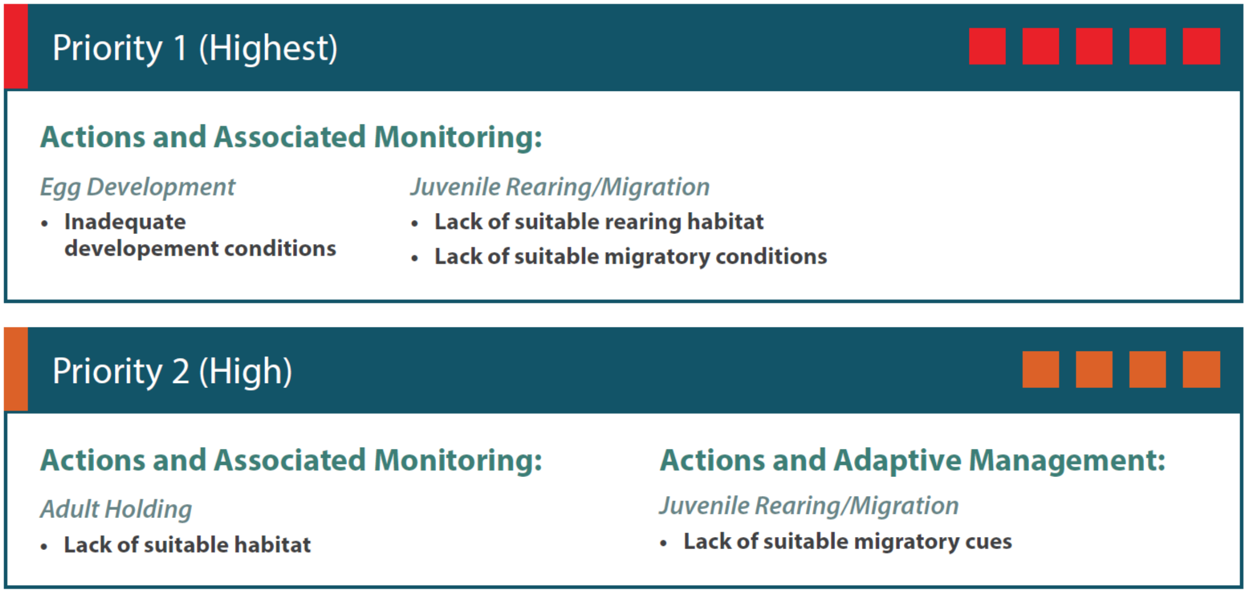



**Figure TS-6**
**Steelhead – Stressor Response Prioritization (Near Term/Coarse Scale)**

Stressors, as explained above, are the obstacles to achieving the desired conditions (i.e., Environmental Objectives) necessary for the species to attain the target population conditions (i.e., Biological Objectives). For any life history stage, progress towards the Biological Objectives can only be expected once the high priority stressors have been addressed and the Environmental Objectives are largely achieved. The efficacy of conservation measures designed to reduce stressors should therefore be measured based on the extent that those measures advance or achieve Environmental Objectives or Biological Objectives.

Once Environmental Objectives have been significantly advanced, or achieved via the resolution of priority stressors, Biological Objectives become metrics to measure species response to the actions and conditions quantified in the Environmental Objectives. In addition, Biological Objectives can serve as triggers for adaptive management actions in cases where Biological Objectives are not being achieved despite Environmental Objectives having been met and stressors resolved.

Although Environmental Objectives and stressors do not have a one-to-one relationship with Biological Objectives, there are several core relationships among them that can serve to guide expectations around biological response to the attainment of Environmental Objectives, including the following:

- **Habitat Quality → Survival**: Given the carrying capacity associated with a given spatial area of habitat, fish condition and survival are largely linked with habitat quality as defined by Environmental Objectives and stressors for a given life history stage.

- **Habitat Spatial Extent → Abundance**: Given habitat quality and suitability (as quantified by the Environmental Objectives) and associated survival rates, increased spatial extent of suitable habitat increases carrying capacity for that life history stage.
- **Habitat Temporal Extent → Diversity and Resilience**: Given sufficient habitat quality and spatial extent, the temporal extent and availability of habitat increases the potential for a given life history stage to express diversity.

Even when the primary stressors for a given life history stage have been addressed, certain Biological Objectives (e.g., population growth and abundance) require success across multiple or all life history stages. It therefore becomes necessary for the high priority stressors to be addressed and Environmental Objectives achieved for all life history stages to see meaningful progress towards the full suite of Biological Objectives.

In general, native species in the Stanislaus River are impacted by changes to river flow (e.g., reduced mean annual flow and an altered hydrograph), habitat alteration (e.g., dams and legacy mining), and biological modification (e.g., non-native species and hatchery-origin fish). In addition, changes to river flow and habitat alteration can influence biological modifications. Thus, the majority of stressors can be addressed through water management or habitat, or a combination of the two. For example, one of the highest priority stressors for juvenile fall-run Chinook salmon is the lack of rearing habitat. To alleviate this stressor, conservation actions would have to include a combination of habitat restoration and flow regimes to adequately inundate the restored habitat for an appropriate duration to support juvenile growth. Flow and habitat are both critical elements of river function and emergent themes necessary for river restoration. Although the SEP Group has not outlined specific actions necessary to alleviate stressors and meet Environmental and Biological Objectives, modifications to both current habitat and current flow regimes will be necessary to achieve the objectives for the Stanislaus River.

## Addressing Uncertainty

Each component of the SEP framework is essential to adaptively managing a comprehensive salmonid conservation strategy. Biological Objectives represent the minimum conditions necessary to achieve Watershed-Specific Goals for the Stanislaus River and its contribution to Central Valley Goals and Objectives for anadromous fish restoration. Management activities must be oriented toward attainment of the Biological Objectives and modified over time, as necessary, to achieve those objectives. That is, proposed conservation actions must be evaluated based on their ability to support the Biological Objectives prior to selection and implementation. Following implementation, monitoring will be needed to assess whether the expected benefits materialize.

Because it is difficult to measure the direct effect of individual actions on Biological Objectives, the Environmental Objectives provide the physical design criteria against which conservation actions (individually and collectively) can be evaluated. Environmental Objectives represent hypotheses of the environmental conditions needed to achieve the Biological Objectives. Stressors, and their relative magnitude and certainty scores, represent hypotheses regarding the existing and expected future barriers to attainment of Environmental and Biological Objectives. Finally, conservation actions will represent hypotheses about the best way to ameliorate stressors and to attain Environmental and Biological Objectives.

An adaptive management framework is necessary to conduct the following:

- Evaluate conservation measures for the hypothesized relationships between proposed actions, Environmental Objectives, and biological outcomes.
- Predict trade-offs between alternative sets of proposed conservation measures, and select the conservation measures with the best predicted outcomes.
- Monitor the response of environmental and biological metrics to implemented conservation measures and predicted outcomes.
- Update hypotheses, stressor evaluations, and Environmental Objectives over time in response to monitoring and new information.

## Next Steps for the Stanislaus River

The next steps in developing a comprehensive conservation strategy for salmonids in the Stanislaus River will be the design of a suite of specific conservation actions (a comprehensive conservation strategy), including the monitoring elements needed to evaluate the performance of actions individually and collectively. Such actions should be evaluated based on their ability to alleviate the priority stressors and to attain the Biological and Environmental Objectives identified in the report. Stakeholders, resource managers, and decision makers can employ the SEP goals, objectives, and stressor evaluations to assess the specific contributions of different conservation actions (alone and together) to the Biological and Environmental Objectives. Following implementation of conservation actions, information developed through monitoring can be synthesized to allow measurement of an action's effects in terms of the environmental conditions (stressors and Environmental Objectives) it was intended to modify. This adaptive management approach enables efficient adjustment of conservation actions and the conservation strategy, as needed. If monitoring indicates that conservation actions are not performing as intended, then changes to the actions, or additional actions, will be implemented to ensure that Environmental Objectives and Biological Objectives are reached.

The SEP's logic chain framework (Figure TS-2) facilitates the design of efficient and powerful monitoring plans. Implementation of the conservation actions will require various levels of monitoring, including site-specific monitoring to document compliance and performance of specific measures as well as system-wide monitoring to evaluate overall effectiveness. Monitoring activities will need to produce data that assess progress at all levels of the logic chain structure. Monitoring results should inform managers whether progress is being made towards the following steps:

1. Intended performance of individual conservation actions
2. Stressor reduction/elimination
3. Environmental Objectives
4. Biological Objectives

The SEP goals, objectives, and stressors also encourage targeted, efficient monitoring of individual conservation actions. When conservation actions are developed, their projected effect on relevant stressors and their expected contribution towards attainment of Environmental Objectives must be described. Monitoring needed to assess performance of conservation actions can only be determined after the conservation strategy is described in detail. However, the monitoring needed to evaluate progress towards larger desired outcomes (items 2 through 4 in the list above) has been defined by the performance metrics presented in the report. In certain instances, the stressors addressed by a conservation action may transcend the effect of any physical or chemical environmental condition; actions that are designed to reduce predation pressure fall into this category. In such cases, monitoring plans that accompany the proposed action should be specific regarding the way in which the action is expected to reduce the stress so that the effect of the action can be tracked by relevant monitoring.

The SEP Group is prepared to evaluate conservation plan proposals for the Stanislaus River to determine how likely they are to produce the Environmental and Biological Objectives. Such an evaluation will be limited to SEP Group members that did not participate in the development of proposed conservations strategies. Evaluations will be conducted using a systematic and transparent process to document likely effects, uncertainties, and potential unintended negative consequences of actions. To be evaluated, a conservation strategy will need to meet the following metrics:

- Be comprehensive (i.e., address desired outcomes throughout the riverine life history of the focal populations)
- Be specific in terms of the scale and timing of actions
- Document its projected effect on stressors and the attainment of objectives

## Beyond the Stanislaus River

In addition to assisting with the evaluation of conservation plans that emerge for the Stanislaus River, the SEP Group intends to develop goals and objectives for the Tuolumne, Merced, and lower San Joaquin rivers. In addition, the SEP Group will evaluate the stressors in each of those environments and how they affect relevant life history stages of the focal populations. This process will culminate in the integration of a basin-wide vision.

Integration of goals and objectives for different waterbodies may require adjustments for the sake of consistency. Additionally, some desired outcomes can only be articulated in the context of goals and objectives for all three San Joaquin River tributaries. For instance, management of adult salmonid straying is a basin-wide issue that will require improved conditions on each of the tributaries and hatchery management objectives. Similarly, identification of effects on one life history stage that are driven by changes in the previous life history stage (e.g., bigger, healthier juvenile outmigrants contribute to better survival through Delta, and less stressful adult migration through Delta/lower river leads to higher spawning success and fecundity upstream) will require a basin-wide approach.

Having created the template with the Stanislaus River process, the application of the SEP approach to other waterways in the San Joaquin River basin can happen much more quickly, provided there is adequate facilitation and technical support. The benefit of the SEP approach is that work towards desired conditions on the Stanislaus River can begin immediately. For example, while Delta restoration is essential to attaining desired conditions for the Central Valley's salmonid populations, there is no need to delay the process of attaining Stanislaus-specific Biological Objectives while required outcomes for the Delta are further defined. The SEP's Watershed-Specific Goals and Biological Objectives are local in scope, achievable, and ready to be applied to the evaluation of conservation actions.

# 1 Introduction

Over the past few decades, efforts have been made to reverse and restore the declining health of riverine and estuarine habitats in the Central Valley and, in particular, their anadromous fish fauna. Yet, these habitats and key populations continue to be at risk of further degradation and decline. This is partially attributable to the lack of a common vision of conservation success among resource agencies, conservation groups, and water districts. A vision of conservation success (i.e., attainment of native salmonid population goals and objectives) must include appropriate targets of success and overarching goals and objectives. In addition, a vision of conservation success provides the framework for developing, evaluating, and implementing appropriate strategies for conservation and restoration. Without such a framework, science-based adaptive management cannot be applied to solve complex ecosystem and water management issues.

The lack of conservation success is recognized in multiple regulatory processes associated with the lower reaches of the San Joaquin River and its major tributaries, the Stanislaus, Tuolumne, and Merced rivers. Because these regulatory processes may affect change in fisheries and the operations of various water and resource management agencies, a large group of stakeholders interested in resolving long-standing ecosystem and water management issues convened to work on a process to negotiate a settlement for these various regulatory processes. This settlement negotiation process, called the San Joaquin Tributary Settlement Process, originally discussed a set of goals for the San Joaquin River system, but the stakeholders soon realized that science-based methods should be used to establish desired outcomes (including goals, biological objectives, and environmental objectives) for the river and to evaluate conservation proposals in the context of those desired outcomes. The San Joaquin Tributary Settlement Process stakeholders decided to focus first on one major San Joaquin River tributary—the Stanislaus River—due to the size and complexities of the overall San Joaquin River basin.

Scientists with appropriate expertise were identified by the various parties to participate in an effort to identify a new pathway for improving the status of Chinook salmon (*Oncorhynchus tshawytscha*) and *O. mykiss* (including Central Valley rainbow trout and California Central Valley steelhead [steelhead]) populations in the San Joaquin River basin. The collaboration involved experts from the California Department of Fish and Wildlife (CDFW), U.S. Fish and Wildlife Service (USFWS), U.S. Bureau of Reclamation (USBR), National Marine Fisheries Service (NMFS), American Rivers, The Bay Institute, Trout Unlimited, and The Nature Conservancy. The process was open to all stakeholders. This collaborative group pursued a Scientific Evaluation Process (SEP) and identified itself as the "SEP Group."

The SEP Group focused on defining desired outcomes for three fish populations: fall-run Chinook salmon, spring-run Chinook salmon, and *O. mykiss* (both resident and anadromous forms). This focus was motivated by the following:

- The understanding that restoring conditions that support these populations would provide significant benefits to other ecosystem attributes and functions in the lower Stanislaus River watershed
- The availability of data on salmonids relative to other aquatic biological resources in the Stanislaus River

The SEP Group developed goals and specific objectives for the salmonid populations of the Stanislaus River that incorporated and harmonized numerous federal and state policies, programs, and plans, including the Anadromous Fish Restoration Program (USFWS 2001), Bay-Delta Water Quality Control Plan (WQC Plan), Endangered Species Act (ESA) recovery plans, and relevant CDFW code sections. The programs and plans that the SEP Group considered as part of this framework are discussed in detail in Section 2.3.1.

The SEP is intended to help provide a common scientific foundation of fact for all parties engaged in developing a comprehensive approach to solving San Joaquin River basin aquatic resource management issues as well as the following parties engaged in relevant regulatory processes:

- The State Water Resources Control Board (SWRCB) update of the WQC Plan, as called for under the state Porter-Cologne Water Quality Control Act and the federal Clean Water Act
- Federal Energy Regulatory Commission relicensing proceedings

The purpose of the SEP is three-fold, as follows:

1. Develop a clear, scientifically justified vision for the desired status of fall-run and spring-run Chinook salmon and *O. mykiss* in the Stanislaus River and larger San Joaquin River basin.
2. Provide well documented and transparent technical guidance on the conditions necessary to attain that vision.
3. Provide a foundation for evaluating the effectiveness of proposed actions to achieve the conditions necessary to realize the vision.

The *Conservation Planning Foundation for Restoring Chinook Salmon (Oncorhynchus tshawytscha) and O. mykiss in the Stanislaus River* (report) explicitly addresses the first two purposes, and its development supports the third purpose as it relates to the Stanislaus River. The vision and technical guidance developed here will inform similar products for other major San Joaquin River tributaries (the Tuolumne and Merced rivers) and for the mainstem San Joaquin River downstream of its confluence with the Merced to the Sacramento-San Joaquin Delta (Delta). The SEP Group envisions that the strategies proposed to achieve the conditions necessary to restore salmonid populations to the Stanislaus River and throughout the San Joaquin River basin would be developed through discussions and multi-party negotiations among resource agencies, conservation groups, and water districts. Proposed strategies (suites of conservation actions) would then be reviewed using a systematic process (e.g., the methodology described for the Delta Regional Ecosystem Restoration Implementation Program that was developed by state and federal agencies). The overarching purpose of these efforts and strategies is to restore the San Joaquin River and its tributaries to support sustainable native fish populations and other living resources.

# 2 Scope, Context, and Considerations

## 2.1 Historical Context

San Joaquin River basin salmonid populations were once some of the largest in California's Central Valley (CDFG 1990). Historically, the San Joaquin River and its tributaries supported fall- and spring-runs of Chinook salmon and steelhead (Yoshiyama et al. 2001; Moyle 2002). As recently as the 1940s, spring-run Chinook salmon were the dominant salmon run in the San Joaquin River basin (Fry 1961).

From the 1940s to the 1980s, extensive water storage development occurred throughout the San Joaquin River watershed, resulting in a large proportion of flow being diverted from river channels. In addition, spawning and rearing habitats were degraded, and access to historical spawning and rearing reaches was blocked by dams. This habitat degradation and loss caused by construction and operation of dams, along with habitat degradation caused by gravel mining, channelization, and other human actions, has led to significant declines in spring- and fall-run Chinook salmon and steelhead populations (Figure 1). For decades, spring-run Chinook salmon were considered to be extirpated from the San Joaquin River basin (Fisher 1994); however, more recently, "spring-running" Chinook salmon have been observed in the Stanislaus and Tuolumne rivers (Franks 2012).

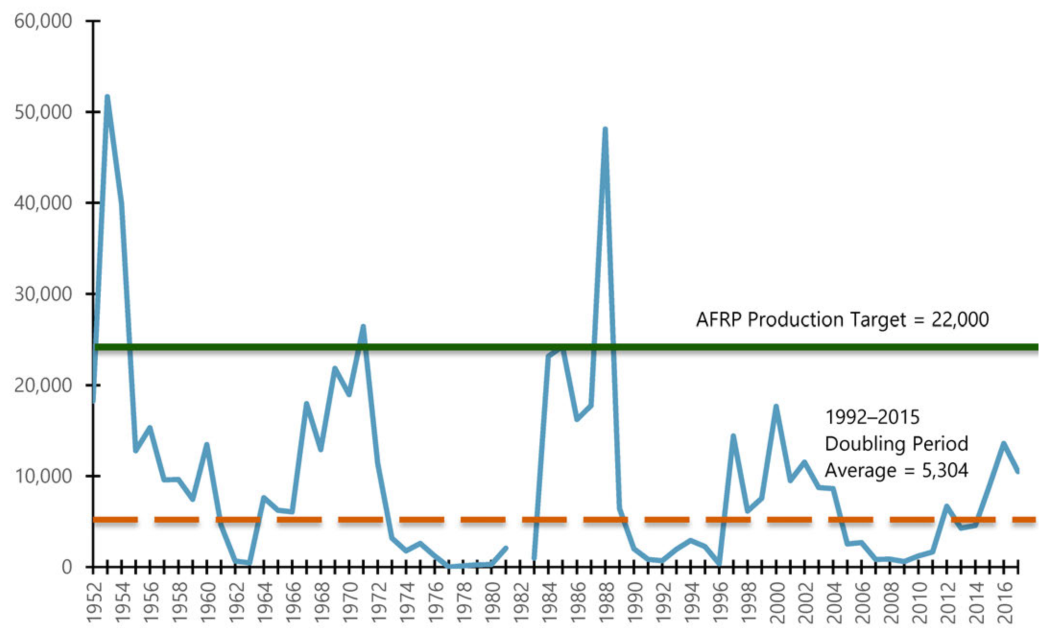



**Figure 1**
**Estimated Yearly Natural Production of Adult Fall-run Chinook Salmon**

Notes:
Fall-run Chinook salmon production estimates are well below AFRP production targets for the Stanislaus River from 1992 to 2015 (USFWS 2001). Figure is modified from USFWS Chinookprod doubling goal graphs available at https://www.fws.gov/lodi/anadromous_fish_restoration/documents/Doubling_goal_graphs_063016.pdf.

## 2.2 Considerations for Biological and Environmental Objectives

The SEP Group expressed its vision for the desired status of Stanislaus River salmonid populations in the form of "Biological Objectives" (Section 6). They developed "Environmental Objectives" (Section 7) to provide technical guidance on the conditions necessary to attain the Biological Objectives. Objectives were developed using the following considerations:

1. Objectives are Specific, Measurable, Achievable, Relevant to overarching goals, and Time bound (S.M.A.R.T.).
2. Biological and Environmental Objectives for the Stanislaus River are specific to conditions that can be controlled or greatly influenced by actions in the Stanislaus River. In cases where setting Stanislaus River-specific objectives require making assumptions regarding outcomes in other parts of the salmonid life cycle, those assumptions are stated. For example, productivity (juvenile survival) objectives for the Stanislaus River assume and reflect anticipated improvements in survival through the Delta because it is not possible to restore adequate salmonid productivity unless conditions improve throughout the freshwater environments used by these fish.
3. Biological and Environmental Objectives provide a framework for evaluating proposed actions. Actions necessary to achieve these objectives are not proposed or evaluated in this document. Biological and Environmental Objectives for the Stanislaus River are intended to serve Central Valley Goals and Objectives.
    - For example, Central Valley Goals and Objectives that set expectations for abundance of salmonids produced by, or returning to, the Stanislaus River have already been identified (e.g., the Anadromous Fish Restoration Plan [AFRP] identifies a target of 22,000 harvestable size, naturally produced fall-run Chinook salmon; USFWS 2001) or were derived with reference to policy guidance and outcomes on similar systems in the Central Valley. These expectations were used to inform development of Biological and Environmental Objectives for the Stanislaus River. However, the SEP Group did not identify adult abundance objectives for the Stanislaus River because the group recognized that abundance is related to conditions throughout the salmonid life cycle and cannot be tied solely to conditions in the Stanislaus River.
4. Four levels of viability parameters—abundance, productivity, diversity, and spatial structure—determine if salmonid populations are viable, healthy, and in good condition and to what level of risk they are exposed (McElhany et al. 2000). These parameters influence each other directly and indirectly. For any population, failure to achieve threshold levels for any one of these parameters represents a threat. Therefore, the SEP Group specifically addresses these four parameters for each population through life history stage-specific Biological Objectives.
5. While the specific Biological and Environmental Objectives reported here have been developed for the Stanislaus River, they are intended to be applied in concert with analogous targets specific to all rivers in the San Joaquin River basin. Thus, the creation of ecological conditions in

the Stanislaus River necessary to support Biological Objectives for the target salmonid populations is only one component of a broader strategy for supporting vibrant and diverse populations of Chinook salmon and *O. mykiss* throughout the San Joaquin River basin.

6. In addition to tributary-specific objectives, San Joaquin River basin-wide objectives will need to be established in some cases.
   - For example, the production of juvenile salmonids from all San Joaquin River tributaries will affect the quantity and quality of rearing and migration habitats needed in the lower San Joaquin River to support the combined outmigration. Additional objectives—to which the Stanislaus River will need to contribute—depend on the relative contributions of other San Joaquin tributaries, which will be developed after the SEP Group develops biological goals and objectives for the Tuolumne and Merced rivers.
7. The objectives discussed in this report focus on salmonid species. However, their cumulative effect is intended to benefit numerous native species and habitat types throughout the Stanislaus River watershed, the San Joaquin River corridor, and into the Delta. Because salmonids are a relatively resilient and hardy species, attainment of objectives designed to restore these populations may not represent the level of restoration of the Stanislaus River, lower San Joaquin River, or Delta required by other species or downstream ecosystems.
8. All objectives identified herein are believed to be measurable using existing technology, and existing monitoring is adequate to monitor attainment of some objectives. However, additional monitoring may be necessary to evaluate the attainment of some of the S.M.A.R.T. objectives identified in this report.
9. Successfully restoring the sustainability and resiliency of anadromous fish populations in the San Joaquin River basin may require restoring access to habitats in watersheds above dams. All major rivers in the San Joaquin River basin are identified by NMFS (2014) as candidates for building fish passage for access to upstream habitats. The SEP Group makes no assumptions that specific measures would occur in the future. Rather, the conservation measures to be developed through future discussions and negotiations are expected to respond to, and serve, the Biological and Environmental Objectives identified in this report and will be evaluated as to how well they support attainment of the objectives.

## 2.3 Scope

The SEP Group developed Biological and Environmental Objectives for the Stanislaus River in the context of policy, geographical, and biological considerations.

### *2.3.1 Policy Considerations*

Numerous laws, programs, and plans at the state and federal level call for restoring healthy anadromous salmonid populations in the Central Valley and the San Joaquin River. The SEP Group's

Biological and Environmental Objectives for restoring salmonids of the Stanislaus River incorporated and attempted to convey technical guidance within a framework that is consistent with and harmonizes the requirements of the laws, plans, and programs listed in this section.

Many policies, laws, and regulations call for the restoration of anadromous fish populations in the Central Valley and the San Joaquin River watershed, but these policies do not necessarily apply consistently to different populations as illustrated in the following examples:

- Central Valley spring-run Chinook salmon and steelhead are listed under ESA, but fall-run Chinook salmon are not listed.
- Doubling of Chinook salmon runs is required under the WQC Plan, California Fish and Game (F&G) Code, and Central Valley Project Improvement Act (CVPIA), and doubling of steelhead is required under the F&G Code and CVPIA. However, specific restoration targets for the San Joaquin watershed and its tributaries were developed under the AFRP only for fall-run Chinook salmon, not spring-run Chinook salmon or steelhead (USFWS 2001).

The Biological and Environmental Objectives developed by the SEP Group for the Stanislaus River were designed to support outcomes consistent with, and goals derived from, application of the laws, policies, and programs described below.

**California Fish and Game Code Sections 2760-2765**

The purpose of the Keene-Nielsen Fisheries Restoration Act of 1985 is to prevent further declines in fish and wildlife; restore fish and wildlife to historical levels where possible; and enhance fish resources through the protection of, and an increase in, the naturally spawning salmon and steelhead resources of the state.

**California Fish and Game Code Section 5937**

This section of the F&G Code is intended to balance the needs of California's native fish and the construction and operations of dams by requiring dam operators to release enough water to maintain fish populations below the dam "in good condition" (Börk et al. 2012). This section of the F&G Code was enacted in 1915 and has rarely been implemented. However, one notable instance where the code was used was a decision by the Court of Appeals on suit brought by California Trout concerning Mono Lake tributaries (California Trout, Inc. v. State Water Resources Control Board 1989 ["CalTrout I"]).

**California Fish and Game Code Sections 6900-6924**

The Salmon, Steelhead Trout, and Anadromous Fisheries Program Act declares that it is the policy of the state to significantly increase the natural production of salmon and steelhead by the year 2000, and it directs the CDFW to develop a plan that strives to double the current natural production of salmon and steelhead resources. This is the same narrative (i.e., a doubling goal) as in the CVPIA.

**Central Valley Project Improvement Act**

In 1992, the CVPIA (Public Law 102-575) revised the goals of the federal Central Valley Project. Title 34 makes protection, restoration, and enhancement of fish and wildlife a goal of the Central Valley Project on par with its water delivery goal. Specifically, Section 3406(b)(1) of Title 34 requires that the secretary of the U.S. Department of the Interior (USDOI) develop and implement a program that makes all reasonable efforts to ensure that, by the year 2002, natural production[3] (i.e., the abundance of fish available for harvest in the ocean fishery excluding fish originating from hatcheries) of anadromous fish in Central Valley rivers and streams will be sustainable on a long-term basis at levels not less than twice the average levels attained during the 1967 through 1991 period. On January 9, 2001, the USFWS released the Final Restoration Plan for the AFRP to comply with this narrative requirement, which is referred to as the "doubling goal" (USFWS 2001). The AFRP calculates an annual natural production target of almost 1 million Chinook salmon (including 750,000 fall-run, 68,000 spring-run, 110,000 winter-run, and 68,000 late fall-run Chinook salmon). Production targets consistent with attainment of the overall "doubling goal" are established for most Central Valley rivers, including the Stanislaus River; however, there are gaps in the river-specific targets of the AFRP. For example, the AFRP established a target of 13,000 naturally produced steelhead at the Red Bluff Diversion Dam (RBDD), but no steelhead targets have been established for the remainder of the Central Valley watershed, which would be much larger than the current (partial) target. Similarly, the AFRP does not establish targets for restoration of spring-run Chinook salmon in San Joaquin tributaries, even though the San Joaquin River basin was once their stronghold in the Central Valley.

**Federal Endangered Species Act Determinations and Plans**

In 1998, NMFS listed the distinct population segment of steelhead in the Central Valley as threatened under ESA (63 Federal Register 13347); steelhead are present in the Stanislaus River. In 1999, NMFS listed the Central Valley spring-run Chinook salmon evolutionarily significant unit (ESU) as threatened under ESA (64 Federal Register 50394). Spring-run Chinook salmon were believed to have been extirpated from the San Joaquin River basin. The final NMFS recovery plan for endangered salmon of the Central Valley calls for reestablishment of at least two viable spring-run populations to the San Joaquin River basin as a critical step in delisting this species (NMFS 2014). Status reviews conducted by NMFS and reported in 2011 resulted in no changes being made to the status of spring-run Chinook salmon or steelhead under ESA (NMFS 2011a, 2011b). In 1999, NMFS considered information about the Central Valley fall-run and late fall-run Chinook salmon ESU and determined

[3] Production refers to the abundance of fish available to the ocean fishery and should not be confused with escapement, which refers to the number of adult fish that return to freshwater habitats to spawn.

that listing was not warranted. However, NMFS considered the fall-run and late fall-run Chinook salmon ESU to be a candidate species for listing in the future, so they are managed as a species of concern (NMFS 2009a).

**San Joaquin River Restoration Program**

After the completion of Friant Dam by the federal government in the 1940s, nearly 95% of the river's flow below the dam was diverted. As a result, 60 miles of the river ran dry, the second largest salmon population in the state was lost, and local fish and wildlife populations declined. Decreased water flows and water quality degradation impacted downstream farms and communities. Since 2009, USBR, USFWS, NMFS, CDFW, and the California Department of Water Resources have been working together to implement the San Joaquin River Restoration Program (SJRRP; resulting from a 2006 legal settlement between environmental groups, the Friant Water Users Authority and the federal government, and subsequent federal legislation) to restore spring- and fall-run Chinook salmon to the mainstem San Joaquin River downstream of Friant Dam. In the long term, this program intends to restore annual runs of up to 30,000 spring-run Chinook salmon and 10,000 fall-run Chinook salmon.

**State Water Resources Control Board's 2006 Water Quality Control Plan**

The WQC Plan contains the current requirements under federal Clean Water Act Section 303(c)(33 U.S.C., § 1313(c)) and Section 13240 of the state Porter-Cologne Water Quality Control Act to protect the beneficial uses of the waters of the San Francisco Bay/Sacramento-San Joaquin Delta Estuary (Estuary). Specifically, it identifies beneficial uses of water in the Estuary, including its watershed, water quality objectives to protect those beneficial uses, and a program of implementation for achieving the water quality objectives. In the 2006 WQC Plan, the narrative objective for salmon protection states the following:

> Water quality conditions shall be maintained, together with other measures in the watershed, sufficient to achieve a doubling of natural production of Chinook salmon from the average production of 1967 to 1991, consistent with the provisions of state and federal law. (SWRCB 2006)

The SWRCB has updated the WQC Plan and adopted new flow standards on the lower San Joaquin River and its three eastside tributaries for the protection of fish and wildlife beneficial uses (SWRCB 2018). However, the new flow standards do not become effective until they are approved by the California Office of Administrative Law.

**The Salmon, Steelhead Trout, and Anadromous Fisheries Program Act of 1988**

The California Advisory Committee on Salmon and Steelhead Trout was created in 1983 to develop a strategy for the conservation and restoration of salmon and steelhead resources in California. The Salmon, Steelhead Trout, and Anadromous Fisheries Program Act of 1988 was signed by the governor of California to implement the advisory committee's recommendations, which included doubling the natural production of Central Valley salmon and steelhead.

### *2.3.2 Geographical Considerations*

The SEP Group focused on the Stanislaus River as a first step toward developing a transparent framework for identifying desired outcomes for salmonids in the San Joaquin River basin and the environmental conditions needed to support those outcomes (Figure 2). This focus was justified by the following:

- Current habitat conditions and potential for restoration of the Stanislaus River
- The relatively large amount of information available on the Stanislaus River compared to others in the San Joaquin River basin
- The high level of interest by the SWRCB and other stakeholders in the WQC Plan update

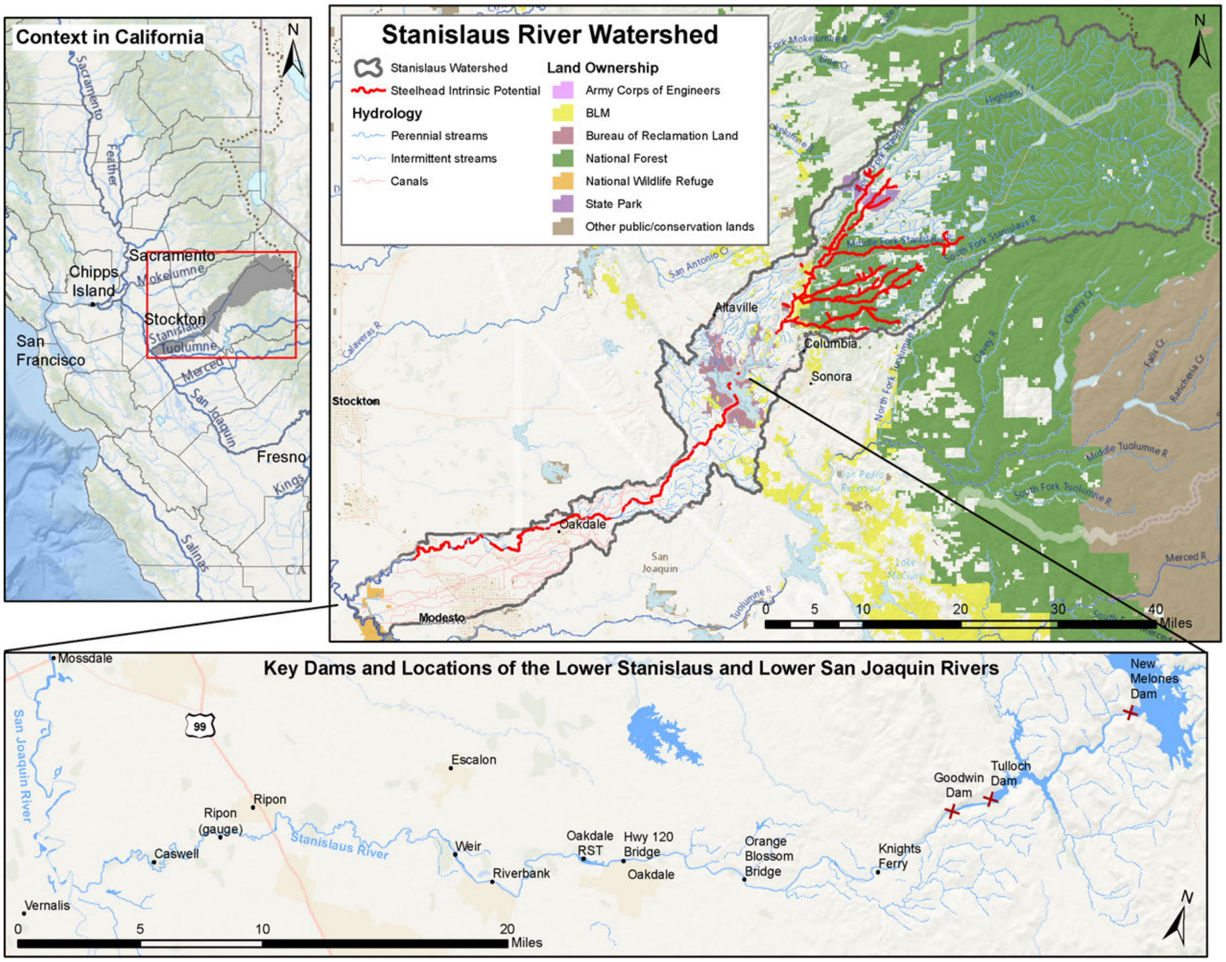



**Figure 2**
**Key Dams and Features of the Lower Stanislaus River**

Focusing on the Stanislaus River meant two things: 1) articulating desired outcomes for its salmonid populations; and 2) defining the suite of environmental conditions on the river that are necessary to attain those outcomes. Plan goals and Biological and Environmental Objectives are specific to outcomes that can be attained by actions on the Stanislaus River. The goals and objectives represent conditions of, and outcomes from, the Stanislaus River that are consistent with laws, policies, and programs related to restoration of salmonids throughout the Central Valley. Additionally, the SEP Group recognized that the Stanislaus River must contribute to conditions in the lower San Joaquin River and southern Delta, but, in many cases, it is not possible to completely define that contribution without performing a similar evaluation of goals and objectives for the other rivers in the San Joaquin River basin. The SEP Group's intent is that the template developed for the Stanislaus River will be used to develop similar sets of Biological and Environmental Objectives for the Tuolumne and Merced rivers and the lower mainstem San Joaquin River (the area of the watershed downstream of the confluence of the San Joaquin and Merced rivers and upstream of the Delta).

The spatial scope of this initial effort to develop Biological and Environmental Objectives for the Stanislaus River includes the Stanislaus River from Goodwin Dam to its confluence with the San Joaquin River (Figure 2). While the Biological and Environmental Objectives are specific to reaches within the Stanislaus River, the SEP Group recognizes that establishing Biological Objectives for Chinook salmon and *O. mykiss* in the Stanislaus River and identifying the ecological conditions required to support them does not end at the Stanislaus River. Suitable habitat conditions in the lower San Joaquin River are necessary for the successful restoration of Chinook salmon and *O. mykiss* populations in the Stanislaus River. The SEP Group estimates that current survival of fall-run Chinook salmon through the Stanislaus River to the San Joaquin's entry into the Delta is extremely low (approximately 1%; Section 6.2.1 and Appendix A).

Biological Objectives for the Estuary and Pacific Ocean were not addressed because these ecosystems respond to ecological drivers and human actions that are beyond the geographic scope identified for the SEP Group's consideration. However, in some cases (e.g., juvenile survival targets), assumptions regarding future conditions in the Estuary and Pacific Ocean were necessary to estimate the Stanislaus River's contribution to attaining larger Central Valley-wide Goals. When assumptions about future conditions beyond the Stanislaus River were necessary to establish targets for this river, the assumptions and the rationale behind them were described in detail.

### *2.3.3 Biological Considerations*

The overarching intent of the SEP is to restore native salmonids and associated habitat and ecosystem processes in the Stanislaus River and throughout the San Joaquin River basin. Salmonids are the focus of many policies regarding environmental and water management in the Central Valley, and they are among the best-monitored and studied organisms in this area. Achievement of all Biological Objectives for a given population is intended to result in a population that is viable, healthy, and sustainable. Achievement of all Environmental Objectives is hypothesized to achieve the Biological Objectives for salmonids and support other native river-dependent species. The Biological Objectives developed by the SEP Group focused on the following species/runs:

- Fall-run Chinook salmon
- Spring-run Chinook salmon
- *O. mykiss*

Attaining the Biological and Environmental Objectives for these salmonids may not be adequate to restore all the important ecological and physical functions of the Stanislaus River. In addition, establishing conditions necessary to attain Biological Objectives for salmonids in the San Joaquin River basin's tributaries may not result in conditions necessary for achieving sustainable benefits in the Delta and Estuary. Thus, protecting and restoring other aquatic resources in the San Joaquin

River basin, the Delta, or the Estuary may require contributions from the Stanislaus River in addition to those described in this report.

## 2.4 Developing Foundational Elements Necessary for Conservation Planning ("Logic Chain")

Conservation planning often begins with identifying and describing a suite of actions without first defining the problem that the actions are meant to solve. Taking these first important steps of defining goals and objectives provides a transparent basis for evaluating implications and trade-offs among proposed actions, implementing actions efficiently and within certain time bounds, and managing actions towards attainment of desired conditions.

The SEP Group did not develop or evaluate conservation actions that should be taken on the Stanislaus River to improve conditions for native salmonid populations. Rather, the group focused on foundational elements needed to understand the nature and magnitude of challenges to restoring target populations; these elements are also essential to managing restoration activities in an adaptive management context. By developing goals and objectives and by ranking and prioritizing the barriers that prevent attainment of those goals and objectives, the SEP Group sought to provide the "design criteria" for subsequent conservation planning and the benchmarks against which to prioritize, implement, and adjust conservation actions adaptively.

The SEP Group addressed the following questions to establish a logic chain for development of the Biological and Environmental Objectives for Chinook salmon and *O. mykiss* in the Stanislaus River and for identifying, ranking, and prioritizing stressors that prevent attainment of goals and objectives (Figure 3).

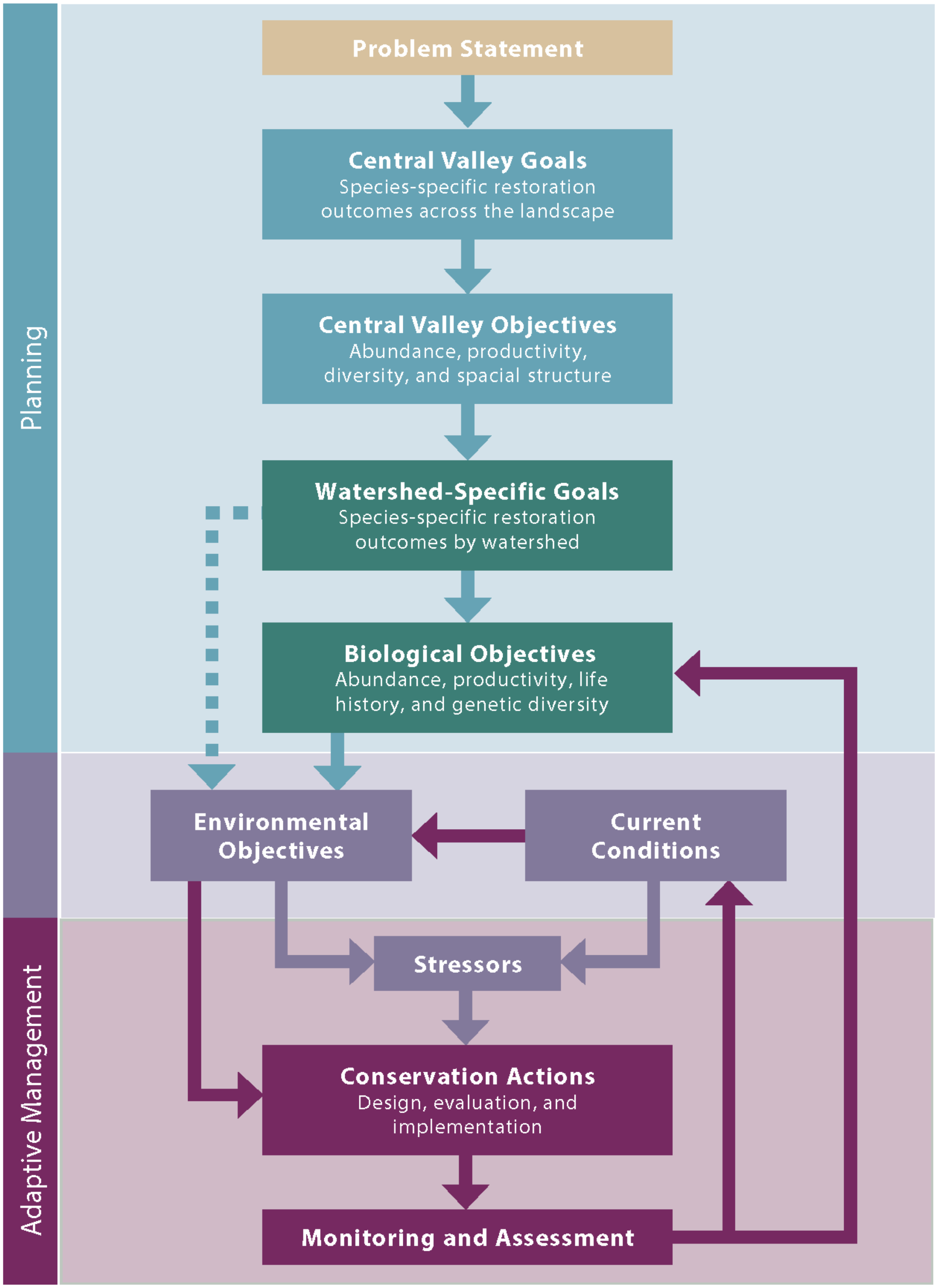



**Figure 3**
**Scientific Evaluation Process Logic Chain**

**What is the problem?**

**Problem statements** provide a concise declaration of the ecological issues that require attention for each target species and the ecosystem. Problem statements are general and factual descriptions of the problems and do not assume the causes of, or solutions to, those problems. For target species, a problem statement would address, at a minimum, each attribute of viability for which the species is deficient. For example, Central Valley spring-run Chinook salmon populations are imperiled because abundance is well below desired levels, survival rates are inadequate to achieve population growth, populations are severely constrained geographically, and the populations express only a narrow range of the life history variants that are typical of this species.

**What outcome(s) will solve the problem?**

**Central Valley Goals** present a vision for species-specific restoration actions across the Central Valley landscape and state desired outcomes that will solve the issue(s) identified in the problem statement. The Central Valley Goals describe outcomes that may be beyond the scope of this or other conservation planning efforts, but they are important for creating a context for any conservation strategy. For example, one Central Valley Goal for spring-run Chinook salmon is to increase the spatial diversity of independent, viable spawning populations of spring-run Chinook salmon, including establishment of populations in the Southern Sierra Diversity Group.

**What does solving the problem and attaining the goal look like?**

**Central Valley Objectives** provide specificity to a related Central Valley Goal. Objectives are S.M.A.R.T. statements that indicate what level of restoration constitutes attainment of the goal. Central Valley Objectives provide a clear standard for measuring progress toward a desired outcome in the larger context of the Central Valley. The function of Central Valley Objectives is to define the magnitude of the problem and set a context for planning so that investment in conservation activities on the local scale (e.g., in the Stanislaus River Basin) is appropriately scaled to the larger conservation challenge.

**What can efforts in the Stanislaus River contribute to the attainment of Central Valley Objectives?**

To identify relevant targets for a specific plan, Central Valley-wide Goals and Objectives are filtered through the biological, geographic, and policy lenses that constrain the current planning effort. Consideration of the scope (i.e., geographic, policy, biological) for the planning effort enables identification of **Watershed-Specific Goals** that can be addressed within that scope. Watershed-Specific Goals are a subset of the Central Valley Goals that are tailored to support attainment of Central Valley Goals and Objectives. Watershed-Specific Goals describe the contribution to Central Valley Goals and Objectives that can be attained within a particular watershed or geographic unit.

For example, one watershed-specific goal for the Stanislaus River is to achieve freshwater survival rates for fall-run Chinook salmon that are typical of other self-sustaining populations of ocean-type Chinook salmon.

**What is the suite of biological outcomes that characterize success?**

**Biological Objectives** define Watershed-Specific Goals in S.M.A.R.T. terms—the biological outcomes that define success in the area and for the species—and they harmonize the policies proscribed by the scope. For example, freshwater survival rates (egg-smolt) for fall-run Chinook salmon spawned on the Stanislaus River will be a defined percentage by a certain year (e.g., XX% by year XXXX) of the plan.

Biological Objectives related to focal species or populations are S.M.A.R.T. targets that must be attained within the plan’s scope to realize Watershed-Specific Goals and thereby support Central Valley Goals and Objectives. That is, the attainment of Stanislaus River Biological Objectives will contribute, in part, to the overall recovery of salmonids in the Central Valley or system-wide.

In the context of adaptive management, Biological Objectives are the metrics towards which all conservation actions and adjustments to those actions are directed. Until Biological Objectives have been attained, conservation actions must be implemented or improved; attainment of the Biological Objectives indicates that conservation efforts have been successful in attaining their related Watershed-Specific Goals.

**What is the suite of physical and ecosystem conditions that characterize success?**

**Environmental Objectives** define the physical, chemical, and biological conditions that the SEP Group hypothesized are needed to attain the Biological Objectives. These values are specific to different species, life history stages, and habitats and are derived from published literature (e.g., temperature and dissolved oxygen [DO] limits), conceptual and quantitative conceptual models (e.g., area of inundated floodplain), and professional judgment. Like other objectives, these values are S.M.A.R.T. They are intended to provide specific guidance for design and prioritization of conservation actions to achieve relevant Biological Objectives; their time bounds are defined by the Biological Objectives that they support.

Environmental Objectives are targets that support the attainment of Biological Objectives and Watershed-Specific Goals. More specifically, Environmental Objectives quantify the conditions that best available science indicates will lead to the attainment of Biological Objectives. In an adaptive management context, Environmental Objectives should be thought of as hypotheses regarding conditions necessary to attain desired biological outcomes that should be evaluated through research and monitoring and adjusted as necessary to support the Biological Objectives. In the absence of new evidence, the working assumption is that until Environmental Objectives are attained, it is unlikely that Biological Objectives will be attained. Producing these conditions is believed to be necessary, but not a substitute for, attainment of the Biological Objectives. Environmental Objectives provide specific guidance and transparent linkages between the Biological Objectives and the design of conservation actions. Similarly, Environmental Objectives inform the design of monitoring activities because monitoring must be capable of detecting progress towards Environmental Objectives that result from conservation actions as well as progress towards Biological Objectives as a function of improvements in environmental conditions. If Biological Objectives are attained on a sustained basis prior to full attainment of Environmental Objectives, that would suggest the need to modify the Environmental Objectives in the light of this new evidence. Conversely, failure to attain Biological Objectives despite success in achieving Environmental Objectives is strong evidence that other stresses are impairing attainment of desired biological outcomes. This failure should trigger the following actions:

- New or enhanced management actions to improve environmental conditions and address additional stressors
- Refinement of the Environmental Objectives and analysis of stressors to capture those additional conditions critical achieving Biological Objectives

**What are the barriers to achieving Environmental and Biological Objectives?**

Restoration of salmonid populations in the Stanislaus River will require substantial improvements in a variety of environmental conditions. To address the barriers to attaining those objectives (referred to in this report as “stressors”) in the most efficient manner, the SEP Group characterized, documented, and scored stressors according to the magnitude and certainty of their effect. Magnitude and certainty scores reflected a comparison of current conditions (e.g., as documented in published peer-reviewed literature, grey literature, monitoring data) with relevant Environmental Objectives. Professional judgement of those most familiar with current conditions on the Stanislaus River was also incorporated into scoring of stressors, but certainty scores were not high when professional judgement was the only source of information on current conditions. Stressor magnitude and certainty scores were then used to prioritize the need for conservation actions (e.g., those that would increase rearing habitat; or actions to reduce thermal stress) to eliminate the stress in the near term (when populations are low) and in the long term (assuming populations increase and anticipated changes to the regional climate materialize). Stressor magnitude and certainty scores were also used to characterize the type of response—conservation action, research, or improved monitoring—that would be appropriate for a conservation plan.

Stressors describe the current environmental conditions that prevent attainment of both Environmental Objectives and (both by extension and directly) Biological Objectives. Stresses to Environmental Objectives are generally measured quantitatively. Stressor scoring reflects a combination of the known and hypothesized magnitude of a given stressors effect on the attainment of Biological Objectives as well as the degree of scientific certainty regarding how resolving a stressor will support attainment of Environmental and Biological Objectives. As conservation actions are implemented, the relative ranking of stressors should change as either 1) their effect is ameliorated; 2) scientific understanding of their effect changes; or 3) both. Monitoring is necessary to determine whether stressors are being ameliorated or becoming worse and whether biological outcomes are responding as expected to any changes in the stressor. Thus, while conservation planning and implementation will focus on attainment of Environmental Objectives and Biological Objectives, adaptive management will address stressors frequently and directly.

**What conservation actions can be taken to achieve the Environmental and Biological Objectives?**

As described above, development and evaluation of conservation actions does not occur in this report. This report provides the basis for focusing, prioritizing, and evaluating conservation actions that will be proposed by others to relieve stress on target salmonid populations and lead to attainment of Environmental Objectives, Biological Objectives, and Watershed-Specific Goals. These actions may include flow regime modifications and non-flow measures. Certain conservation actions may address Biological Objectives directly without addressing a specific Environmental Objective. For example, a conservation measure intended to reduce juvenile mortality rates (e.g., by directly manipulating competitor or predator populations) would be evaluated by its contribution to attainment of Biological Objectives for productivity.

Conservation actions are intended to produce beneficial effects. These effects must directly relate to the reduction of high priority stressors and progress towards Environmental and Biological Objectives. Monitoring should be designed to detect whether actions are having intended benefits or unintended negative effects relative to objectives. Adaptive management will apply monitoring results to adjust conservation actions to maximize the intended effect and eliminate or minimize undesirable effects.

For each run of Chinook salmon and the life history types of *O. mykiss* discussed in this report, development of the Biological Objectives centered on achieving the following generalized Watershed-Specific Goals:

- Support the fullest natural expression of life history diversity as needed to increase population stability, resilience, and productivity.
- Support productivity (survival) rates characterizing a viable population that are necessary to attain Central Valley abundance and productivity objectives.
- Maintain genetic integrity of wild stocks to avoid deleterious or undesirable effects to wild populations from introgression and hatchery influence.

Based on these goals, the SEP Group developed the following:

- Biological Objectives related to life history, productivity, and genetic attributes of viability
- Environmental Objectives needed to support the Biological Objectives
- Descriptions and prioritization of stressors that prevent attainment of Biological Objectives now and in the future

# 3 Viable Salmonid Population Attributes

The SEP Group's approach to defining Watershed-Specific Goals and Biological Objectives for the Stanislaus River was based on four key attributes of viable populations—abundance, life history and genetic diversity, productivity, and spatial structure (McElhany et al. 2000; Lindley et al. 2007; NMFS 2014). These four attributes are referred to as the viable salmonid population (VSP) parameters. Criteria for VSPs (a concept developed by NMFS [McElhany et al. 2000]) inform the ecosystem and habitat conditions needed to restore Chinook salmon and steelhead. By defining distinct attributes of a viable population in a measurable form, the VSP approach allows for a comprehensive, measurable description of a healthy population and for prioritization of threats to a population's health. The VSP approach is useful for describing a vision for restored salmonid populations because it acknowledges that healthy populations cannot be characterized by any one population attribute (e.g., abundance); rather, all VSP metrics must reach acceptable levels before a population can be deemed "healthy."

The Biological Objectives described in this report reflect the distinct outcomes required for salmonid populations in the Stanislaus River and acknowledge that these VSP criteria are inter-related and mutually supportive. For example, natural levels of intra-population diversity and productivity are necessary for a population to display an abundance associated with restoration on a sustainable, long-term basis. The scope of this effort (the Stanislaus River) necessitated a different degree of emphasis on each of the VSP parameters. For example, spatial structure (described in in Section 3.4) refers to the number and distribution of spawning populations, but the Stanislaus River will only support one spawning population of each of the target salmonids. In other words, spatial structure is most relevant at the species scale and thus is outside of this effort's scope, which is focused on the populations within the Stanislaus River.

## 3.1 Abundance

Abundance, or the number of organisms in a population, is a common species conservation and management metric. Populations or species with low abundance are generally less viable and at higher risk of extinction than large populations for reasons that include increased susceptibility to environmental variation, demographic stochasticity, loss of genetic diversity, and interruption of mating systems. Abundance correlates with, and contributes to, other viability parameters, including spatial structure (i.e., distribution and extent; Section 3.4), diversity (Section 3.2), and productivity (Section 3.3). Simply increasing the abundance of organisms (or any other single viability parameter) is not sufficient to guarantee viability into the future. In other words, population viability depends on maintaining acceptable levels of each attribute of viability.

Abundance is also a key metric for determining acceptable levels of harvest for commercially and recreationally valuable species like Chinook salmon. As a result, population abundance targets for this species must exceed the minimum necessary to insulate the population from extinction threats. Production targets (i.e., abundance measured as the number of fish that reach the age where they are targeted by the ocean fishery) for different populations of Chinook salmon and steelhead have been set for many Central Valley rivers. These targets are incorporated into numerous state and federal policies and regulations such as the AFRP (USFWS 2001) and WQC Plan (SWRCB 2006).

Abundance is the product of fecundity and survival rates that occur throughout the salmonid life cycle. At the Stanislaus River's carrying capacity, available habitat will constrain abundance. The river's carrying capacity can be adjusted to be consistent with Central Valley Goals and Objectives for the Stanislaus River (e.g., by expanding spawning or rearing habitat availability). However, because abundance is not controlled solely by conditions on the Stanislaus River (i.e., many factors controlling abundance are beyond the geographic scope of this process), the SEP Group did not establish Biological Objectives for abundance of focal salmon populations.

## 3.2 Life History and Genetic Diversity

Genetic diversity and life history diversity are interrelated components. With respect to genetic diversity, the ability of Chinook salmon and steelhead to navigate and spawn in the rivers where they were born contributes to the highly variable life history patterns and genetic diversity characteristics by facilitating local adaptation (Taylor 1991; Waples 1991). Genetic differences among the ESUs of Chinook salmon are maintained because many of the life history traits, such as the season of adult migration, are genetically inherited (Banks et al. 2000; Carlson and Seamons 2008). Individuals within an ESU may have locally adapted gene complexes that improve the survival of their offspring in that habitat (Waples 1991). Introgression among the ESUs or between hatchery and natural-origin salmon can disrupt these gene complexes, thereby changing life history traits and potentially reducing the success of offspring (Ford 2002; Araki et al. 2007). Therefore, to maintain the diversity and productivity of Chinook salmon in the Central Valley and allow ESUs to adapt to local conditions, it is important to create conditions that both encourage successful reproduction within locally adapted gene pools and limit gene flow among ESUs or with hatchery-origin populations.

Life history diversity is often cited as a crucial component of salmonid population resiliency. This is based on theoretical and empirical evidence that the maintenance of multiple, diverse salmon stocks fluctuating independently of each other reduces extinction risk and long-term variation in regional abundances (Roff 1992; Hanski 1998; Hilborn et al. 2003; Schindler et al. 2010). This "portfolio effect" of spreading risk across stocks can also act at the within-population scale (Greene et al. 2009; Bolnick et al. 2011). For example, juvenile Chinook salmon leave their natal rivers at different sizes, ages, and times of the year, and this life history variation is believed to contribute to population resilience (Beechie et al. 2006; Miller et al. 2010; Satterthwaite et al. 2014). Thus, preserving and restoring life history diversity is an integral goal of many salmonid conservation programs (Ruckelshaus et al. 2002). Finally, it is increasingly recognized that strengthening a salmon population's resilience to environmental variability (including climate change) will require expanding habitat opportunities to allow a population to express and maintain its full suite of life history strategies (Bottom et al. 2011).

As with Chinook salmon, life history diversity is critical to the success of *O. mykiss* populations. The native range of *O. mykiss* is widespread, in part, because of its diverse portfolio of life history patterns. *O. mykiss* have the ability to exist as anadromous or adfluvial forms, rear in high elevation headwater streams or coastal estuaries, and reside in lakes. In addition to the genetic component of life history diversity, some phenotypic diversity appears to be driven by individual condition and in response to prevailing environmental conditions. Studies have shown that juvenile steelhead need to reach a minimum smolt size of approximately 140 millimeters (mm; 5.5 inches [in]) fork length (FL) to survive to maturity (Ward et al. 1989; Bond et al. 2008). As river systems vary widely in productivity (e.g., availability of food for juvenile fish), steelhead parr can take anywhere from 1 to 3 or more years to reach this size, so smolt ages vary depending on parr growth rates (Seelbach 1993). Age at first maturity can range from 1 to 4 years in the ocean, with jacks spending just 1 year and most adults spending 2 or 3 years in marine environments before sexually maturing. Unlike Pacific salmon, adult steelhead have the ability to spawn several times in their lifespan. This repeat spawning helps compensate for the relatively small run sizes relative to salmon and periodic inaccessibility or unsuitability of natal streams. A steelhead population's spawning timing can last several months (typically December to April), and emigration of smolts can span several months (typically February to June). Variability in smolt age, age at first maturity, spawning timing, and smolt emigration combine to produce a species that is highly adaptable to a wide range of stream environments, enabling it to succeed in many types of aquatic habitats—from Alaska's large glacial-fed rivers to small coastal streams in southern California.

An important property of wild steelhead that emerges from this variation is that there are usually not distinct cohorts of adults (Kendall et al. 2014). Wild adult steelhead in a river are typically a mix of many cohorts, with fish that smolted at 1 to 3 years of age and matured after 1 to 3 years at sea, with some on their second or third spawning run. Total ages of the adults can range from 2 to 7 or more years. The loss of one cohort to a poor year is not as critical to the viability of the population as it would be if the entire population were based on one or two strong cohorts.

Within the Central Valley, the extensive loss of historical habitat due to dams and the poor quality of the remaining spawning, rearing, and migratory habitats have led to a drastically reduced overall abundance of *O. mykiss* and the near-loss of the steelhead (i.e., anadromous) form in many watersheds. The steelhead form is especially sensitive to habitat loss because its persistence requires high quality fluvial spawning and rearing areas, migratory corridors with high survival, and reasonable ocean survival and productivity. Currently, many rivers in the Central Valley are dominated by one form of *O. mykiss*, the freshwater fluvial, or resident, form. The steelhead form is now largely dominated by hatchery fish, all of which are released as age-1 smolts, that increasingly mature after only 1 year in the ocean. Reversing the loss of life history diversity in *O. mykiss* and establishing conditions that favor the anadromous form to be expressed will require extensive habitat improvements in the rivers and the Delta.

Certain components of genetic and life history diversity are controllable by actions taken in the Stanislaus River basin, whereas other components will require actions across the larger San Joaquin River basin watershed or larger geographic areas. For example, the diversity of juvenile ages and sizes at outmigration reflects conditions during the rearing and migration phases that occur in the river. The SEP Group established Biological Objectives for life history diversity of each focal population related to the distribution of size and timing of juvenile migration. On the other hand, limiting the influence of hatchery production on the genetic diversity of local populations may require both watershed-specific and region-wide actions. The SEP developed Biological Objectives related to genetic diversity and the stressors that prevent attainment of those objectives now and in the future. Local, watershed-specific solutions may result in progress towards those objectives, although full-attainment of the objectives may require a region-wide approach (i.e., as part of integrating desired outcomes for the Stanislaus with those to be developed for the Merced and Tuolumne rivers).

## 3.3 Productivity

Productivity represents the ability for populations to grow when conditions are suitable, which is essential to conservation success. Species or populations that display persistent negative population growth, as well as populations with limited ability to respond positively to favorable environmental conditions, are less viable and are at higher risk of extinction. The productivity parameters used in developing Biological Objectives for the Stanislaus River are expressed as population rates (e.g., survival, offspring per adult female). In the absence of density-dependent factors, these productivity parameters measure the ability of salmon to survive to reproduce and reproductive success (McElhany et al. 2000).

Desirable population growth rates are commonly determined by identifying an abundance target and a future date by which that abundance should be attained (e.g., NMFS 2012). The population growth rate is then calculated as the minimum average population growth needed to achieve the desired abundance in the predetermined timeframe. However, this approach does not always result in productivity estimates that reflect healthy populations. (An example of this would be if the abundance target could be achieved in less time by a population displaying growth rates typical of the species as a whole.)

While population growth rates vary depending on environmental conditions, population demography, and how abundance relates to local habitat carrying capacity, species are often characterized as having “intrinsic” population growth rates that reflect their life history and demographic characteristics (e.g., age at first reproduction, fecundity, survival, and sex ratio). The reproductive success rates and life history stage-specific survival rates observed in VSPs are valid reference points for determining adequate productivity goals and targets for managed populations in the absence of density-dependent limitations.

Stage-specific productivity (e.g., egg to smolt survival) can be affected by creating suitable conditions within the habitat used by each life history stage. The SEP Group developed Biological Objectives for productivity (survival rates) of salmonid life history stages that utilize the Stanislaus River. The SEP Group recognizes that these survival rates may not be achieved when abundance levels approach the carrying capacity of the habitat; thus, the Biological Objectives for juvenile survival are intended to be measured when population abundance is not near estimated carrying capacity (McElhany et al. 2000). In addition, SEP Environmental Objectives specify the extent of habitat creation needed to expand carrying capacity of the Stanislaus River going forward.

## 3.4 Spatial Structure

Spatial structure refers to the geographic distribution of populations or individuals in a population. McElhany et al. (2000) suggest that a population's spatial structure is made up of the geographic distribution of individuals in the population and the processes that generate that distribution. The structure of a population depends on the quality of habitat available to the population, how the habitat is configured spatially, the dynamics of the habitat, and the dispersal characteristics of individuals in the population (McElhany et al. 2000).

Fresh et al. (2009) point out that spatial structure helps contribute to population persistence by doing the following:

- Reducing the chance of a catastrophic loss because groups of individuals are widely distributed spatially
- Increasing the chance that locally extirpated or dwindling groups will be rescued by recolonization
- Providing more opportunity for long-term demographic processes to buffer a population from future environmental changes

In addition, there is evidence that broader geographic extent may decrease the extinction risk of North American fishes (Rosenfield 2002). Restoring areas that support source populations can increase the overall stability of metapopulations by increasing the number of individuals available to support nearby populations (Fullerton et al. 2011).

The SEP Group did not develop Biological Objectives for spatial structure because this parameter is typically evaluated at the species scale (e.g., number and distribution of populations throughout the Central Valley), and the geographic scope of this effort was limited to the Stanislaus River. Restoring the spring-run Chinook salmon spawning population to the Stanislaus River (i.e., attaining the Watershed-Specific Goals and Biological Objectives identified in this report) serves Central Valley Goals and Objectives regarding salmonid spatial extent because the Stanislaus River would represent an entirely new (restored) spawning population for this ESU in the Central Valley, as a whole, and the Southern Sierra Diversity Group, in particular (NMFS 2014). In addition, attaining Biological Objectives for fall-run Chinook salmon and *O. mykiss* will allow these populations to serve as vibrant source populations within their respective San Joaquin River basin metapopulations. Therefore, attaining desired biological outcomes on the Stanislaus River contributes to the system-wide spatial structure objectives for Chinook salmon and steelhead throughout the Central Valley (NMFS 2014).

# 4 Current Status of Chinook Salmon and *O. mykiss* in the San Joaquin River Basin

A general overview of the current status relative to historical status is described for each species below.

## 4.1 Fall-run Chinook Salmon

Historical records made by Spanish explorers in the early 1800s and later that century by John Muir, Livingston Stone, and others suggest that fall-run Chinook salmon were historically abundant throughout the San Joaquin River basin (Yoshiyama et al. 1996). As European settlement occurred in the area, salmon runs diminished due to habitat degradation and loss. According to a report by the Stanislaus River Fish Group, hydraulic mining and the dams associated with that practice likely caused the initial decline of Chinook salmon and steelhead runs in the Stanislaus River (SRFG et al. 2003). These early dams were small, temporary, and only partial impediments to movement.

While spring-run Chinook salmon were believed to be the primary salmon run in the Stanislaus River, fall-run Chinook salmon also historically inhabited the river and became dominant following construction of Goodwin Dam in 1912, which blocked upstream migration (Yoshiyama et al. 1996). Today, though not a state or federally listed species, fall-run Chinook salmon populations across the Central Valley are also severely impacted and vulnerable to extinction (Katz et al. 2012).

Production of fall-run Chinook salmon in the San Joaquin River basin often falls to extremely low levels (USFWS 2001). Fall-run Chinook salmon production in the Stanislaus River was estimated to average 10,868 fish from 1967 to 1991 (SFWO 2014). This estimate was used to generate the Central Valley Objective (AFRP target derived from the CVPIA "doubling goal") of natural production of 22,000 fish. Adult fall-run Chinook salmon escapement into the Stanislaus River averaged 3,087 fish from 2003 to 2013 (Gutierrez 2014). Escapement, which includes post-harvest mortality, is always less than production, which measures abundance prior to harvest, in a given year. Still, these low levels of escapement indicate failure to achieve the CVPIA and AFRP production targets.

Fall-run Chinook salmon life history diversity is believed to be constrained in the Stanislaus River (Sturrock et al. 2015), as demonstrated in the following examples:

- Based on fall-run Chinook salmon size and date-at-migration from the Caswell rotary screw trap (RST; Figure 2 and Table 8), half of the smolt phenotype migrates within a period of less than 3 weeks in many years.
- Some smolt migrants are detected when temperatures or other conditions in the lower San Joaquin River may be inhospitable (e.g., after early June).
- Fifty percent of parr-sized fish pass Caswell in a period that is usually less than 1 month (Tables 6 and 8).

- In certain years, a small percentage of juvenile migrants are parr- or smolt-sized fish, whereas in other years when juvenile production is low, larger-sized migrants represent the vast majority of all juveniles detected at Caswell (Johnson 2014, pers. comm.).

This constriction means that juvenile migrants do not exhibit the life history diversity that may be needed to capitalize on supportive conditions in the lower San Joaquin River, Delta, Estuary, and nearshore ocean environments. Fall-run Chinook salmon exhibit high inter-annual variation in size at migration on the Stanislaus River that is related to annual hydrology (Sturrock et al. 2015), which may be exacerbated by a lack of adequate rearing habitat. Comparison of adult returns with subsequent juvenile outmigrant counts suggests density-dependent limitation on the Stanislaus River salmon population during dry years (Figure 4; Sturrock and Johnson 2016, pers. comm.).

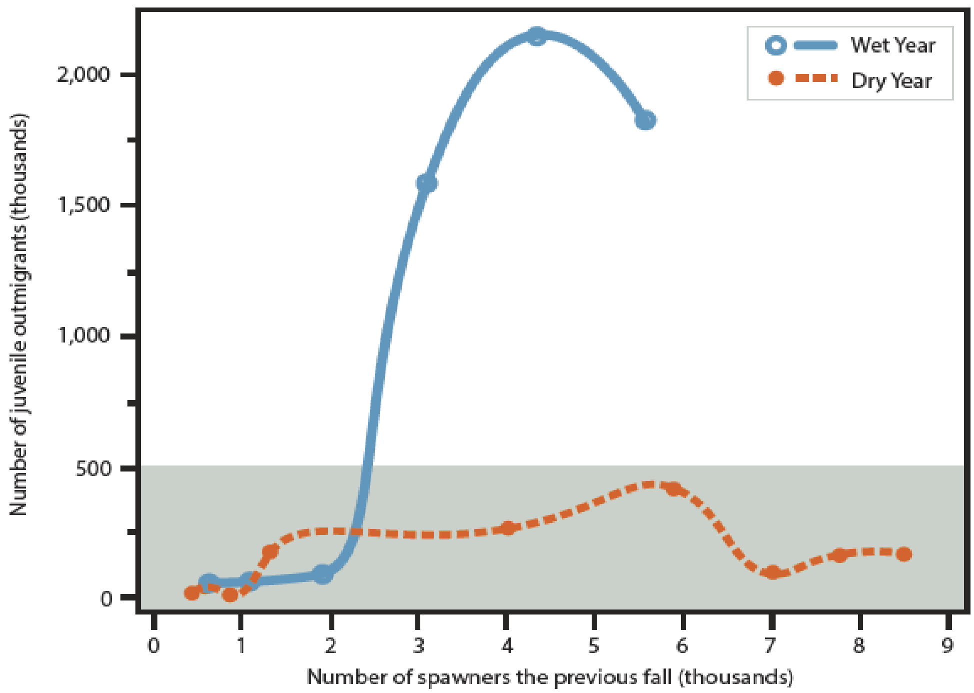



**Figure 4**
**Relationship of Spawners to Subsequent Juvenile Production**

Notes:
As measured at Caswell RST on the Stanislaus River
Wet versus dry year type distinction is based on actual river flows.
Modified from Sturrock and Johnson 2016, unpublished data

## 4.2 Spring-run Chinook Salmon

Historically, spring-run Chinook salmon occurred in the headwaters of all major river systems in the Central Valley, where natural barriers to migration were absent (NMFS 2014). This habitat was estimated to have supported runs as large as 500,000 fish between the late 1880s and 1940s

(CDFG 1990; Yoshiyama et al. 2001). Although spring-run Chinook salmon were probably the most abundant salmonids in the Central Valley under historical conditions, large dams eliminated access to almost all historical habitat, and the run has suffered the most severe declines of any of the four Chinook salmon runs in the Sacramento River basin (Fisher 1994). Dams currently block access to the vast majority of historical spawning and rearing habitat of spring-run Chinook salmon and steelhead in the Central Valley. Figure 5 depicts the loss of historical spawning habitat for steelhead, which is also generally representative of spring-run Chinook salmon habitat loss.

Before the construction of Friant Dam, 200,000 to 500,000 adult spring-run Chinook salmon were estimated in the San Joaquin River (Yoshiyama et al. 2001). For decades, spring-run Chinook salmon were considered extirpated from the San Joaquin River basin (Fisher 1994). More recently, there have been reports of "spring-running" Chinook salmon in San Joaquin tributaries, including the Stanislaus and Tuolumne rivers (NMFS 2013a), which suggests the potential for spring-run Chinook salmon to recolonize and persist in the Stanislaus River. In addition, in 2014, a reintroduction program was initiated as part of the SJRRP, and 54,000 juvenile spring-run Chinook salmon were released into the river.

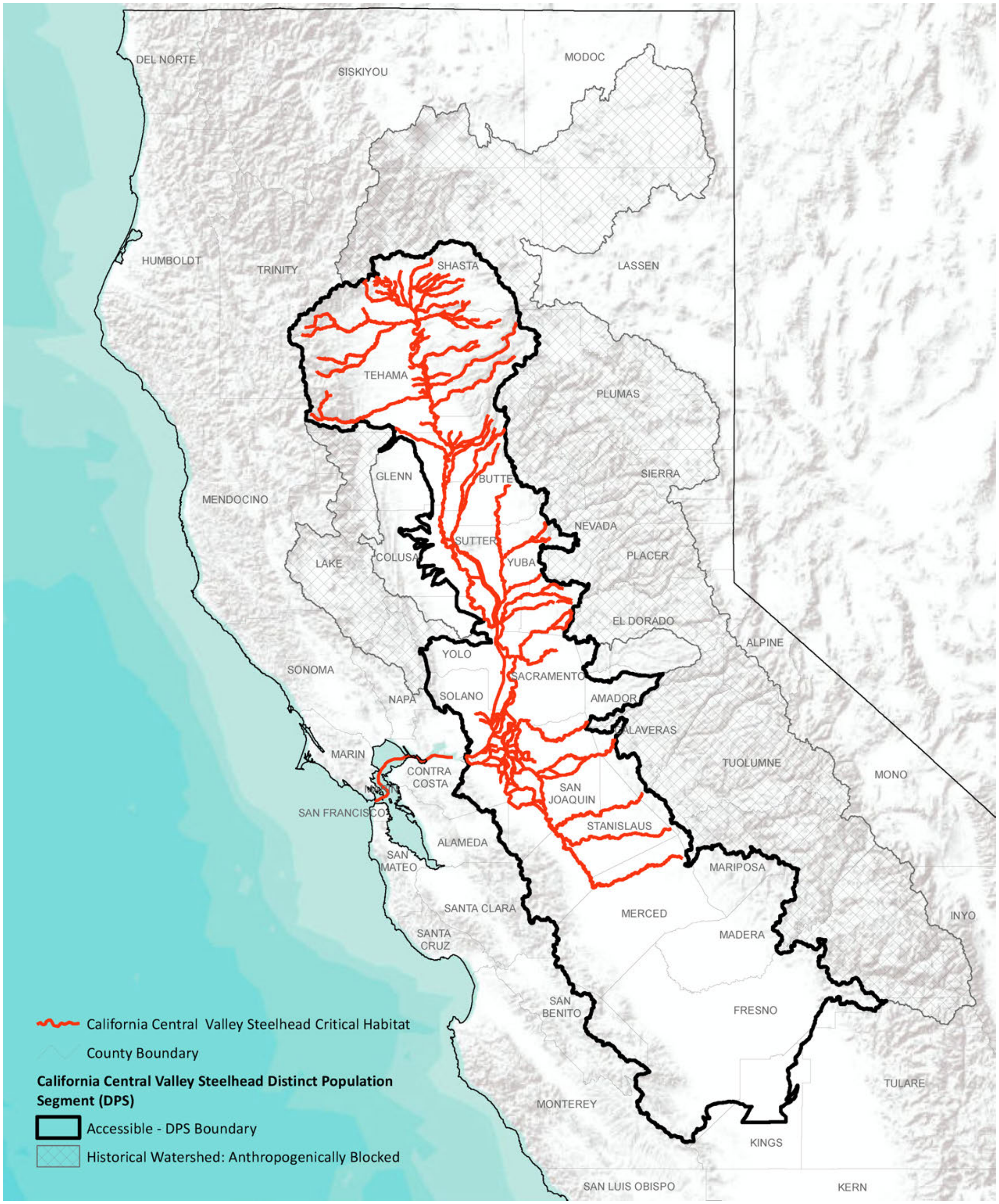



**Figure 5**
**Map of the Critical Habitat for California Central Valley Steelhead**

Source: Lindley et al. 2006

## 4.3 O. mykiss (Steelhead and Resident Rainbow Trout)

Historically, *O. mykiss* were found from the upper Sacramento and Pit rivers south to the Kings River and possibly the Kern River systems and in east- and west-side Sacramento River tributaries (Yoshiyama et al. 1996). Lindley et al. (2006) estimated at least 81 *O. mykiss* populations were distributed throughout the tributaries of the Sacramento and San Joaquin rivers. Presently, dams block access to 80% of historically available habitat and all spawning habitat for about 38% of historical populations (Figure 5; Lindley et al. 2006).

In the San Joaquin River basin today, steelhead are rare; they were once thought to be extirpated (McEwan 2001). Zimmerman et al. (2008) found evidence of steelhead presence in all three San Joaquin River tributaries, but their methods could not provide estimates of abundance. Monitoring has also detected small populations of non-hatchery-origin steelhead in the Stanislaus River and other streams previously thought to be devoid of steelhead (McEwan 2001). Steelhead are found in most Central Valley watersheds where people have made a concerted effort to look for them. Twenty-three steelhead larger than 406 mm (16 in) in length returned to the Stanislaus River from 2003 to 2011 based on weir count data distributed regularly by FISHBIO, although no sampling was conducted during spring for 2 years during this period (2006 and 2008).

An issue associated with estimating steelhead abundance is the difficulty in distinguishing anadromous fish from the resident form of *O. mykiss* that have matured in the river. In addition, due to their large size and strong swimming abilities, juvenile steelhead are rarely captured in RSTs such as the one located at river mile (RM) 8 near Caswell State Park. It is unclear at this time whether this lack of catch is due to the scarcity of smolts produced in the river, the known poor efficiency of RSTs at catching large juvenile steelhead, steelhead outmigration timing being outside the RST monitoring period, or some combination of these factors. However, despite the RST limitations, these catches shed insight into steelhead emigration timing and size where alternative data sources are scarce.

Downstream of the Stanislaus River in the San Joaquin River, the Mossdale trawl has captured 210 steelhead between May 1994 and February 2016. Nearly 92% of these were caught in April and May, corresponding to peak managed flows for spring outmigration. Sizes of captured outmigrants ranged from 155 to 360 mm (average 224 mm, median 239 mm). Using long-term beach seining in the Lower San Joaquin River from January 1996 through April 2018, 197 untagged steelhead from 137 to 360 mm (average 248 mm, median 247 mm) were collected. Juveniles were collected predominantly in April and May (98%), though only 31% of samples were collected during those months. Interestingly, steelhead were only captured downstream of the confluence with the Stanislaus River despite several sampling locations upstream of the confluence.

While neither trawling nor beach seining is an ideal method for studying steelhead migration, both have provided year-round data with consistent sampling over a long period. These methods offer a glimpse at peak timing for migration, provide size information for outmigrants vulnerable to capture, and are providing similar results regarding timing and size of steelhead emigration.

The resident rainbow trout population of the lower Stanislaus River is relatively abundant compared to the rare anadromous form. These stream-maturing and permanent river residents are most abundant in the cold, gravel-bedded reach from Goodwin Dam to Oakdale, and they support a popular sport fishery. They are typically found in areas with high to moderate water velocity and some type of structure or cover such as boulders or cobble, large wood, or aquatic vegetation. Demographic information on the population, such as total abundance, age structure, and productivity, are largely unknown. One recent study by Bergman et al. (2014) estimated the total population of rainbow trout in the reach extending from the base of Goodwin Dam to 200 meters (m) downstream at about 3,400 fish. Captures of *O. mykiss* labeled as adults in the Oakdale RST show fish in this stage ranging from 300 mm FL to 475 mm FL. Records of rainbow trout caught at the weir have identified residents up to 550 mm FL, though most are in the 300- to 500-mm FL range.

## 4.4 Late Fall-run Chinook Salmon

Recent adult salmon weir counts in the Stanislaus River have documented small numbers of Chinook salmon migrating upstream in January, February, and March. Yoshiyama et al. (1996) mention that late fall-run Chinook salmon possibly occurred in the San Joaquin River (based on CDFW reports of late fall-run fish).

Although the SEP Group did not develop Watershed-Specific Goals or Biological Objectives for late fall-run Chinook salmon in the Stanislaus River, it recognized the importance and potential value of diversity in timing of adult migrations that would be provided by such a population, especially considering the potential effects of projected climate change on environmental conditions. Restoration of this run to the Stanislaus River may be worth considering in the future.

# 5 Stanislaus Watershed Description

The Stanislaus River is a major tributary of the San Joaquin River, approximately 113 miles in length, with a watershed covering approximately 1,075 square miles (USFWS 2008; Figure 2). The Stanislaus River originates as the north, middle, and south forks in the western slopes of the Sierra Nevada, mainly in the Stanislaus National Forest. Approximately 90% of the upper watershed (above Goodwin Dam) is forest and 10% is agriculture. The upper watershed (approximately 940 square miles) remains relatively undeveloped. However, the lower watershed has been extensively developed to provide water, hydroelectric power, and gravel. The lower watershed has also been converted from floodplain habitat to agricultural and residential uses (SRFG et al. 2003), with 61% of the land area in agricultural production, 34% in urban development, and 5% being undeveloped.

The Stanislaus River is extensively dammed and diverted. The 32 dams within the Stanislaus River watershed have a total capacity of about 2.85 million acre-feet (maf), or 237% of the average unimpaired runoff (SRFG et al. 2003). On the mainstem, New Melones Dam (RM 68) blocks the river downstream of the confluence of the south, middle, and north forks of the Stanislaus River. New Melones Dam was completed by the U.S. Army Corps of Engineers in 1979; the reservoir is now the largest storage reservoir in the basin, with a storage capacity of 2.4 maf. New Melones Dam and New Melones Lake were designed to control floods up to the 100-year flood (Kondolf et al. 2001). Downstream from New Melones Lake is Tulloch Dam (RM 60), which forms Tulloch Reservoir. Approximately 1.5 miles downstream of Tulloch Dam is Goodwin Dam (RM 58), which is the main water diversion point on the Stanislaus River. Goodwin Dam (completed in 1913) blocks passage to the upper watershed for returning anadromous fish.

The average unimpaired runoff in the watershed is about 1.2 maf (USBR 2008). The median historical unimpaired runoff is 1.1 maf per year, with a range of between 0.2 and 3 maf (USFWS 1995). Snowmelt contributes the largest portion of the flows in the Stanislaus River, with the highest runoff occurring in April, May, and June (USBR 2008). Agricultural water supply development in the Stanislaus River watershed began in the 1850s, significantly altering the basin's hydrologic conditions. The current hydrograph differs greatly from unimpaired flow conditions. Spring and summer flows are often capped at 1,500 cubic feet per second (cfs), barring flood releases, while summer flows are increased to maintain downstream water quality. The river section below Goodwin Dam has been identified on the U.S. Environmental Protection Agency (USEPA) Clean Water Act Section 303(d) list for not meeting water quality standards for diazinon, chlorpyrifos, Class A pesticides, unknown toxicity, mercury, and temperature (USEPA 2011).

Historically, 113 miles of the Stanislaus River were anadromous fish habitat (USFWS 2008). Currently, only the lower 58 RMs are accessible to anadromous fish, with access terminating at Goodwin Dam

(KDH Environmental Services 2008). Compared to historical conditions, the area of suitable salmonid spawning and rearing habitats has been substantially reduced due to anthropogenic influences.

The Stanislaus River differs from the neighboring tributaries (Tuolumne and Merced rivers) in several ways. The large reservoir capacity in the Stanislaus River relative to average unimpaired flow allows for more resilience in the face of droughts, coupled with a lower frequency of flood releases. Instream flows on the Stanislaus River are largely dictated by the NMFS Biological Opinion issued in 2009, while much smaller volumes of environmental water are provided on the Tuolumne and Merced rivers under Federal Energy Regulatory Commission licenses. The Stanislaus River has roughly 4 miles of canyon habitat accessible to anadromous fish that, coupled with required summer temperature criteria, offer *O. mykiss* and spring-run Chinook salmon an opportunity to withstand warm summer air temperatures. These conditions are largely absent on the Merced and Tuolumne rivers. The Merced River also possesses a fall-run Chinook salmon hatchery, while the Stanislaus and Tuolumne river escapements are only influenced by non-natal hatchery-origin adults. Finally, the Merced River migratory path is considerably longer than that of the Stanislaus and Tuolumne rivers. The distance to Crocker-Huffman Dam on the Merced River is more than 35 miles farther than the rim dams on the Stanislaus and Tuolumne rivers from a common downstream location in the San Joaquin River.

# 6 Development of Goals and Objectives Specific to the Stanislaus River

## 6.1 Overall Approach

The SEP Group developed Watershed-Specific Goals and Biological Objectives to reflect improvements that could be attained within the geographic and policy scope (Section 2.3) for the salmon VSP criteria (Section 3). Watershed-Specific Goals and Biological Objectives were developed for population productivity as well as genetic and life history diversity. Watershed-Specific Goals and S.M.A.R.T. Biological Objectives quantify the watershed population-scale desired conditions for the focal species. As such, they can serve as a basis for measuring success in, or progress towards, achieving those desired conditions and support the development of additional restoration or adaptive management actions.

Because the establishment and maintenance of viable and healthy populations of Chinook salmon and *O. mykiss* in the Stanislaus River contribute to the Central Valley Goal of improving spatial structure for each species addressed in this report, there was no need to set Watershed-Specific Goals and Biological Objectives for spatial structure. Establishing populations that meet the criteria for other VSPs, as described in the Biological Objectives, would also support the Central Valley Goal of improving spatial structure for these populations.

In addition, S.M.A.R.T. Biological Objectives were not defined for focal population abundance, though many previous policies define Central Valley Goals and Objectives for Chinook salmon and *O. mykiss* in terms of target abundance (Section 2.3.1). One of the Watershed-Specific Goals for each focal population is increased abundance. However, many factors limit abundance in each life history stage throughout the entire life cycle of Chinook salmon and *O. mykiss*. These factors occur outside of the spawning and rearing habitat of the Stanislaus River. Thus, actions and actors on the Stanislaus River have only partial control over salmonid abundance in any given year, and Biological Objectives for abundance are inappropriate given the geographic scope of this effort. The Watershed-Specific Goals and Biological Objectives are intended to contribute to all the Central Valley Goals and Objectives, including abundance, though target abundances were not incorporated into Biological Objectives for the Stanislaus River.

The SEP Group developed Watershed-Specific Goals for each of the species and runs that would improve and maintain the VSP parameters of genetic and life history diversity and productivity (i.e., population growth rates as affected by survival rates). One of the Biological Goals identified was to support the fullest expression of Chinook salmon and *O. mykiss* life history diversity to increase population stability, resilience, and productivity. For Chinook salmon populations, productivity goals were described in the following three phases:

1. Attain juvenile survival rates that allow for population growth.
2. Attain juvenile survival rates that allow for rapid reattainment of Central Valley Objectives after years with low escapement.
3. Attain juvenile survival rates that reflect those typical among other Chinook salmon populations across the West Coast.

The Biological and Environmental Objectives developed to help achieve the Watershed-Specific Goals vary among the species and runs. These objectives were designed to be measurable and monitored over time. Section 6 defines the specific metrics associated with each Biological Objective needed to achieve the Central Valley Goals and Objectives and describes the rationale and approach for each metric.

## 6.2 Fall-run Chinook Salmon

### *6.2.1 What is the Problem?*

Central Valley fall-run Chinook salmon populations are a species of special management concern for the following reasons:

- Natural production is well below desired levels.
- Survival rates are inadequate to achieve population growth and maintain population resilience.
- The populations express only a narrow range of the life history variants that are typical of this species.
- Hatchery influence on wild stocks compounds all of the aforementioned problems.

The production[4] of San Joaquin fall-run Chinook salmon often falls to very low levels, with generally low spawning escapements across years. Escapement is related to hydrology, with very low escapement following drought conditions and higher (but still subpar) escapement generally following years with high spring runoff (USFWS 1995; Sturrock et al. 2015). Abundance has generally declined since the 1967 through 1991 period that was used to set AFRP (USFWS 2001) ocean production objectives. Actual fall-run Chinook salmon counts (escapement) in the Stanislaus River are variable, averaging 3,087 fish from 2003 to 2013 (Gutierrez 2014). Similarly, productivity (measured as juveniles per spawner) appears to be constrained by hydrology, with more juveniles

[4] As used here, "production" means the number (abundance) of fish available to the ocean fishery: 2-year-old salmon in the ocean. This term should not be confused with "productivity," which refers to population growth rates and/or the population vital rates (e.g., survival, fecundity) that the determine population growth rate.

produced for a given number of spawners in years when river flows are high (Figure 4). Juvenile survival rates are generally low for this population (AFRP 2005).

Life history diversity of the fall-run Chinook salmon population is constrained throughout the Central Valley (Lindley et al. 2009; Miller et al. 2010; Carlson and Satterthwaite 2011) and in the Stanislaus River, in particular. The influence of hatchery-produced spawners on the Stanislaus River fall-run Chinook salmon population (Kormos et al. 2012; Palmer-Zwalen and Kormos 2013) is well above limits indicative of healthy populations, suggesting that population viability is compromised by hatchery stocks (Araki et al. 2007; Lindley et al. 2007; Johnson et al. 2012). The spatial diversity of fall-run Chinook salmon spawning habitats within the San Joaquin River basin is not a primary concern, as fall-run Chinook salmon spawn in each of the San Joaquin River's main tributaries and are being restored to the San Joaquin mainstem.

### *6.2.2 What Outcome(s) (Central Valley Goals) will Solve the Problem?*

Where applicable, the SEP Group used existing laws, policies, and programs to identify Central Valley Goals. In some cases, the expression of desired conditions in existing laws, policies, and programs was quite general (e.g., to maintain "fish in good condition"), and the SEP Group needed to translate the policy intent into more specific language that would be relevant to planning and management.

**Abundance**

Increasing abundance of fall-run Chinook salmon is a goal of state and federal law for the Central Valley, including the San Joaquin River and its three salmon-bearing tributaries. The CVPIA (Section 3406 of the CVPIA, Title 34 of Public Law 102-575) calls for naturally spawning populations of anadromous fish that are double the 1967 to 1991 baseline within 10 years. State law (F&G Code § 6902(a)) and water quality regulations (SWRCB 2006) express the same target.

**Productivity and Life History Diversity**

Improvements in fall-run Chinook salmon productivity (measured as juvenile survival and adult migration success in freshwater) and increased life history diversity (i.e., size at and timing of juvenile migration) are necessary to achieve desired conditions. These desired conditions are described in several relevant policies, including reaching abundance targets for fall-run Chinook salmon in the Central Valley (USFWS 2001), maintaining fish "in good condition" (F&G Code § 5937), and achieving acceptable levels of the criteria NMFS uses to evaluate salmonid population viability (Lindley et al. 2007). The goals of improving productivity and life history diversity among Central Valley salmonids are also consistent with all known fisheries-related management policies in this area.

**Genetic Diversity**

For fall-run Chinook salmon, concerns about the level of genetic diversity needed to support a healthy and viable population revolve around the influence of hatchery production and management (Williamson and May 2005; Williams 2006). A high occurrence of straying of fall-run Chinook salmon occurs between the San Joaquin and Sacramento basins (Johnson et al. 2012; Kormos et al. 2012), potentially due to the relative river flows across various Central Valley tributaries during the return migration as well as hatchery release practices (Marston et al. 2012).

In 2010, the U.S. Congress established and funded a hatchery review process in California due to concerns that the genetic resources required to support a sustainable salmon fishery and recover at-risk runs of salmon were not being adequately managed using traditional hatchery practices (HSRG 2012). The need to reform hatchery practices system-wide has been identified by scientists and policymakers based on growing concerns and scientific findings about the potential effects of hatcheries on the viability of salmon and steelhead in their natural habitats (HSRG 2012). Strategies that allow for and enhance local adaptation of naturally produced salmon and steelhead to individual tributary watersheds should be adopted along with hatchery reform. In addition, eliminating genetic introgression with spring-run Chinook salmon, or reducing it to a very low level, is a major goal for the maintenance and restoration of fall-run Chinook salmon in the Central Valley (Lindley et al. 2006; HSRG 2014). Thus, providing opportunities for fall-run reproductive isolation is particularly important for the maintenance of fall-run populations in rivers with dams that cause spring-run and fall-run Chinook salmon to spawn in the same area.

### *6.2.3 What Does Solving the Problem Look Like (Central Valley Objectives)?*

Where applicable, the SEP Group used existing laws, policies, and programs to identify Central Valley Objectives. Central Valley Objectives are presented below to provide context for Watershed-Specific Goals and Biological Objectives on the Stanislaus River.

**Abundance**

Fall-run Chinook salmon production levels for each Central Valley river that would be consistent with the Central Valley-wide Goals of the CVPIA were calculated by the AFRP. The AFRP objective for ocean production of fall-run Chinook salmon for the three salmon-bearing tributaries in the San Joaquin River basin is 78,000, which is divided among the Stanislaus (22,000), Tuolumne (38,000), and Merced (18,000) rivers. Achievement of these targets was intended to occur within a decade after the passage of the CVPIA (USFWS 2001).

**Productivity**

Laws, policies, and programs that provide guidance for Central Valley Objectives generally do not provide explicit targets for salmonid productivity. However, the AFRP and CVPIA provide insight into the desired rate of population growth for fall-run Chinook salmon—doubling from a baseline within roughly three Chinook salmon generations. Furthermore, the AFRP and CVPIA targets imply that population growth rates will be sufficient to make populations resilient against periodic cohort failures (Johnson et al. 2010). Populations may fluctuate above and below the production target, but they should be resilient such that periodic years of low production, due to any cause, do not prohibit reattainment of an abundance target in the next generation.

These two elements of the AFRP and CVPIA goals for Central Valley production—rebuilding a population over three generations and resilience of the population to short-term declines—were used to develop Watershed-Specific Goals and Biological Objectives for productivity (i.e., survival) rates in the Stanislaus River. Furthermore, the SEP Group looked to other viable populations of Chinook salmon to gauge freshwater survival rates that would characterize a Chinook salmon population as being in good condition. It determined that freshwater survival rates needed to support doubling the population growth rate in 9 years and survival rates required to produce a resilient population were lower than is typical of Chinook salmon. Thus, a third Central Valley Objective was established—achieve freshwater survival rates typical of Chinook salmon within 24 years (approximately eight salmon generations).

**Life History Diversity**

No policies speak directly to Central Valley Objectives for necessary improvements in the life history diversity of fall-run Chinook salmon. However, there is increasing evidence that habitat loss and simplification have constrained fall-run Chinook salmon life history strategies, and improvements will be necessary to attain the other Central Valley Goals for this run of Chinook salmon (Ruckelshaus et al. 2002; Lindley et al. 2009; Miller et al. 2010; Schindler et al. 2010; Carlson and Satterthwaite 2011; Satterthwaite et al. 2014).

**Genetic Diversity**

Benchmark metrics have been established based on genetic models to reduce the proportion of hatchery-origin spawners in Central Valley rivers to less than 20% of adult spawners, and preferably less than 5% (even when the hatchery of origin is a conservation-orientated facility using best management practices). A high proportion of hatchery-origin spawners has the potential to increase competition for spawning habitat, reduce reproductive success, and erode mechanisms required for local adaptation of salmon to their environment. This ultimately puts the population at a high risk of extinction (Araki et al. 2007; Lindley et al. 2007). Specific gene-flow criteria (less than 2% introgression) between ESUs have been proposed to achieve long-term genetic integrity and maintain a low extinction risk for natural populations in the Central Valley (Lindley et al. 2007; HSRG 2014).

### *6.2.4 How Will this Effort Contribute to Attainment of Central Valley Objectives (Watershed-Specific Goals)?*

The scope of the SEP Group's current effort is the Stanislaus River through the lower San Joaquin River to the Delta. Specific goals and objectives for the Stanislaus and lower San Joaquin rivers were developed to support the system-wide goals identified in Section 6.2.

**Abundance**

Increased abundance of fall-run Chinook salmon on the Stanislaus River is a Watershed-Specific Goal that supports Central Valley Goals and Objectives. Because abundance is the product of fecundity and survival rates throughout the life cycle (and is therefore controlled in many locations, including the Stanislaus River), there is no S.M.A.R.T. Biological Objective for abundance to accompany this goal (i.e., no Biological Objective for the Stanislaus River).

There is evidence that salmon abundance and productivity on the Stanislaus River are constrained by limited carrying capacity. Specifically, in years when winter and spring flow rates on the Stanislaus River are low, the number of juveniles produced does not increase as spawning escapement increases. However, juvenile production increases with spawning escapement under high flow conditions (Figure 4).

The SEP Group used the Central Valley Objective—average annual natural production of 22,000 fall-run Chinook salmon within three salmon generations—to set a context for determining Environmental Objectives (e.g., physical, chemical, and biological conditions necessary to support and achieve Biological Objectives) for the Stanislaus River. The purpose of this was to ensure that the Environmental Objectives—especially those related to spatial extent of habitat—included sufficient carrying capacity to attain and support Watershed-Specific Goals and the Central Valley Goals and Objectives for Chinook salmon.

**Productivity**

Adult escapement and ocean production reflect previous spawning stock, female fecundity, and survival through different life history stages and Chinook salmon habitats. The juvenile survival rate is the relevant metric that can be controlled at the local spatial scale to affect attainment of Central Valley Goals and Objectives for abundance. Furthermore, productivity is an important attribute of population viability beyond its contribution to abundance (McElhaney et al. 2000). Egg-outmigrant survival rates calculated for the Stanislaus River (Appendix A) reveal that productivity is too low to maintain population viability; survival rates appear to respond positively when winter-spring flow rates are elevated (Figure 4).

The Central Valley Goals and Objectives were used to guide development of Watershed-Specific Goals for productivity (freshwater survival rates). Watershed-Specific Goals for freshwater survival become progressively more protective over time and describe freshwater survival rates sufficient to generate the following:

- Rebuilding: Achieve a population growth rate that supports increasing populations in a relatively short time span (i.e., doubling the population in three generations).
- Resilience: Achieve a population growth rate that allows the population to rebound after years with poor returns (i.e., increasing the population up to 2.5-fold in one generation).
- Sustainability: Achieve freshwater survival rates that are characteristic of salmon in human-modified rivers on the West Coast of North America (i.e., outmigrating smolt represent at least 10% survival from eggs to smolt).

**Life History Diversity**

The Watershed-Specific Goal for fall-run Chinook salmon life history diversity is to support the fullest expression of fall-run Chinook salmon life history diversity (as seen in other Central Valley populations and in other rivers that support this phenotype) to increase and maintain population stability, resilience, and productivity.

Life history diversity must be maintained at a level that allows Chinook salmon populations to respond to varying climatic, hydrologic, and oceanic conditions over time (Beechie et al. 2006; Miller et al. 2010; Spence and Hall 2010; Satterthwaite et al. 2014). There is strong evidence that life history diversity among juvenile Chinook salmon originating from the Stanislaus River is severely constrained, and limited diversity impairs population growth, resilience, and viability (Zeug et al. 2014; Sturrock et al. 2015). The SEP Group identified Watershed-Specific Goals for life history diversity that must be met to achieve a self-sustaining population of naturally produced fall-run Chinook salmon in the Stanislaus River. For this application, life history diversity objectives were characterized in terms of the size distribution and time distribution of juveniles leaving the river system.

**Genetic Diversity**

The SEP Group adopted the following Watershed-Specific Goal for genetic diversity to mirror the Central Valley Goal: maintain genetic integrity of wild fall-run Chinook salmon stocks by minimizing hatchery influence. To achieve this goal, river conditions that support restoration of a self-sustaining, fall-run Chinook salmon phenotype must be established on the Stanislaus River. Establishing and maintaining such a distinct population requires that gene flow between distinct life history types be limited. It also requires the Environmental Objectives to support the fall-running phenotype during all life history stages.

In addition, the impact of hatchery-origin spawning fish has a large influence on the genetic diversity of the natural-origin Chinook salmon population on the Stanislaus River. Hatchery management is a San Joaquin River basin-wide and Central Valley-wide issue in that there are no hatcheries on the Stanislaus River. The SEP Group believes it is important to include the goal within the Stanislaus River scope, to the extent practical, and that attaining this Central Valley Goal relies on actions taken and conditions established within the Stanislaus and lower San Joaquin rivers.

### *6.2.5 What Suite of Species-Specific Outcomes (Biological Objectives) Characterize Success?*

Fall-run Chinook salmon abundance continues to decline in the Stanislaus River, indicating that current population biological attributes are not sufficient to maintain a self-sustaining, viable population, much less to attain the SEP Group's goals and objectives. The objectives below were developed to achieve the SEP Group's Watershed-Specific Goals for fall-run Chinook salmon on the Stanislaus River.

#### 6.2.5.1 Rationale for Productivity Objectives

In many cases, the desired survival rate of salmonids in any life history stage has been calculated based on the desire to attain a given abundance target within a predetermined period. However, survival rates calculated by this method are not necessarily the survival rates that reflect healthy productivity of a Chinook salmon population. Indeed, Pacific salmon populations are characterized by high intrinsic rates of growth (Healey 1991; Quinn 2005) that arise from a strategy of placing eggs in low-productivity riverine environments where development and juvenile success rates are relatively high. The high resilience displayed by some Chinook salmon populations suggests that the attainment of robust population sizes may be achievable over several generations under the right environmental conditions (Issak and Thurow 2006). The capacity to quickly colonize new habitats and rapidly rebound from periods of poor recruitment explain, in part, the widespread and long-term success of Pacific salmon. Furthermore, historical accounts from across the Pacific coast of abundant spawning runs of Chinook salmon attest to the fact that these populations were often limited only by competition for mates and suitable spawning habitats, not survival rates during freshwater juvenile or marine life history stages.

Three reviews of Chinook salmon survival in freshwater across their range were assessed by the SEP Group (Healey 1991; Bradford 1995; Quinn 2005). Each study synthesized results of other studies to produce average egg to smolt survival. In some cases, the same rivers were studied, but the time series used appeared to differ. Members of the SEP Group contacted the authors of these studies to understand the methodologies that were used and to confirm that the populations studied represented "typical" (i.e., not pristine) conditions across the Chinook salmon range. Using this approach, a freshwater survival rate of 10% was determined to be representative of Chinook salmon in human-modified rivers on the West Coast of North America.

By analyzing current survival rate estimates for Stanislaus River salmon, the SEP Group also learned that it would be extremely difficult or impossible to achieve freshwater survival targets without improvement in the river and Delta environments (Appendix A). No historical data are available from this system to establish the appropriate balance between in-river and through-Delta survival, and no analogous salmon-bearing river systems with such a large inland estuary exist elsewhere. The SEP Group found no reason that survival rates in-river should be greater than or equal to through-Delta survival. Calculated improvements necessary in overall freshwater survival were therefore distributed proportionately across riverine and estuarine habitats. The same approach to allocating responsibility for improved freshwater survival rates was employed by NMFS (2012).

At higher levels of survival required to attain the Watershed-Specific Goals of resilience and sustainability, the approach of generating "equal improvement" for in-river and through-Delta relative survival rates produced survival rate targets in the Delta that may be unachievable (i.e., they would not meet S.M.A.R.T. criteria). Through-Delta survival rates were capped at 50%, and in-river survival rates were adjusted accordingly to attain desired freshwater survival rates.

Freshwater survival rates for rebuilding and resilience assume current post-Delta survival rates through the Estuary and Pacific Ocean. If survival rates in the bay or ocean change substantially, the freshwater survival rate objectives may be adjusted. However, freshwater survival rates for sustainability are typical of Chinook salmon populations across their range (i.e., they reflect the typical "productivity" of Chinook salmon populations).

Survival rates in freshwater may be impacted by density-dependent factors when populations approach local carrying capacity. Freshwater survival rate objectives produced by the SEP Group apply only to situations where the spawner population is lower than the system's targeted carrying capacity (i.e., in years when there should be little effect on overall survival rates of density-dependent competition). As spawner populations increase, the SEP Group may refine productivity objectives to apply to years where the spawner and juvenile cohorts approach intended carrying capacity (i.e., Environmental Objectives for habitat area) for the system. Thus, attainment of current survival objectives should be measured only when the spawning population is below a certain threshold (McElhany et al. 2000). That threshold has not been determined.

In-river productivity rates are also affected by conditions that influence adult migration, holding, and spawning success among adults. Unsuitable conditions (including high temperatures, low DO concentrations, or other migration barriers) during adult migration and holding may result in sub-lethal impacts that reduce productivity between escapement and subsequent juvenile outmigration. Thus, objectives for desired adult migration, holding, and spawning success were developed. Because the holding period for adult fall-run Chinook salmon is abbreviated compared to that observed among spring-run Chinook salmon, a detailed description of the rationale and approach for adult productivity objectives for spring-run Chinook salmon is provided in Section 6.3.5.1.

#### 6.2.5.2 Methods for Productivity Objectives

The SEP Group created a spreadsheet-based life cycle model to investigate which changes to current survival rates in different life history stages are necessary to attain Watershed-Specific Goals for population growth rates (Appendix A). The purpose of this model is two-fold:

- Estimate and evaluate relative survival rates of juvenile Chinook salmon emigrating from the Stanislaus River through the lower San Joaquin River and the Delta
- Serve as a tool for the development of specific freshwater juvenile survival (productivity) objectives for Chinook salmon and the allocation of improvements in survival rates systematically across different reaches of juvenile freshwater habitat at discrete times in the future

The spreadsheet model is based on a set of survival rate estimates for freshwater and marine environments generated from data sources used by resource managers. Despite natural variance and measurement uncertainty associated with these data, they represent the best available data. The spreadsheet model can be used to estimate relative differences in survival rates across different habitats and the magnitude of improvement required to meet Biological Objectives for salmon in the Stanislaus River and lower San Joaquin River.

Survival rates for various life history stages of San Joaquin River basin Chinook salmon were collected from previous reports and existing data sources (Table 1). Where estimates differed among reports, the SEP Group determined the estimates that were most likely to reflect actual conditions; these estimates are referred to as the “Consensus Estimate” in Table 1. Previous studies did not account for mortality between the lowest sampling station in the Stanislaus River (i.e., the RST at Caswell) and the Delta, which begins at Vernalis on the San Joaquin River (Figure 2). Survival in this 10.5-RM stretch was estimated from the per-RM average of survival rates upstream of the stretch between Oakdale and Caswell and through the Delta.

**Table 1**
**Calculated Recruits per Spawner Based on Survival Consensus Estimates**

| Reach | Fishbio 2007, Fuller 2013, Anderson et al. 2015, CDFW 2018 | NMFS 2012 | Consensus Estimates | RM | Survival per RM |
|---|---|---|---|---|---|
| Eggs to Caswell | 6.64% | 5.64% | 1.87% | 46.5 | 91.79% |
| Eggs to Oakdale | - | | 10.62% | 14.4 | 85.58% |
| Oakdale to Caswell | - | | 16.02% | 32.1 | 94.46% |
| Caswell to Vernalis[1] | - | | 54.09% | 10.5 | 94.32% |
| Vernalis to Chipps Island | 5% | 3.75%[2] | 3.75% | 72.5 | 95.57% |
| Chipps Island to Adult[2] | - | - | 5.4%[5] | - | - |
| Adult to Spawner[3] | 50% | 70% | 60.24% | - | - |
| Recruits per Spawner[4] | - | - | 0.043 | - | - |

Notes:

1. No existing data were available to estimate survival in the reach between Caswell and the Delta boundary. Survival in this reach was estimated as a function of the average per-RM survival from Oakdale to Caswell and from Vernalis to Chipps Island.
2. Vernalis to Chipps Island survival (3.75%; Brandes, pers. comm.)
3. Assumes no change from current estimated survival rates after juvenile salmon pass Chipps Island (the western edge of the Delta)
4. Recruits per spawner is calculated as the product of survival rates (e.g., Eggs to Caswell × Caswell to Vernalis × Vernalis to Chipps Island × Chipps Island to Adult × Adult to Spawner) × estimated population sex ratio (60% female spawners) × estimated average fecundity (5,813 eggs per spawner).
5. Geometric mean of the lower 95% confidence bounds for annual estimates calculated by Michel (2018).
6. Survival in this table refers to the estimated juvenile survival rates in different segments of the migration corridor for Stanislaus River Chinook salmon, including survival from egg stage to the RST at Caswell ("Eggs to Caswell"); Eggs To Oakdale RST ("Eggs to Oakdale"); Caswell RST to the Delta ("Caswell to Vernalis"); through the Delta ("Vernalis to Chipps Island"); Delta exit to age-2 fish in the ocean ("Chipps Island to Adult"); and ocean harvest and other adult mortality prior to escapement ("Adult to Spawner").
7. Consensus estimates are based on calculations from data collected at RSTs located at Oakdale and Caswell, as reported by USFWS, and survival estimates in each segment of fall-run Chinook salmon migration beyond the Caswell RST that the SEP Group considered to be the most accurate. See Section 6.2.5.2 for a description of the Stanislaus River Survival Model and Appendix A.

The model is based on estimated egg deposition (i.e., run size × estimated sex ratio × measured average fecundity) and life history stage survival estimates. The conceptual diagram for the spreadsheet model is depicted in Figure 6. Survival estimates were developed for the following:

- Two reaches of the Stanislaus River (i.e., survival from egg deposition to the RSTs at Oakdale (Stanislaus reach 1) and survival from Oakdale to the RSTs at Caswell (Stanislaus reach 2)
- A reach including the lower Stanislaus and San Joaquin rivers from Caswell to Vernalis (San Joaquin River reach)
- The Delta from Vernalis to Chipps Island (Delta reach)
- The marine environment prior to harvest
- Losses from maturity to spawning escapement

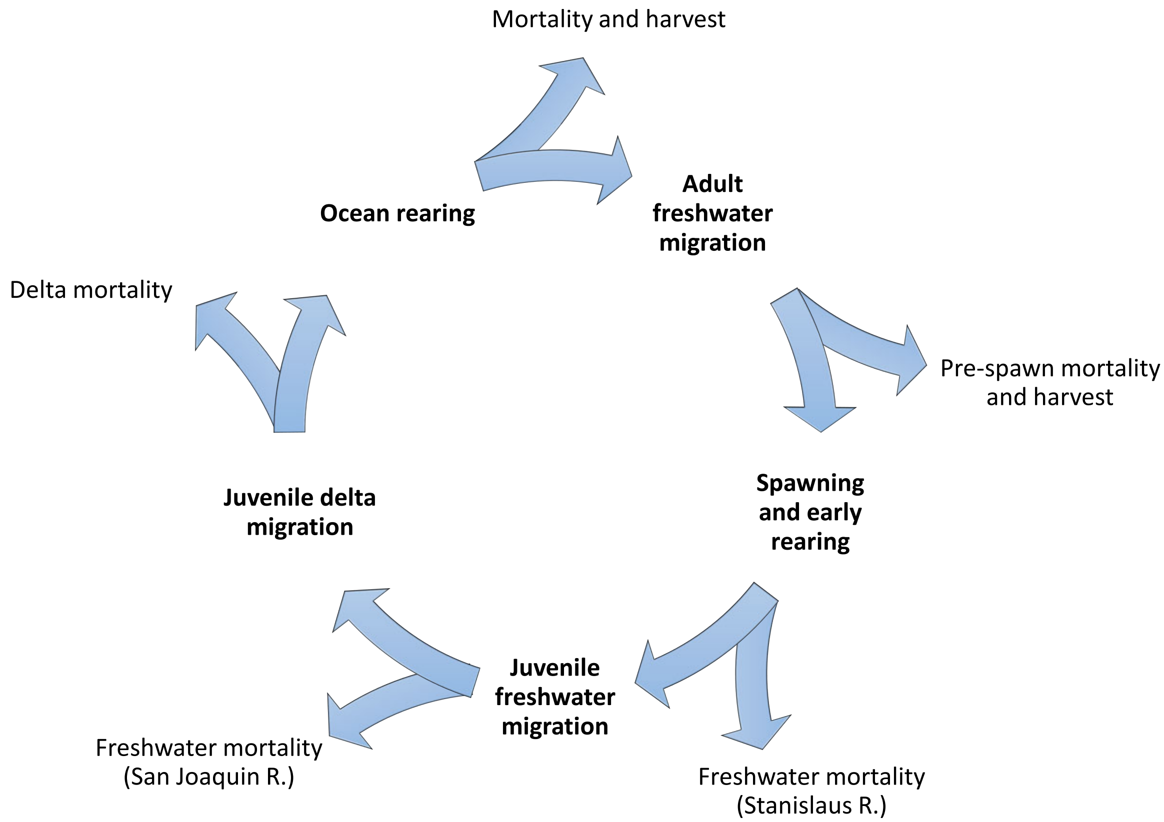



**Figure 6**
**Life Cycle Diagram and Potential Sources of Mortality used in the Stanislaus Survival Model**

### *6.2.5.2.1 Data Sources and Derived Metrics*

The following data and derived metrics are represented in the spreadsheet-based Stanislaus Survival Model provided in Appendix A. The following derived variables are based on the best available information.

**Year**

"Year" represents the calendar year when data were recorded. Note that calculation of survival from eggs to subsequent enumeration of juveniles uses data from two different calendar years: the year in which escapement/spawning occurs (year x) and the year in which juvenile outmigrants are caught by RSTs (year x + 1).

**Water Year Index**

Water years extend from October 1 of 1 year to September 30 of the next year (e.g., the 2010 water year is from 1 October 2009 to 30 September 2010) to capture the typical wet season in California. The water year index represents hydrology in 1 of 5 categories of water year type: wet, above normal, below normal, dry, and critical. Data for the workbook were obtained from California Department of Water Resources.

**Oakdale RST Expanded Passage**

Oakdale RST expanded passage is the estimated number of Stanislaus River-origin juvenile Chinook salmon passing Oakdale derived from RST estimates (Fishbio 2007).

**Caswell RST Expanded Passage**

Cramer RST expanded passage is the estimated number of Stanislaus River-origin juvenile Chinook salmon passing Caswell derived from RST estimates (Anderson et al. 2015).

**Adult Production**

Adult production is the estimated number of Stanislaus River-origin adult Chinook salmon in a given year-class in the ocean prior to harvest as estimated by the sum of harvest and escapement within a specified year-long period (Newman and Hankin 2004; USFWS 2016).

**Ocean Harvest**

Ocean harvest is the estimated number of Stanislaus River-origin adult Chinook salmon in a given year-class harvested by an ocean fishery (Newman and Hankin 2004; USFWS 2016).

**Freshwater Harvest**

Freshwater harvest is the estimated number of adult Stanislaus River-origin Chinook salmon in a given year-class harvested by a freshwater fishery (Newman and Hankin 2004; USFWS 2016).

**Total Harvest**

Total harvest is the estimated number of adult Stanislaus River-origin Chinook salmon migrating to the basin harvested by either an ocean or a freshwater fishery (Newman and Hankin 2004; USFWS 2016).

**Grandtab Escapement**

Grandtab escapement is the estimated number of adult Chinook salmon returning to the Stanislaus River each year (CDFW 2018).

**Weir Escapement**

Weir escapement is the estimated number of adults migrating upriver after harvest derived from resistance board weir counts (Fuller 2013). These numbers differ from Grandtab escapement because the sampling methodology differs. Results between the two escapement estimates are not systematically different (i.e., one is not consistently larger than the other), and the Grandtab dataset covers a longer time period than the weir escapement dataset. Thus, weir escapement is provided for reference in the data sheets with model inputs (Appendix A), but weir escapement is not used in the model calculations.

**Median Percent Females**

The median percentage of females is calculated from fish surveyed on the Stanislaus River from 1995 to 2013 as 60% of the spawning population of Chinook salmon (see tab titled "Stan sex ratio + fecundity" in Appendix A; Swank 2014, pers. comm.).

**Median Fecundity**

Median fecundity is estimated from fish surveyed by CDFW on the Stanislaus River from 1995 to 2013 using a length-fecundity relationship for San Joaquin fall-run Chinook salmon developed by Loudermilk et al. (1990). The median value of 5,813 eggs per female adult Chinook salmon (see tab titled "Stan sex ratio + fecundity" in Appendix A; Swank 2014, pers. comm.) is used for the model calculations.

**Vernalis to Chipps Island Survival**

Vernalis to Chipps Island survival is 3.75% based on regionally accepted evaluations (NMFS 2012; Swank 2014, pers. comm.).

**Chipps Island to Adult Survival**

Chipps Island to Adult survival ("marine survival") was estimated by Michel (2018) using acoustic tag data from hatchery-raised late fall-run Sacramento River Chinook salmon. These fish are much larger than typical fall-run or spring-run Chinook salmon juveniles in the Stanislas River, and their hatchery rearing suggests that they are in better condition than would be typical of most wild fish. As a result, the SEP Group expected marine survival of this test group to exceed marine survival of wild-origin Chinook salmon from the San Joaquin River. To reduce the bias of large hatchery fish on survival, the estimate for marine survival of wild juvenile San Joaquin River Chinook salmon was estimated to be the geometric mean of the lower 95% confidence bound of Michel's (2018) results.[5]

[5] A better estimate of marine survival specific to wild-spawned San Joaquin River juvenile Chinook salmon is desirable. Also, current marine survival rates may change if the migrant condition responds positively to improvements in the habitat conditions of riverine and freshwater estuarine (Delta) environments. However, until such data are available, the SEP Group's estimate of San Joaquin Chinook salmon marine survival rates as the lower end of measured survival rates for hatchery-raised Sacramento River Chinook salmon juveniles seems prudent.

**Ocean to Spawning Escapement**

Ocean to spawning escapement is calculated annually as the ratio of Grandtab spawning escapement and adult production. The geometric mean of annual values is used to parameterize the survival model.

**Estimated Egg Deposition**

Estimated egg deposition is calculated annually as the product of Grandtab spawning escapement, median proportion of females, and median fecundity.

**Eggs to Oakdale Survival**

Eggs to Oakdale survival is calculated annually as the ratio of Oakdale RST passage in year x + 1 and estimated egg deposition in year x. The geometric mean of annual values is used to parameterize the survival model.

**Eggs to Caswell Survival**

Eggs to Caswell survival is calculated annually as the ratio of Caswell RST passage in year x + 1 and egg deposition in year x. The geometric mean of annual values is used to parameterize the survival model.

**Oakdale to Caswell Survival**

Oakdale to Caswell survival is calculated annually as the ratio of Caswell RST passage in year x and Oakdale RST passage in year x. The ratio between survival from Eggs to Oakdale and survival from Oakdale to Caswell has been used to develop secondary objectives for egg to fry productivity. Note that the time series for Eggs to Caswell survival and Eggs to Oakdale or Oakdale to Caswell survival is not equal (because of differences in the number of years for which an expanded passage estimate at Oakdale RST has been calculated).

**Calculated Caswell to Vernalis Survival**

Caswell to Vernalis survival is calculated annually based on Oakdale to Caswell survival and Vernalis to Chipps Island survival. Survival per RM is first calculated for Oakdale to Caswell and Vernalis to Chipps Island by taking the root equal to the number of RMs. For example, Vernalis to Chipps Island survival is calculated as shown in Equation 1:

$$Survival\ per\ RM = 0.0375^{\frac{1}{54.5}} = 0.9415$$

Caswell to Vernalis survival per RM is calculated as the weighted average of estimated Oakdale to Caswell survival per RM and Vernalis to Chipps Island survival per RM. Caswell to Vernalis survival for the reach is calculated by taking survival per RM multiplied to the power equal to the number of RMs. The geometric mean of annual values is used to parameterize the survival model.

**Eggs to Vernalis Survival**

Eggs to Vernalis survival is calculated annually as the product of Eggs to Caswell survival and Caswell to Vernalis survival.

Target population growth rates (i.e., cohort replacement rates [CRR]) were calculated for each productivity goal—rebuilding, resilience, and sustainability—using the exponential growth equation as shown in Equation 2 (from Equation 2.2 in Haddon 2001):

$$e = \left(\frac{N_t}{N_0}\right)^{\frac{1}{t}}$$

where:

| | | |
|---|---|---|
| e | = | growth rate |
| t | = | number of generations |
| $N_t$ | = | population at generation t |
| $N_0$ | = | population at generation 0 (initial population) |

Freshwater survival rates (Eggs to Chipps Island) necessary to achieve the desired growth rate for each productivity goal were calculated by assuming that current population sex ratio, fecundity, and post-Delta survival rates (including ocean harvest rates) were fixed. Following the approach taken by NMFS (2012), the SEP Group apportioned the necessary increase in freshwater survival equally to two reaches: riverine (Eggs to Vernalis) and estuarine (Vernalis to Chipps Island). Survival necessary to achieve each productivity goal in each reach (riverine and Delta) was calculated by multiplying current survival rates in those two habitats by the same multiplier. For each productivity goal, the multiplier for Delta and riverine reaches represented the square root of the quotient of target total freshwater survival rate (those needed to achieve each of the productivity goals) divided by the current estimated survival rate through freshwater (see "Consensus Estimate" of current survival rate from Eggs to Caswell × Caswell to Vernalis × Vernalis to Chipps Island in Table 1).

Within the riverine reach, the target survival rate was further divided into target survival for Eggs to Oakdale, Oakdale to Caswell, and Caswell to Vernalis. The reach from Caswell to Vernalis was calculated as a weighted average of per-mile survival rates in the Delta (Vernalis to Chipps Island) and the Stanislaus River (Eggs to Vernalis). Once the 10.5-mile Caswell to Vernalis survival rate was calculated, it was possible to solve for the remaining stretch of river (Eggs to Caswell) by dividing the river-wide survival rate by the Caswell to Vernalis reach. The Eggs to Caswell survival rate is the

Stanislaus-specific survival rate Biological Objective for each of the three juvenile productivity goals, and it is accompanied by the Caswell to Vernalis survival rate that will be affected by conditions (e.g., flows, water temperatures) contributed by the Stanislaus River and other San Joaquin tributaries.

Although several population metrics in Equations 1 and 2 were fixed mean values (proportion of females, fecundity, current Vernalis to Chipps Island survival, and Chipps Island to Adult survival), some parameters were based on annual observed data (Eggs to Vernalis survival and Ocean to Spawning survival; Appendix A). The SEP Group calculated 95% confidence intervals for target freshwater survival rates based on the observed variation in the annual estimates for these two parameters. Using a generic statistics program (Program R), the SEP Group simulated target freshwater survival using data and selecting the logit function to ensure target survival rates were constrained between 0 and 1. The program was run 100,000 times for the simulation.

An upper limit of 50% was imposed on target freshwater survival rates for Stanislaus River and Delta reaches. This upper limit assumes that survival rates greater than 50% in either the riverine or the estuarine portion of the freshwater life cycle would be unrealistic. The 50% survival rate limit only affects Biological Objectives for the Delta reach—current Delta survival is greater than survival in-river—for the final increment of improvement in productivity (e.g., freshwater survival rates consistent with the sustainability phase).

### 6.2.5.3 Current Productivity

The SEP Group summarized annual survival estimates for different portions of the freshwater life cycle of fall-run Chinook salmon originating in the Stanislaus River using values found in agency reports and monitoring data (Table 1). The SEP Group used consensus to determine the best survival estimate for a given reach based on available information (i.e., the consensus estimate). The consensus estimate of survival per reach and survival per RM within each freshwater reach were derived from the following (in order of priority):

1. Annual observed data
2. Mean values derived from observed data and reported in agency documents
3. Estimated survival based on the mean per-RM survival rate immediately upstream and downstream

Consensus estimates are based on the geometric mean of annual estimates where annual data are available. Overall, the estimated median recruits per spawner for the fall-run Chinook salmon population in the Stanislaus River is 0.04. This growth rate is much lower than the value of 1 necessary for a stable population; thus, the current population on the Stanislaus River is in decline. The number of juvenile outmigrants per spawner is strongly and positively correlated with winter-spring flow conditions in the Stanislaus River (Figure 4 and Appendix A). Further, the spawning cohort in one year is strongly correlated with San Joaquin River flows in the year that that cohort migrated to the ocean (Sturrock et al. 2015).

#### *6.2.5.3.1 Rebuilding: Recruits per Spawner Equals 1.26*

The initial phase Biological Objective for productivity, which is intended to support the goal of rebuilding the Stanislaus River fall-run Chinook salmon population, required establishing survival rates within the Stanislaus and lower San Joaquin River that would support a population growth rate (or CRR) of 1.26. A sustained CRR of 1.26 leads to population doubling in three generations. The SEP Group assumed no change in mean survival from Chipps Island to adult (marine survival) and from adult to spawner (i.e., reflecting harvest rates). Survival in the river (Eggs to Vernalis) and Delta (Vernalis to Chipps Island) were assumed to improve proportionate to current levels.

The survival rate necessary in the river (Eggs to Vernalis) and in the Delta (Vernalis to Chipps Island) to achieve a CRR of 1.26 was estimated (Table 2). Given current estimates of marine survival to adulthood and ocean harvest, achieving a 1.26 CRR would require freshwater survival of juvenile Chinook salmon at 1.11%. Attaining this overall freshwater survival goal in 10 years would require the following (Table 7):

- Median annual survival from Eggs to Vernalis of 5.47%
- Median annual survival from Vernalis to Chipps Island of 20.31%

Variance around estimated survival rate targets, which was simulated using observed data and the logit function of R (100,000 simulations), indicated that 95% confidence intervals were constrained between 0 and 1 for survival from Eggs to Vernalis (95% confidence interval: 2.96% to 28.57%) and Vernalis to Chipps Island (95% confidence interval: 7.95% to 71.81%).

**Table 2**

**Survival Rates in Freshwater Environments Necessary to Support Watershed-Specific Goal of Rebuilding Stanislaus River Fall-Run Chinook Salmon Population**

| Reach | Current | RM | Target Survival[4] | Target Survival[4] per RM |
|---|---|---|---|---|
| Eggs to Vernalis | 1.01% | 57.0 | 5.47% | 95.03% |
| Vernalis to Chipps Island | 3.75% | 72.5 | 20.31% | 97.83% |
| Chipps Island to Adult[1] | 5.4%[2] | - | 5.4%[2] | - |
| Adult to Spawner[1] | 60.24% | - | 60.24% | - |
| Recruits per Spawner[3] | 0.043 | - | 1.26 | - |

Notes:

1. Assumes no change from current estimated survival rates after juvenile salmon pass Chipps Island (the western edge of the Delta)
2. Geometric mean of the lower 95% confidence bounds for annual estimates calculated by Michel (2018)
3. Recruits per spawner is calculated as the product of survival rates (e.g., Eggs to Vernalis × Vernalis to Chipps Island × Chipps Island to Adult × Adult to Spawner) × estimated population sex ratio (60% female spawners) × estimated average fecundity (5,813 eggs per spawner).
4. Target survival assumes an equal increase over current survival in Delta and riverine habitats.

#### *6.2.5.3.2 Resiliency: Recruits per Spawner Equals 2.5*

The population growth rate associated with the rebuilding objective (CRR equals 1.26; Section 6.2.5.3.1) would lead to a situation where low production in 1 year could severely constrain production in the subsequent generation (i.e., the population would not be resilient). A higher CRR is consistent with Central Valley Goals and Objectives for this population, as the Watershed-Specific Goal and this Biological Objective are designed to ensure that survival rates in the river environment do not prevent attainment of AFRP production targets following years with low returns (e.g., as would be necessary to hit a 5-year running average). Again, there is no Biological Objective related to attainment of the AFRP or other abundance target; this productivity objective simply specifies survival rates that are consistent with attainment of goals and objectives for the Central Valley and Watershed-Specific Goals.

The SEP Group's second phase of productivity improvement is intended to establish population resilience by achieving freshwater survival rates that support a population growth rate (or CRR) of 2.5. The increase in survival necessary in the river (Eggs to Vernalis) and in the Delta (Vernalis to Chipps Island) to support population resilience—a minimum of 2.5 recruits per spawner—was estimated assuming no change in mean survival from Chipps Island to adult or adult to spawner (Table 3). Under these assumptions, a CRR of 2.5 would require freshwater survival of 2.2%. Although freshwater survival of 2.2% is higher than current survival estimates, the SEP Group considered it to be reasonable and achievable after 15 years of restoration effort, especially because it is well below typical freshwater survival for Chinook salmon populations across their range.

To achieve a freshwater survival rate of 2.2% overall—within 15 years and assuming proportionate improvements in survival in the riverine and Delta environments—would require the following:

- Median annual survival from Eggs to Vernalis of 7.7%
- Median annual survival from Vernalis to Chipps Island of 28.6%

Variance around estimated survival rate targets, which was simulated using observed data and the logit function of R (100,000 simulations), indicated that 95% confidence intervals were constrained between 0 and 1 for survival from Eggs to Vernalis (95% confidence interval: 5% to 37.51%) and Vernalis to Chipps Island (95% confidence interval: 11.83% to 81.61%).

**Table 3**
**Survival Rates in Freshwater Environments Necessary to Support Watershed-Specific Goal of Resiliency for Stanislaus River Fall-Run Chinook Salmon Population**

| Reach | Current | RM | Target Survival[4] | Target Survival[4] per RM |
|---|---|---|---|---|
| Eggs to Vernalis | 1.01% | 57.0 | 17.7% | 95.6% |
| Vernalis to Chipps Island | 3.75% | 72.5 | 28.6% | 98.29% |
| Chipps Island to Adult[1] | 5.4%[2] | - | 5.4%[2] | - |
| Adult to Spawner[1] | 60.24% | - | 60.24% | - |
| Recruits per Spawner[3] | 0.043 | - | 2.5 | - |

Notes:
1. Assumes no change from current estimated survival rates after juvenile salmon pass Chipps Island (the western edge of the Delta)
2. Geometric mean of the lower 95% confidence bounds for annual estimates calculated by Michel (2018)
3. Recruits per spawner is calculated as the product of survival rates (e.g., Eggs to Vernalis × Vernalis to Chipps Island × Chipps Island to Adult × Adult to Spawner) × estimated population sex ratio (60% female spawners) × estimated average fecundity (5,813 eggs per spawner).
4. Target survival assumes an equal increase over current survival in Delta and riverine habitats.

### *6.2.5.3.3 Sustainability: Recruits per Spawner Equal 11.35*

Quinn (2005) summarized stage-specific survival rates from numerous modern-day Chinook salmon populations, including those in highly managed rivers, and reported average egg-to-smolt survival of 10%. The SEP Group adopted this characteristic of typical of Chinook salmon populations as its final target for median freshwater survival rates of Stanislaus River juvenile Chinook salmon. This value was selected because Quinn (2005) was the most recent study available on this topic, and this value was approximately the mid-point of the values from the two other studies (Healey 1991; Bradford 1995). Assuming no change in marine survival to adult or harvest (adult to spawner survival rate), the SEP Group's third phase of productivity improvement—establishing population sustainability by achieving freshwater survival of 10%—would result in a CRR of 11.35.[6]

The assumption of proportionate improvement in survival in the river (Eggs to Vernalis) and Delta (Vernalis to Chipps Island) produced an estimated target for Delta survival (Table 4) that was judged not achievable on a sustained basis (i.e., not S.M.A.R.T.) for juvenile Chinook salmon from the Stanislaus River. Some fraction of this population is expected to rear for significant periods in the Delta, even after restoration of rearing habitat in the riverine environment, and, other factors being equal, mortality and duration of rearing in a given environment are expected to correlate inversely. Thus, maximum median through-Delta survival was assumed to be approximately 50%. To achieve the target freshwater survival objective, through-Delta survival of 50% was assumed (adjusted target

[6] This result is similar to Quinn's (2005) estimate of "adults per female" for typical modern-day Chinook salmon populations, which includes those in managed rivers. Converting recruits per spawner into "adults per female" for a spawning population with 60% females results in a value (18.9) that compares well with Quinn's (2005) calculated estimate for a typical Chinook salmon population (17.5).]

survival; Table 4). Thus, to achieve an overall freshwater survival rate of 10%, the following will need to be achieved in each reach within 24 years (Table 7):

- Median annual survival rate from Eggs to Vernalis of 20%
- Median annual survival rate from Vernalis to Chipps Island of 50%

Variance around estimated survival rate targets, simulated using observed data and the logit function of R (100,000 simulations), indicated that 95% confidence intervals were constrained between 0 and 1 for survival from Eggs to Vernalis (95% confidence interval: 9.91% to 55.32%) and Vernalis to Chipps Island (95% confidence interval: 19.27% to 91.55%).

**Table 4**
**Calculated Survival Required to Achieve Population Sustainability (10% Freshwater Survival)**

| Reach | Current | RM | Calculated Target Survival[4] | Adjusted Target Survival[4] | Target Survival[4] per RM |
|---|---|---|---|---|---|
| Eggs to Vernalis | 1.01% | 57.0 | 16.41% | 20% | 97.22% |
| Vernalis to Chipps Island | 3.75% | 72.5 | 60.95% | 50% | 99.05% |
| Chipps Island to Adult[1] | 5.4%[2] | - | - | 5.4%[2] | - |
| Adult to Spawner[1] | 60.24% | - | - | 60.24% | - |
| Recruits per Spawner[3] | 0.043 | | | 11.35 | |

Notes:

1. Assumes no change from current estimated survival rates after juvenile salmon pass Chipps Island (the western edge of the Delta)
2. The geometric mean of the lower 95% confidence bounds for annual estimates calculated by Michel (2018)
3. Recruits per spawner is calculated as the product of survival rates (e.g., Eggs to Vernalis × Vernalis to Chipps Island × Chipps Island to Adult × Adult to Spawner) × estimated population sex ratio (60% female spawners) × estimated average fecundity (5,813 eggs per spawner).
4. Summarizes the proportional increase in survival needed to achieve 10% freshwater survival based on published values (Healey 1991; Bradford 1995; Quinn 2005), or a minimum of 11.35 recruits per spawner. A proportionate increase of river and Delta survival rates (as described in Section 6.2.5.3.3) resulted in Delta survival rates that the SEP Group believed were unrealistically high. Therefore, the necessary increase in river (Eggs to Vernalis) survival rates was calculated based on a median Delta (Vernalis to Chipps Island) survival rate of 50%.

## 6.2.5.4 Results: Productivity Objectives

### *6.2.5.4.1 Reach-Specific Juvenile Freshwater Survival Objectives*

Tables 2, 3, and 4 present the CRRs, total freshwater survival rates, and riverine and Delta survival rates necessary to achieve the three Watershed-Specific Goals of rebuilding, resilience, and sustainability. The Eggs to Vernalis survival targets form the basis of Biological Objectives that can be attained in the geographic scope of the SEP. The SEP Group estimated survival targets in each freshwater reach bounded by monitoring points (Oakdale, Caswell, Vernalis/Mossdale, and Chipps Island) that are needed in order to achieve the total freshwater survival rates consistent with the three productivity goals (Table 5).

**Table 5**
**Current Reach-Specific Survival and Survival Objectives for Three Productivity Goals**

| Reach | Current | RM | Productivity Goals | | |
|---|---|---|---|---|---|
| | | | Rebuilding | Resilience | Sustainability |
| Eggs to Caswell | 1.87% | 46.5 | 8% | 10.7% | 24.4% |
| Caswell to Vernalis | 54.09% | 10.5 | 68.2% | 72.2% | 82% |
| Vernalis to Chipps Island | 3.75% | 72.5 | 20.3% | 28.6% | 50% |
| Freshwater Survival | 0.04% | | 1.11% | 2.2% | 10% |

Current survival from Caswell to Vernalis was estimated based on the average per-RM survival rates for Eggs to Oakdale and Oakdale to Caswell (Table 1). This average per-RM survival rate was applied to the 10.5 miles of river between Caswell and Vernalis; thus, the increase in survival assigned from Caswell to Vernalis was calculated by averaging the target per RM survival of the Eggs to Vernalis reach and the Vernalis to Chipps Island reach. Survival rates in the Stanislaus River reaches above Caswell (Eggs to Caswell) are those that will achieve the necessary river survival rates when multiplied by the survival rates calculated from Caswell to Vernalis (the last part of the riverine migration). That survival rate was disaggregated into components expected upstream and downstream of the first RST at Oakdale. Current survival rates from Eggs to Oakdale and from Oakdale to Caswell were compared only for years where Oakdale RST data were available. Survival upstream and downstream of Oakdale was calculated only for a subset of the time series used to calculate median Eggs to Caswell survival. As a result, the product of Eggs to Oakdale survival and Oakdale to Caswell survival does not equal the survival estimate for Eggs to Caswell. However, it was assumed that the proportionate survival in these two reaches was well-estimated by the years in which data were available.

Survival targets for Eggs to Caswell and Caswell to Vernalis were adopted as Biological Objectives for productivity to attain the Watershed-Specific Goals for population rebuilding, resilience, and sustainability (Table 7).

#### *6.2.5.4.2 Supplemental Guidance to Support Productivity Objectives in the Stanislaus River*

The productivity objectives described in the previous section will require improved success across several life history stages, including fecundity, egg viability, development success, and juvenile survival, throughout the Stanislaus River and lower San Joaquin corridors. Although overarching juvenile productivity rates (measured as survival from Eggs to Caswell and survival from Caswell to Vernalis) are the central focus of efforts to restore population productivity on the Stanislaus River, the SEP Group also developed guidance for egg and early juvenile productivity. This guidance allows for identification, prioritization, monitoring, and adaptive management of stressors affecting life history stage transitions between adults and early fry as compared to those stressors that affect later juvenile survival (e.g., downstream of Oakdale).

**Egg Viability**

Viability of Chinook salmon eggs incubated under hatchery conditions is well studied and generally extremely high (more than 90%; Tappel and Bjornn 1983). Egg viability may be compromised by deleterious conditions experienced by migrating adult Chinook salmon (McCullough 1999; USEPA 2003). Such negative effects can be detected by measuring hatchability of eggs taken from females that have completed their migration through freshwater. Low hatching success of eggs incubated under standardized conditions would reveal whether adult migration conditions inhibit attainment of the overall productivity (juvenile outmigrants-per-adult) objective.

The SEP Group established guidance for mean egg viability in hatchery conditions of 95% for eggs taken from female Chinook salmon that completed migration. This sub-objective should be attained by year 9 (Table 7). A small sample from one study on the Stanislaus River indicated mean egg survival ranged from 70% to 72.8% (Carl Mesick Consultants and KDH Environmental Services 2009). Ideally, attainment of this sub-objective would involve eggs taken from females caught in the early part of the fall-run migration season, as this is when physical conditions are most stressful to migrating fall-run Chinook salmon females.

**Development Condition**

Egg development may be compromised in the field by conditions that are unsuitable physically or chemically (e.g., due to gravel size distribution, temperature, and fine sediment accumulations). The SEP Group identified supportive, stressful, and detrimental levels of physio-chemical variables that are important to egg development success (Section 7.2.4). The combined effect of various levels of these variables on development success can be predicted based on previous studies of hatching success where conditions where controlled and varied systematically (e.g., for gravel size distribution; Tappel and Bjornn 1983).

The SEP Group determined that physical conditions in the river should be those that would support development success rates of 80%, 85%, and 90% for all redds deposited in a given year, as predicted by hatchability under conditions studied by Tappel and Bjornn (1983) and other studies (e.g., Mesick 2001) by years 9, 15, and 24, respectively (Table 7). The SEP Group emphasizes that it is not anticipating actual egg hatchability of greater than or equal to 80% in the field. Rather, the sub-objective provides guidance that physical and chemical conditions (e.g., gravel quality, water temperature, DO, and contaminant levels) should be consistent with conditions needed to produce these levels of development success in a controlled environment.

**Fry Productivity**

Egg-outmigrant productivity may also be compromised by low survivorship in very early life history stages (larvae, early fry). Because it is extremely challenging to measure development success of naturally deposited eggs directly, the SEP Group established guidance to capture impacts to development success as well as mortality that occurs immediately after hatching. By estimating escapement and female fecundity, the potential number of eggs deposited during a spawning season can be estimated. By measuring fry production just downstream of the spawning reach (e.g., at the Oakdale RST), productivity from the egg stage to the fry stage can be estimated. USFWS (2014) employs such a calculation to estimate winter-run Chinook salmon productivity rates on the Sacramento River. Egg-fry productivity rates have been studied in other Chinook salmon populations (e.g., Quinn 2005), and these estimates informed the sustainability objective for expected egg-fry productivity on the Stanislaus River.

The SEP Group established guidance for expected fry production at the Oakdale RST. The geometric mean of egg-fry survival rates at the Oakdale RST from 1995 to 2013 was approximately 11% (based on assumptions regarding spawner sex ratio and female fecundity detailed in Appendix A). Under the assumption that survival of Chinook salmon upstream and downstream of Oakdale improved proportionately, egg to fry survival at Oakdale would be 18.8% and 21.6% by years 9 and 15, respectively, in order to attain the overarching productivity objectives (Eggs to Caswell survival rates; Table 7). The SEP Group's guidance for minimum egg to fry survival to Oakdale RST was slightly lower than that derived mathematically. There was no intention for this guidance to become prescriptive or constrain allocation of restoration effort. The final guidance target for egg to fry productivity (35% by year 24; Table 6) matched typical Chinook salmon egg to fry survival rates measured elsewhere (Healy 1991; Quinn 2005).

**Table 6**
**Guidance Related to Egg Viability and Development Success for Chinook Salmon (Fall- and Spring-run) in the Stanislaus River**

| Sub-objective | Metric | To be Achieved by |
|---|---|---|
| Egg viability | In hatchery hatching success equals 95% (lower 90% confidence interval ≥ 87%, n= 5 to 10 females) | Year 9 |
| Development condition | Field environmental conditions consistent with greater than 80% hatchery development success | Year 9 |
| | Field environmental conditions consistent with greater than 85% hatchery development success | Year 15 |
| | Field environmental conditions consistent with greater than 90% hatchery development success | Year 24 |
| Egg to fry productivity | Egg to fry (at Oakdale RST) survival greater than 18% | Year 9 |
| | Egg to fry (at Oakdale RST) survival greater than 21% | Year 15 |
| | Egg to fry (at Oakdale RST) survival greater than 35% | Year 24 |

#### *6.2.5.4.3 Adult Migration, Holding, and Redd Success Objectives*

Adult migration, holding, and redd success objectives include the following:

- At least 90% of adult migrants that pass through the weir survive to spawning
- Less than 10% of female carcasses retain 10% or more of eggs
- Chinook salmon redd viability rate of greater than 90% (as projected by monitoring of temperature, flow, and superimposition)

The rationale for and approach to objectives related to fall-run Chinook salmon adult migration, holding, and redd success are described in detail in Section 6.3.5.1. Productivity-related objectives and guidance for fall-run Chinook salmon are summarized in Table 7.

**Table 7**
**Chinook Salmon Productivity Objectives**

| Objective[1] | | Productivity[1] | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Life History Stage | | Juvenile Rebuilding | | | Juvenile Resiliency | | | Juvenile Sustainability | | | Adult and Egg | | | |
| Description | Overview | Juvenile survival rate consistent with population growth rate of 2x over three generations (CRR is 1.26) | | | Juvenile survival rate consistent with population resilience (CRR is 2.5) | | | Juvenile survival rate in freshwater typical of Chinook salmon populations across the Pacific coast (10%) | | | Survival/reproductive success of adult migrants and indicators of egg development success | | | |
| | Achieved by When? | Year 10 | | | Year 15 | | | Year 24 | | | Year 9 | Year 9 | Varies (Year 9, 15, 24; see below) | Varies (Year 9, 15, 24; see below) |
| | Measure What? | Survival from/to | Survival from/to | Survival total | Survival from/to | Survival from/to | Survival total | Survival from/to | Survival from/to | Survival total | Survival from/to | Egg viability/ deposition | Egg/redd viability | Egg-emergence survival of surrogates |
| | Measured Where? | Spawning to Caswell[2] | Caswell to Vernalis[2] | Freshwater[3] | Spawning to Caswell[2] | Caswell to Vernalis[2] | Freshwater[3] | Spawning to Caswell[2] | Caswell to Vernalis[2] | Freshwater[4] | Caswell to spawning grounds at onset of spawning[5] | Spawning grounds | Spawning grounds | Spawning grounds |
| Fall-run and Spring-run | Wet | 12% | | | 15% | | | 24.4% | | | ≥ 90% | a) In hatchery hatching success is 95%; b) < 10% of female carcasses retain ≥ 10% of eggs | a) Environmental conditions consistent with in-hatchery development success: ≥ 80% (year 9); ≥ 85% (year 15); ≥ 90% (year 24) b) ≥ 90% redds remain intact through development period | Egg to fry survival (at Oakdale RST): ≥ 18% (year 9); ≥ 21% (year 15); ≥ 35% (year 24) |
| | Median Year | 8% | 68.2% | 1.11% | 10.7% | 72.2% | 2.2% | 82% | 80.7% | 10.0% | | | | |
| | Dry | 4% | | | 7% | | | 10% | | | | | | |

Notes:

1. Juvenile productivity and life history objectives refer only to those Chinook salmon that migrate before temperatures in the mainstem San Joaquin reach 25°C (77°F).
2. Survival objectives from Spawning to Caswell are premised on attainment of Caswell to Vernalis survival rate. If median Caswell to Vernalis survival rate is unattainable or exceeded, the Spawning to Caswell survival rate objective will be adjusted accordingly.
3. For reference purposes. This includes through-Delta survival. Conditions on the San Joaquin River and its tributaries affect Delta survival; however, responsibility of San Joaquin tributaries for through-Delta survival outcomes is yet to be determined. Improvement in freshwater survival rates assumes river survival rates and Delta survival rates will improve proportionately from current levels.
4. For reference purposes. This assumes through-Delta survival of 50%. In this case, the improvement in river and Delta environments is no longer proportionate, as adherence to the proportionate improvement standard would require median survival of greater than 50% in the Delta. There was no consensus that survival rates of greater than 50% in the Delta could be achieved.
5. Currently, adult survival objectives are only developed for spring-run Chinook after they have migrated past Caswell. This reflects desired outcomes in the ability of spring-run to successfully "hold" in the river through the summer. Adult survival objectives may be developed (and potentially for fall-run Chinook and steelhead) in the mainstem San Joaquin; however, those objectives would be part of basin-wide planning and may require adult migration monitoring in the lower San Joaquin.

#### 6.2.5.5 Rationale for Timing of Migration Life History Objective

Differences in juvenile Chinook salmon size at migration and timing of migration are believed to represent different life history strategies. As discussed in Section 3.2, this "portfolio effect" of spreading risk through life history diversity is thought to maximize survival across the subsequent environments that salmon are exposed to (e.g., mainstem river, Delta, and ocean). The ideal timing of migration for any size-class is believed to be variable across years (i.e., depending on future conditions in subsequent environments). Migration of Chinook salmon of different sizes across a broad migration window will reveal that the river environment is supporting a wide range of life history types that are characteristic of healthy Chinook salmon populations. A migration timing window is necessary to ensure that river function is maintained throughout a normal migration period for fall-run Chinook salmon.

The SEP Group recognized that it would not be desirable to retain fish in the Stanislaus River beyond the time each year where temperatures in the lower San Joaquin River are unsuitable. Thus, migration timing windows may be truncated in any year when temperatures exceed a threshold temperature prior to the end of the time period specified.

#### 6.2.5.6 Methods for Timing of Migration Life History Objective

The metric for this Biological Objective is the presence (or absence) of fall-run Chinook salmon juveniles measured on a weekly basis. The timing windows reflected herein are similar to those already detected by RSTs in the Stanislaus River. For example, in 2000 (a wet year), outmigrants were detected at Caswell from 2 January to 25 June. In 2003 (a drier year), outmigrants were detected at Caswell from 23 January to 8 May. A summary of outmigrant timing data collected at the Caswell RST from 1996 to 2014 is provided in Table 8.

**Table 8**
**Start and End Dates of Migration through the Lower Stanislaus River for Three Migratory Phenotypes of Juvenile Chinook Salmon, as Detected at Caswell Rotary Screw Trap from 1996 to 2014**

| Year | Fry (Smaller than 55 mm [2.2 in] FL) | | Parr (Larger than 55 mm [2.2 in], smaller than 75 mm [3 in] FL) | | Smolt (Larger than 75 mm [3 in] FL) | |
|---|---|---|---|---|---|---|
| | Start Date | End Date | Start Date | End Date | Start Date | End Date |
| 1996 | February 1 | April 12[2] | February 16 | May 26 | February 4 | June 27 |
| 1997[1] | – | – | – | – | – | – |
| 1998 | January 3 | April 29 | February 18 | May 26 | March 6 | June 30 |
| 1999 | January 13 | June 4 | February 14 | June 13 | March 6 | June 30 |
| 2000 | January 2 | April 25 | February 4 | May 29 | March 8 | June 25 |
| 2001 | January 1 | May 13 | March 7 | June 10 | January 17 | June 17 |
| 2002 | January 11 | April 1 | February 9 | June 11 | March 1 | June 12 |
| 2003 | January 23 | April 12 | February 5 | June 2 | February 24 | June 10 |
| 2004 | January 19 | April 17 | February 26 | May 31 | February 29 | June 8 |
| 2005 | January 1 | April 12 | February 14 | June 11 | January 9 | June 21 |
| 2006[1] | – | – | – | – | – | – |
| 2007 | January 7 | May 13 | March 10 | June 24 | February 24 | June 27 |
| 2008 | January 20 | March 31 | February 29 | May 2 | March 18 | June 16 |
| 2009 | January 9 | April 3 | March 8 | May 7 | March 8 | June 2 |
| 2010 | January 11 | May 12 | March 3 | May 12 | February 9 | June 1 |
| 2011 | January 1 | May 10 | February 14 | May 2 | February 21 | June 27 |
| 2012 | January 12 | May 11 | March 12 | June 11 | March 3 | June 29 |
| 2013 | January 1 | April 19 | February 22 | June 4 | January 22 | June 4 |
| 2014 | January 4 | May 11 | January 21 | June 2 | February 17 | June 8 |

Notes:
1. These years had trap issues, and the data could not be included.
2. The range shows the first and last detection.

Sources: Cramer Fish Sciences RST database in Zeug et al. 2014; Table from Sturrock et al. 2015.
– no data

For this objective, parr and smolt migration windows were set 1 to 2 weeks earlier than is typically detected. This reflects the desire to produce faster growth rates in-river and thus the earlier appearance of larger size-classes among outmigrants. The SEP Group considered these objectives to be easily attainable, as the minimum required to demonstrate the suitability of the river corridor (for this objective) is the detection of one juvenile fish in a given size category each week.

The SEP Group recognizes that distinguishing between fall-run Chinook salmon juveniles and spring-run Chinook salmon juveniles in the field is challenging at this time. Thus, the objective will be satisfied by detection of any Chinook salmon juveniles in the specified time window, without regard to parentage. If field techniques that allow distinction between juveniles of different runs become available, the SEP Group will consider how the objective should be implemented on a run-specific basis.

### 6.2.5.7 Results: Timing of Migration Life History Objective

By year 10, in every year, migration of fall-run Chinook salmon will be detected in every week between the dates shown in Table 9, until such time that the mean daily temperature at Mossdale is greater than or equal to 25°C (77°F).

**Table 9**
**Fall-run Chinook Salmon Timing of Migration Objectives**

| Size-Class | Caswell RST | | Mossdale[1] Trawl | |
|---|---|---|---|---|
| | Start Week | End Week | Start Week | End Week |
| Fry (smaller than 55 mm [2.2 in]) | Last of January | Second of April | N/A[2] | N/A[2] |
| Parr (larger than 55 mm [2.2 in], smaller than 75 mm [3 in]) | First of February | Last of May | Second of February | First of June |
| Smolt (larger than 75 mm [3 in]) | Third of February | First of June | February | June |

Notes:
1. Tributary contribution can be assigned (e.g., by otolith analyses).
2. Mossdale Trawl does not reliably detect fish smaller than 55 mm (2.2 in).

N/A: not applicable

### 6.2.5.8 Rationale for Size at Migration Life History Objective

Juvenile Chinook salmon size at migration classes were assumed as a proxy for life history strategies. It is important to have a portfolio of such strategies to improve overall survival rates across years (Beechie et al. 2006; Miller et al. 2010; Satterthwaite et al. 2014). Currently, in wet years, the Stanislaus River produces a very large proportion of fry-sized juvenile migrants. For example, in 2000, 85% of total outmigrants at Caswell were fry-sized, with a smaller proportion of smolt-sized juveniles (5%). These smaller-sized fish likely have lower outmigration survival rates (Sturrock et al. 2015). Conversely, in dry years, such as 2003, a larger proportion of outmigrants are smolt-sized, with approximately 34% of total outmigrants at Caswell classified as smolt-sized (Table 10).

The SEP Group is concerned that smolt-sized fish may not survive a late spring migration through the lower Stanislaus River and San Joaquin River due to prohibitively warm temperatures during dry years. In wet years, a high proportion of outmigrants leave as fry, likely due to flushing flows and lack of rearing habitat (Fuller 2013, pers. comm.). A more balanced proportional representation of outmigrant size-classes across the full winter-spring migration season would allow for bet-hedging and likely result in increased survival across years.

**Table 10**

**Abundance and Proportions of Fry, Parr, and Smolt Outmigrants Sampled by Rotary Screw Traps and Timing of Migration from Stanislaus River in 2000 and 2003**

| Outmigration Cohort | Migratory Phenotype | N (95% Confidence Interval) | Proportion of 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 to 2,495,523) | 0.85 | 115 days (January 2 to April 25) | 4 days (February 14 to February 17) | February 16 |
| | Parr | 212,042 (141,238 to 310,174) | 0.1 | 116 days (February 4 to May 29) | 29 days (March 18 to April 15) | April 1 |
| | Smolt | 101,467 (70,181 to 145,793) | 0.05 | 110 days (March 8 to June 25) | 34 days (April 15 to May 18) | May 9 |
| | **Total** | **2,151,165 (1,577,638 to 2,911,393)** | | | | |
| 2003 (drier) | Fry | 79,862 (59,795 to 103,916) | 0.5 | 80 days (January 23 to April 12) | 4 days (January 27 to January 30) | January 29 |
| | Parr | 25,729 (17,889 to 36,282) | 0.16 | 118 days (February 5 to June 2) | 27 days (March 18 to April 13) | March 21 |
| | Smolt | 55,465 (38,415 to 76,289) | 0.34 | 107 days (February 24 to June 10) | 21 days (April 18 to May 8) | April 25 |
| | **Total** | **161,056 (119,868 to 209,151)** | | | | |

Source: Sturrock et al. 2015

#### 6.2.5.9 Methods for Size at Migration Life History Objective

The SEP Group recognized that prescribing specific size-class distributions was not wise or possible because size-class distributions naturally fluctuate (stochastically and with respect to environmental conditions) from year to year, and the ideal size-class distribution for conditions in any given year are unknowable in advance. On the other hand, the SEP Group believed that it was possible to identify minimum thresholds for the relative abundance of different size-classes because failure to produce these minimum distributions would indicate a failure of the river environment to support a portfolio of life history strategies.

Objectives were not prescriptive. Rather, the SEP Group asked the following question, "Below what proportion of a given size-class would we be concerned that the river was not providing adequate opportunities for the life history strategies associated with that size-class?" The Biological Objectives described below anticipate the attainment of Environmental Objectives (i.e., chemical, physical, and biological conditions) that would allow for greater in-river rearing opportunities. The ranges represent the following:

- Fry: The target is a percentage of the range currently observed across year types, scaled to accommodate an increase in the percentage of parr and smolt size outmigrants while still resulting in a total of well below 100% across all size-classes (Sturrock and Johnson 2016, pers. comm.).
- Parr: The target for wetter years is approximately double the proportion of parr that is currently observed in wetter years (Sturrock and Johnson 2016, pers. comm.). The target for drier years is approximately 1.5 times the proportion currently observed during drier years. The intent is to set a reasonable target for improved growth and rearing.
- Smolt: The target for wetter years is approximately double the proportion of smolt migrants currently observed in wetter years. The target for drier years is currently attained.

The SEP Group included a temperature off-ramp for measuring the proportional production of each of these size-classes to account for the low likelihood of survival for fish entering the lower San Joaquin River when temperatures exceeded a critical threshold.

#### 6.2.5.10 Results: Size at Migration Life History Objective

By year 12, annual emigrant size-class distribution as measured at Caswell RST (includes only juveniles that migrate before daily mean temperatures exceed 25°C (77°F) at Mossdale) are detailed in Table 11.

**Table 11**
**Fall-run Chinook Salmon Size at Migration Objectives**

| Size-Class | Wetter Years | Drier Years |
|---|---|---|
| Fry (smaller than 55 mm [2.2 in]) | 20% minimum | 20% minimum |
| Parr (larger than 55 mm [2.2 in], smaller than 75 mm [3 in]) | 20% minimum | 30% minimum |
| Smolt[1] (larger than 75 mm [3 in]) | 10% minimum | 20% minimum |

Notes:
Initial estimates of size-class distribution are based on Sturrock et al. (2015).
1. Includes only juveniles that migrate before daily mean temperatures greater than 25°C (77°F) at Mossdale

Size distribution of migrants will be measured on an annual basis, but can also serve to guide management within each year (e.g., approach of the 25°C [77°F] temperature threshold can be used as a trigger to stimulate migration earlier during dry years).

Table 12 summarizes life history diversity objectives for fall-run Chinook salmon.

**Table 12**
**Chinook Salmon Biological Objectives – Life History Diversity Objectives**

| Objective | | Life History Diversity (Migration Timing)[1] | | | | Life History Diversity (Age-Class Distribution Minima)[1] | |
|---|---|---|---|---|---|---|---|
| Description | Overview | Support range of juvenile migration dates to maintain life history diversity | | | | Support range of sizes at juvenile migration dates to maintain life history diversity | |
| Description | Achieved by When? | Year 10 | Year 10 | Year 10 | Year 10 | Year 12 | Year 12 |
| Description | Measure What? | Detection every week no later than… | Detection every week through at least… | Detection every week no later than… | Detection every week through at least… | Minimum % juvenile migrants annually (wetter years) | Minimum % juvenile migrants annually (drier years) |
| Description | Measured Where? | Caswell RST | Caswell RST | Mossdale Trawl | Mossdale Trawl | Caswell RST | Caswell RST |
| Fall-run | Fry | Last week of January | Second week of April | N/A | N/A | 20% | 20% |
| Fall-run | Parr | First week of February | Last week of May | Second week of February | First week of June | 20% | 30% |
| Fall-run | Smolt | Third week of February | First week of June | Last week of February | Second week of June | 10% | 20% |
| Spring-run | Fry | First week of January | Second week of April | TBD | TBD | 20% | 20% |
| Spring-run | Parr | | | | | 20% | 30% |
| Spring-run | Smolt | | | | | 10% | 20% |
| Spring-run | Yearling [2] | Detection in ≥ 50% weeks October to January | Detection in ≥ 50% weeks February to April | TBD | TBD | ≥ 1.5 yearlings per 1,000 female spawners | |

Notes:

1. Juvenile productivity and life history objectives refer only to those fish that migrate before temperatures in the mainstem San Joaquin reach 25°C (77°F).
2. The yearling life history strategy is associated with spring-running adults (fall-run adults may produce yearlings as well, but it is considered to be extremely rare). Production of some yearlings is expected whenever spring-run Chinook reproduce successfully; however, detection of yearlings is only required when sufficient numbers of spring-run salmon reproduce.

TBD: to be determined

### 6.2.5.11 Rationale for Genetic Objective

The primary genetic concern for fall-run Chinook salmon in the Stanislaus River is the influence of hatchery-produced fish on the fitness of the local stock and introgression with spring-run Chinook salmon. Artificial propagation of salmon in hatcheries has long played a role in meeting harvest and conservation goals for salmon and steelhead in California. The life history diversity and productivity objectives described in Sections 6.2.5.4 and 6.2.5.7 will only be achieved if managers can ensure little or no deleterious consequences to natural populations from hatchery-origin fish. It is necessary to achieve a low level of extinction risk for fall-run Chinook salmon, and part of attaining that acceptable level of risk relates to implementing hatchery best management practices.

Current escapement to the Stanislaus River reflects a very high proportion of hatchery fish produced in other river systems. In 2007, CDFW began marking and tagging a constant fraction (25%) of hatchery production (Constant Fractional Marking Program in Kormos et al. 2012 and Palmer-Zwahlen and Kormos 2013). Escapement in years 2010 and 2011 were the first 2 years where juveniles from this marking effort returned as 2-, 3-, and 4-year-olds to spawn in freshwater habitats as adults. Approximately 50% and 83% of the adults that returned in 2010 and 2011, respectively, were strays from hatcheries and were not produced from parents who spawned successfully in the Stanislaus River (Kormos et al. 2012; Palmer-Zwalen and Kormos 2013). The majority of the strays were fish that were trucked and released into net-pens in the Estuary (Kormos et al. 2012; Palmer-Zwalen and Kormos 2013). Releases of juveniles in-river versus out-of-basin have been found to have a significant effect on the likelihood that adults will stray to non-natal rivers (Kormos et al. 2012; Palmer-Zwalen and Kormos 2013).

The rationale for establishing a fall-run Chinook salmon Biological Objective related to minimizing introgression with spring-run Chinook salmon mirrors the approach described for the spring-run Chinook salmon Biological Objectives (Section 6.3).

### 6.2.5.12 Methods for the Genetic Objective

#### *6.2.5.12.1 Hatchery Influence*

The science of hatcheries focuses on several key management concepts that, if implemented, would make a greater contribution to harvest than the existing natural habitat can sustain on its own (HSRG 2014). For integrated hatcheries, one key element is managing hatchery- and natural-origin fish as two components of a single gene pool that is locally adapted to the natural habitat. The SEP Group relied on existing literature regarding targets for minimizing hatchery influence in the Central Valley in order to identify objectives for the maximum level of hatchery influence on the Stanislaus River. The SEP Group acknowledged that hatchery impacts are a regional concern and must be managed throughout the San Joaquin River basin and beyond. Still, an important component of minimizing hatchery influence relates to conditions on the target stream and the health of its natural spawning populations.

#### *6.2.5.12.2 Introgression*

The approach for establishing a fall-run Chinook salmon Biological Objective related to minimizing introgression with spring-run Chinook salmon mirrors the approach described for spring-run Chinook salmon in Section 6.3.

### 6.2.5.13 Results: Genetic Objectives

Benchmark metrics have been established based on genetic models to reduce the proportion of hatchery-origin spawners to less than 20% of adult spawners. Therefore, the genetic objective for fall-run Chinook salmon is to achieve a spawning population that consists of greater than 80% Stanislaus River-produced fish by year 9 of plan implementation (Table 13). In addition, at any time that spring-running Chinook salmon adults are in the river, conditions in the Stanislaus River will support fall-run Chinook salmon spawning success in a way that reinforces long-term genetic integrity as measured by greater than 98% of fall-run Chinook salmon spawning with other fall-run Chinook salmon.

**Table 13**
**Genetic Objectives**

| Objective | | Genetic | |
|---|---|---|---|
| Life History Stage | | Adult | Egg/Juvenile |
| Description | Overview | Maintain wild run genetic integrity | |
| | Achieved by When? | Year 9 | Whenever spring-running fish are present |
| | Measure What? | Percentage hatchery-origin spawners | Introgression |
| | Measured Where? | Spawning grounds | Spawning grounds |
| Fall-run | Wet | Proportion of hatchery-origin spawners < 20% of spawners | < 2% hatchery influence |
| | Median Year | | |
| | Dry | | |
| Spring-run | Wet | N/A | < 2% inter-run mating |
| | Median Year | | |
| | Dry | | |

## 6.3 Spring-run Chinook Salmon

### *6.3.1 What is the Problem?*

Central Valley spring-run Chinook salmon populations are listed under state and federal ESAs for the following reasons:

- Natural production is well below acceptable levels.
- Survival rates are inadequate to achieve population growth and maintain population resilience.
- Spatial extent is extremely constrained relative to historic conditions.
- Populations express only a narrow range of the life history variants that are typical of this species.
- Introgression with fall-run Chinook salmon populations threatens to homogenize this distinct gene pool as well as compound the other problems.

Spring-run Chinook salmon populations throughout the Central Valley are extremely constrained with regard to all viability criteria (Yoshiyama et al. 2001; Lindley et al. 2007; NMFS 2014). These problems are most evident in the San Joaquin River basin, where spring-run Chinook salmon were extirpated following the construction of impassable dams in the middle 20th century. The spring-run was historically the most abundant run of Chinook salmon in the San Joaquin River basin and was among the largest runs along the Pacific Coast (Fry 1961; CDFG 1972, 1990; Yoshiyama et al. 2001). Prior to major dam construction in the middle 20th century, spring-run was the dominant Chinook salmon population in the Stanislaus River (CDFG 1972). Until recently, spring-run Chinook salmon were considered to be extirpated from all waterways in the San Joaquin River basin. There have been manual spring-run Chinook salmon reintroduction efforts on the San Joaquin mainstem below Friant Dam as part of the SJRRP. There is growing recognition that spring-running Chinook salmon adults have been observed in San Joaquin tributaries in recent years (Franks 2012); however, the origin of these fish is unknown.

Throughout the Central Valley, genetic threats to spring-run Chinook salmon include introgression with fall-run Chinook salmon (CDFG 1998; Banks et al. 2000) wherever these two populations are forced to spawn in the same habitat (because dams block passage into the higher elevation habitats historically utilized by spring-run). Genetic introgression with fall-run Chinook salmon is a threat to the unique morphological, behavioral, and life historical phenotypes and genotypic distributions that make spring-run Chinook salmon distinctive (Smith et al. 1995; CDFG 1998; Banks et al. 2000). Thus, maintaining opportunities for temporal and spatial isolation of spawning between fall-run and spring-run Chinook salmon is a challenge that efforts to restore spring-run Chinook salmon to the San Joaquin River basin need to address.

### 6.3.2 What Outcome(s) (Central Valley Goals) will Solve the Problem?

**Abundance**

Increasing abundance of Central Valley spring-run Chinook salmon is a goal documented by Hanson (2007, 2008), NMFS (2014), USFWS (2001), and Section 3406 of the CVPIA (Title 34 of Public Law 102-575). These plans stem from different laws (or legal settlements) and take different approaches to restoration; for example, they cover different geographies within the Central Valley and address conceptually different standards for population restoration. As a result, there are multiple restoration goals for abundance of spring-run Chinook salmon in the Central Valley and San Joaquin River basin. However, no single goal applies across the Central Valley except for the narrative goal described in F&G Code § 5937, which states that dam operators must maintain fish populations "in good condition." This requirement has not been specifically defined for individual rivers. Thus, the SEP Group worked from the clear intent of existing policies to restore spring-run Chinook salmon in rivers throughout the Central Valley that they historically occupied, and they identified goals and defined objectives that would satisfy that intent in the San Joaquin River basin from a biological perspective.

**Productivity and Life History Diversity**

Improvements in spring-run Chinook salmon productivity (measured as juvenile survival and adult migration and holding success in freshwater) and increased life history diversity (i.e., size at and timing of juvenile migration) are necessary for the following:

- Achieve abundance targets for spring-run Chinook salmon in the Central Valley (CVPIA/AFRP).
- Maintain fish "in good condition" (F&G Code § 5937).
- Attain acceptable levels of the criteria NMFS uses to evaluate salmonid population viability (McElhany et al. 2000; NMFS 2014).
- Be consistent with other fisheries-related and water management-related policies.

No specific goal statements for these attributes have been defined, so the SEP Group worked to define Plan Goals for spring-run Chinook salmon that were appropriate to the geographic and policy scope of this effort.

**Spatial Diversity**

The NMFS (2014) Recovery Plan for Central Valley salmonids specifies that spring-run Chinook salmon populations will be restored to the Southern Sierra Diversity Group (i.e., the San Joaquin River basin) such that "two populations [are] at low risk of extinction" and "multiple populations at [are maintained at no worse than] a moderate risk of extinction." Restoration of spring-run abundance, productivity, and life history diversity to the San Joaquin River tributaries and mainstem will serve to improve the spatial diversity of this distinct run throughout the Central Valley.

**Genetic Diversity**

Eliminating genetic introgression with fall-run Chinook salmon or reducing it to a very low level is a major goal for the maintenance and restoration of spring-run Chinook salmon in the Central Valley (Lindley et al. 2007; HSRG 2014). Thus, providing opportunities for spring-run reproductive isolation is particularly important for the maintenance of spring-run populations in rivers where high elevation habitat is blocked by dams.

### *6.3.3 What Does Solving the Problem Look Like (Central Valley Objectives)?*

**Abundance**

Understanding the Central Valley Objectives for abundance of Stanislaus River spring-run Chinook salmon provides valuable context for determining what the Stanislaus River can contribute to restoring spring-run Chinook salmon in the Central Valley as a whole. Furthermore, Central Valley Objectives for spring-run Chinook salmon are essential to determining Environmental Objectives (i.e., physical, chemical, and biological conditions necessary to support juvenile rearing) for the Stanislaus River that will support attainment of the Watershed-Specific Goal (increasing abundance of spring-run Chinook salmon on the Stanislaus River) and goals and objectives in the larger context of the Central Valley.

The CVPIA (Section 3406 of the CVPIA, Title 34 of Public Law 102-575) calls for naturally spawning populations of anadromous fish that are double the 1967 to 1991 baseline within 10 years. The AFRP identifies Central Valley production targets for spring-run Chinook salmon, but it does not provide specific targets for spring-run production from San Joaquin River tributaries as it does for fall-run (USFWS 2001). This is likely because spring-run Chinook salmon were not detected in the San Joaquin River basin at the time when the CVPIA was passed in 1992 or when the AFRP was finalized in 2001. Still, spring-run Chinook salmon produced naturally on the Stanislaus River would contribute to the CVPIA and AFRP objectives for total natural production of spring-run Chinook salmon in the Central Valley.

The NMFS Recovery Plan (NMFS 2014) identifies the level of spring-run Chinook salmon abundance that is sufficient to achieve the narrow outcome of "recovery," which in the ESA context means delisting this population. The Central Valley goal particular to the San Joaquin River basin states that there must be at least two populations at low risk of extinction in the Southern Sierra Diversity Group. For a population to have a "low risk" of extinction, NMFS (2014) specifies, among other things, that it must achieve a census population size of at least 2,500 individuals. Spread over a 3-year generation length, this translates to a 3-year running average population of approximately 833 returning adults.

The SEP Group determined that delisting spring-run Chinook salmon, per the NMFS (2014) Recovery Plan, would represent only a preliminary step to fully restoring spring-run Chinook salmon to the San Joaquin River basin and Stanislaus River. In other words, the SEP Group's view was that delisting was a preliminary desired outcome, but this outcome would not satisfy other Central Valley-wide policies regarding spring-run Chinook salmon (e.g., CVPIA, F&G Code § 5937).

Historically, the Stanislaus River's spring-run Chinook salmon population was larger than its fall-run population (CDFG 1972; Yoshiyama et al. 2001), and the SEP Group found no biological reason to expect that the spring-run population would be only a small fraction of the fall-run Chinook salmon population in the future following restoration of the river. A Stanislaus River population of 833 returning spring-run spawners per year would be less than 10% of the escapement of approximately 13,225 fish that is implied by the Central Valley Objective for Stanislaus River fall-run Chinook salmon (assuming current harvest rates; Table 1). In addition, the SEP Group found no biological reason to expect that the Stanislaus River would not be capable of supporting as many spring-run or total Chinook salmon as the restored San Joaquin mainstem below Friant Dam. The SJRRP has a target of restoring 30,000 spring-run Chinook salmon and 10,000 fall-run Chinook salmon to the mainstem below Friant Dam (Hanson 2007, 2008). Finally, the SEP Group noted that observed annual escapement to Butte Creek (a tributary to the Sacramento River that is much smaller than the Stanislaus River) has exceeded 10,000 spring-run Chinook salmon in more than half the years since carcass surveys began in 2001 (CDFW 2018). As a result of these considerations, the SEP Group determined that the Central Valley Objective for the natural production of Stanislaus River spring-run Chinook salmon roughly equals the Central Valley Objective for natural production of Stanislaus River fall-run Chinook salmon, which is the natural production in the ocean of 22,000 2-year-old salmon per year on average. The SEP Group believes this Central Valley Objective for the Stanislaus River may be conservative.

**Spatial Diversity**

NMFS (2014) calls for multiple populations in the San Joaquin River basin to be established. At least two of these populations must be at "low risk" of extinction, and others must be at no greater than "moderate risk" of extinction NMFS (2014).

**Productivity**

The SEP Group determined that Central Valley Objectives for productivity of spring-run Chinook salmon (young-of-the-year [YOY] juveniles and adults) are identical to those for fall-run Chinook salmon. The AFRP (USFWS 2001) and CVPIA provide guidance regarding the desired rate of population growth for anadromous fish populations in the Central Valley as a whole. The CVPIA is clear that anadromous fish populations in the Central Valley are expected to double from a baseline within 10 years. Furthermore, the CVPIA and AFRP imply that populations should be resilient such that periodic years of low production (due to any cause) do not constrain a population’s ability to reattain any abundance targets in the following generation. In addition, restoration of a spring-run Chinook salmon population to a state where it is “in good condition” (per F&G Code § 5937) was taken to mean that spring-run Chinook salmon below dams in the Central Valley should display survival rates that support population growth rates typical of this species throughout its range. The SEP Group also looked to other viable populations of Chinook salmon to gauge freshwater survival rates that would characterize a restored Chinook salmon population in the Stanislaus River.

Spring-run Chinook salmon are different from fall-run Chinook salmon in that they return to freshwater several months before they spawn. They wait in freshwater, without feeding, throughout the summer in a process known as “holding.” This protracted period of freshwater residence exposes spring-run Chinook salmon adults to additional mortality in freshwater if environmental conditions are not adequate. Maintenance of the unique life history strategy of spring-run Chinook salmon requires protection of all phases of their life cycle, especially the holding period.

**Life History Diversity**

Spring-run Chinook salmon are noted for producing a yearling life history variant. Yearling juveniles spend up to a full year in rivers before migrating to the ocean (Moyle 2002; Williams 2006). No policies speak directly to Central Valley-wide Objectives for necessary improvements in the life history diversity of spring-run Chinook salmon. However, there is increasing evidence that life history strategies of spring-run Chinook salmon are constrained in the Stanislaus River, and improvements will be necessary to attain Central Valley Goals for this population. There is evidence of yearling juvenile salmon that are likely not sub-yearling progeny of fall-run Chinook salmon and may represent the yearling life history strategy (Figure 7). From 1996 to 2013, 49 yearlings (visually defined) were detected prior to May 1 at the Caswell RST (Zeug et al. 2014; Cramer Fish Sciences 2013, unpublished data).

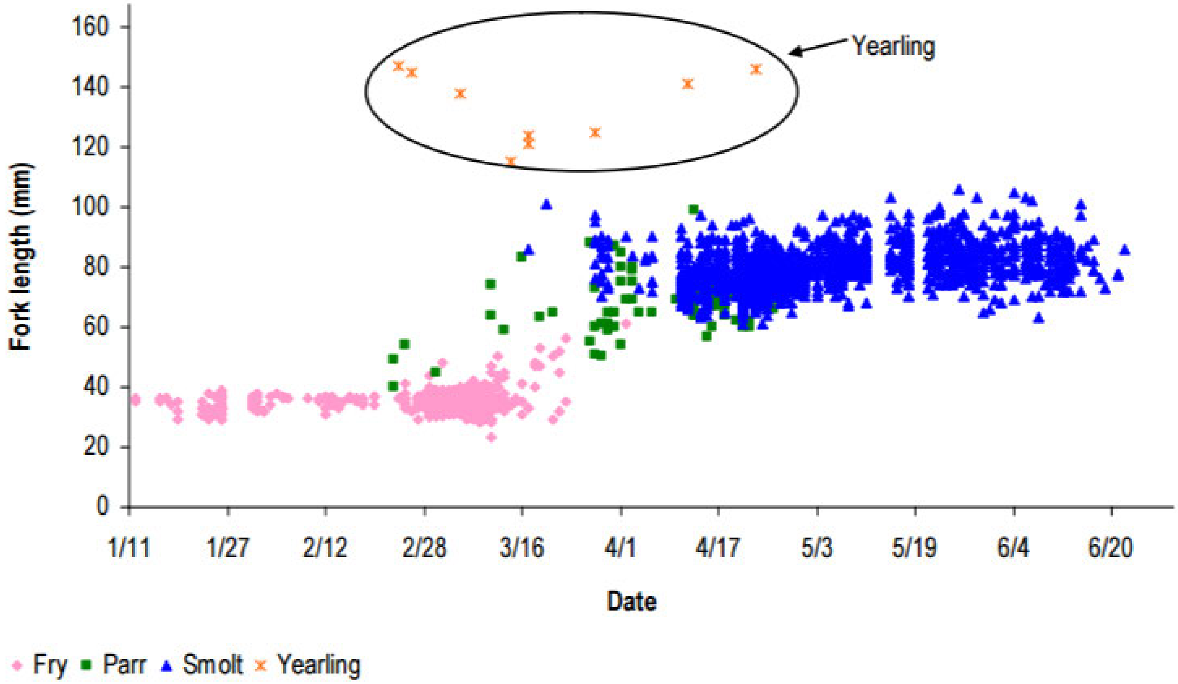



**Figure 7**
**Estimates of Natural- and Hatchery-Produced Fish Contributions to Stanislaus River Spawning Population**

Source: Watry et al. 2007.

#### Genetic Diversity

Specific gene-flow criteria (less than 2% introgression) between ESUs have been proposed to achieve long-term genetic integrity and maintain a low extinction risk for natural populations in the Central Valley (Lindley et al. 2007; HSRG 2014).

### *6.3.4 How Will this Effort Contribute to Attainment of these Central Valley Objectives (Watershed-Specific Goals)?*

The scope of the SEP Group's current effort is the Stanislaus River through the lower San Joaquin River to the Delta. Specific goals and objectives for the Stanislaus and lower San Joaquin rivers were developed to support the system-wide goals identified in Section 6.2.

#### Abundance

Establishing a self-sustaining population of spring-run Chinook salmon on the Stanislaus River is a Watershed-Specific Goal that will advance Central Valley Goals and Objectives, including delisting this species and achieving CVPIA production targets. No specific abundance target for spring-run Chinook salmon on the Stanislaus River accompanies this goal. Attainment of a Central Valley abundance objective for any river requires adequate conditions throughout the fish's life cycle. Abiotic and biotic conditions in the Stanislaus River and lower San Joaquin River must support, but may not be sufficient to result in, attainment of this objective, depending on conditions in the Delta and ocean. Thus, increased abundance is a Watershed-Specific Goal, but no specific abundance target was established as a Biological Objective for spring-run Chinook salmon in the Stanislaus River.

As with other anadromous populations in the SEP's scope, the SEP Group used Central Valley Objectives for abundance as the context for defining Watershed-Specific Goals and Environmental Objectives for the Stanislaus River. Specifically, to appropriately scale Environmental Objectives for the river, it was assumed that natural production of spring-run Chinook salmon from the Stanislaus River would be roughly equivalent to the Central Valley Objective for fall-run Chinook salmon (i.e., 22,000 fish per year on average). The adult returns (escapement) that would result from this level of ocean production of spring-run Chinook salmon depends on assumptions regarding ocean and in-river harvest targets. Such targets are zero currently because the spring-run Chinook salmon is threatened. However, commercial and recreational fisheries may be restored as spring-run populations are restored across the Central Valley.

**Spatial Diversity**

The Stanislaus River watershed is believed to be amongst the most likely candidates in the Southern Sierra Diversity Group to support a population of spring-run Chinook salmon at low risk of extinction, given the current habitat available below dams. As a result of the geographic limits set by this scope, Watershed-Specific Goals and Biological Objectives were not required for the spatial diversity of spring-run Chinook salmon. The SEP Group's focus on restoring spring-run abundance, life history diversity, productivity, and genetic integrity to the Stanislaus River satisfies, in part, the spatial diversity objectives in the Central Valley.

**Productivity**

Central Valley Goals and Objectives were used to guide development of Plan Goals for productivity (freshwater survival rates). The goals for spring-run Chinook salmon productivity track those for fall-run Chinook salmon. The goals are to be implemented in phases and become progressively more protective over time to achieve freshwater survival rates sufficient to generate the following results:

- Rebuilding: Achieve a population growth rate that supports increasing populations in a relatively short time (i.e., doubling the population in three generations).
- Resilience: Achieve a population growth rate that allows the population to rebound after years with poor returns (i.e., increasing the population up to 2.5-fold in one generation).

- Sustainability: Achieve freshwater survival rates that are characteristic of salmon in human-modified rivers on the West Coast of North America (i.e., outmigrating smolt represent at least 10% survival from eggs to smolt).

The SEP Group acknowledges that it would be extremely difficult or impossible to achieve freshwater survival targets without improvement in the river and Delta environments. Thus, necessary improvements in overall freshwater survival were distributed across riverine and estuarine habitats.

**Life History Diversity**

Life history diversity must be maintained to allow for Chinook salmon populations to respond to varying climatic, hydrologic, and ocean conditions over time (Beechie et al. 2006; Miller et al. 2010; Spence and Hall 2010; Satterthwaite et al. 2014). The Watershed-Specific Goal for spring-run Chinook salmon life history diversity is to support the fullest expression of spring-run Chinook salmon life history diversity (as seen in other Central Valley populations and in other rivers that support this phenotype). In particular, a goal for spring-run population restoration in the Stanislaus River is to achieve measurable production of yearling juveniles, a life history type that is the hallmark of stream-type Chinook salmon such as the spring-run. Attaining the fullest expression will result in increased population stability, resilience, and productivity.

**Genetic Diversity**

The SEP Group's intent is to create conditions that support restoration of a self-sustaining spring-run phenotype that contributes to the overall diversity, productivity, abundance, and resilience of Chinook salmon populations in the San Joaquin River basin and the Central Valley as a whole. The SEP Group adopted a Watershed-Specific Goal for genetic diversity to mirror the Central Valley Goal: maintain genetic integrity of wild spring-run Chinook salmon by minimizing genetic introgression with fall-run Chinook salmon.

Establishing and maintaining such a distinct population requires that gene flow between distinct life history types be limited. It also requires that Environmental Objectives support the spring-running phenotype at all life history stages.

### *6.3.5 What Suite of Species-Specific Outcomes (Biological Objectives) Characterize Success?*

In many cases, Biological Objectives for spring-run Chinook salmon in the Stanislaus River are identical to those the SEP Group adopted for fall-run Chinook salmon on the Stanislaus River. For large portions of their life cycle, spring-run and fall-run Chinook salmon from the same river are exposed to similar or identical conditions. Therefore, juvenile survival and somatic growth rates, YOY size distribution, and timing of juvenile migration for spring-run and fall-run Chinook salmon are expected to overlap (Yoshiyama et al. 1998; Moyle 2002; Williams 2006). Furthermore, it is not currently possible to distinguish definitively between juvenile fall-run and spring-run Chinook salmon in the field; monitoring for differences between these populations' vital rates would be difficult.

Substantial differences between spring-run and fall-run Chinook salmon are apparent in their upstream migration timing, the protracted delay between migration and spawning ("holding") that spring-run display, and the production of a small but measurable fraction of yearling migrants by spring-run Chinook adults (Figures 7 and 8). These differences in behavior and life history lead to variances in the environmental conditions that are needed to support spring-run and fall-run Chinook salmon.

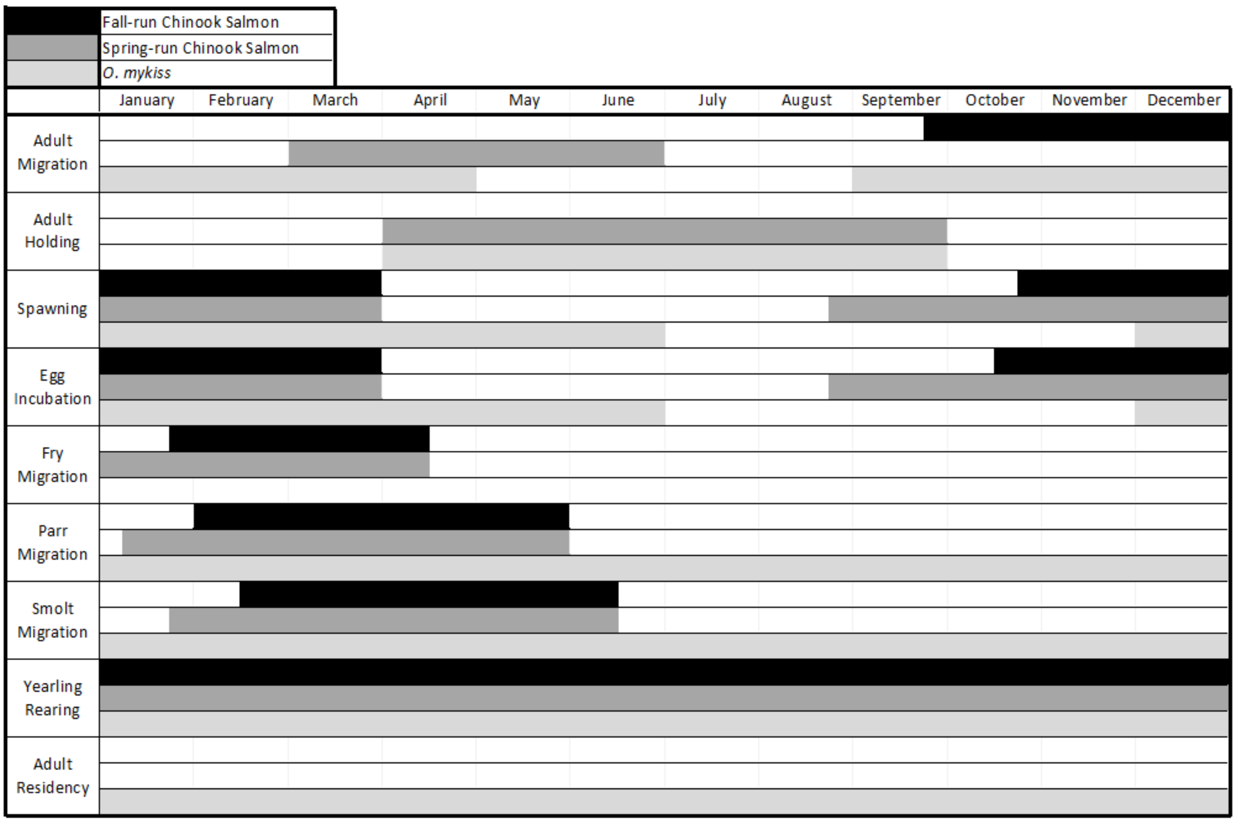



**Figure 8**
**Timeline for Chinook Salmon and *O. mykiss* Migration and Rearing Periods in the San Joaquin River Basin**

### 6.3.5.1 Rationale for Productivity Objectives

The Watershed-Specific Goals for productivity (survival) of juvenile spring-run Chinook salmon are the same as those set for fall-run Chinook salmon. Although it is possible to distinguish spring-run Chinook salmon from fall-run Chinook salmon (using genetic and/or otolith markers), the SEP Group considered it impractical to measure differences in the survival rate of spring-run and fall-run Chinook salmon juveniles. The SEP Group found no reason to expect different juvenile survival rates among YOY spring-run Chinook salmon juveniles than those identified for fall-run Chinook salmon in the Stanislaus River. Because juvenile per spawner productivity objectives are the same for fall-run and spring-run Chinook salmon, total juvenile production expected at Caswell in any year should reflect the total number of Chinook salmon adults returning in the prior year. The proportional mix between spring-run and fall-run spawners will not affect the juvenile production objective. Similar to fall-run Chinook salmon, should productivity objectives not be met, monitoring for the attainment of egg productivity targets and adult productivity objectives will facilitate the identification of the phase(s) of the life cycle in which problems occur (e.g., pre-spawning mortality or egg viability impacts vs. egg development impacts).

Spring-run Chinook salmon juvenile productivity might differ from fall-run Chinook salmon productivity if the production of the yearling life history phenotype far exceeds the objectives for this life history type, making it a larger proportion of outmigrants than observed in other rivers. This outcome is explicitly addressed within the objectives for yearling production, as the objective for yearling production includes a specific conversion between yearlings and YOY migrants such that overall egg to outmigrant survival can be evaluated fairly.

The same freshwater survival rates for spring-run Chinook salmon and fall-run Chinook salmon will generate different population growth rates if ocean mortality for spring-run is different than that assumed (based on recent data) for fall-run Chinook salmon from the Stanislaus River. The assumption that spring-run ocean mortality will ultimately be similar to current fall-run ocean mortality cannot be addressed at this stage because it is not known how fishing regulations will change to reflect restoration of spring-run Chinook salmon, and there is some amount of spring-run Chinook salmon bycatch in the current fishery. If ocean mortality rates for spring-run Chinook salmon remain different from those for fall-run Chinook salmon, productivity objectives for year 10 (rebuilding) and year 15 (resilience) may be modified accordingly.[7]

The SEP Group designed targets for adult holding success and redd persistence that apply to fall-run and spring-run Chinook salmon. These objectives are described in the context of spring-run Chinook salmon because, unlike fall-run Chinook salmon, spring-run Chinook salmon experience a prolonged period of holding between their arrival in the river and the onset of spawning. It is during this period that spring-run Chinook salmon complete gametogenesis. The amount of time spent holding by fall-run Chinook salmon is generally much less than for spring-run. Yet, there is frequently a holding period between the end of migration and onset of spawning, and the objectives described in this

[7] The third productivity objective (sustainability) is not influenced by ocean survival rates.

report provide necessary context for evaluating and improving conditions during fall-run adult migration (the life history stage in which this run completes gametogenesis).

Survival and success rates of Chinook salmon during holding periods can strongly influence overall population productivity—having survived through so many other phases of the life cycle, holding fish are extremely valuable from a population dynamics point of view. Holding and redd persistence objectives support the goals of restoring the unique behavioral phenotype of spring-run Chinook salmon and improving productivity for fall-run and spring-run Chinook salmon.

#### 6.3.5.2 Methods for Productivity Objectives

##### *6.3.5.2.1 Juvenile Productivity*

Specific calculations and assumptions regarding the Biological Objectives for juvenile survival of spring-run Chinook salmon and for guidance regarding egg productivity targets are described in Section 6.2.5.2 for fall-run Chinook salmon productivity objectives. Because the survival objectives for spring-run and fall-run juvenile Chinook salmon are the same, the total number of Chinook salmon spawners (fall and spring) in a given year results in a minimum number of juvenile Chinook salmon outmigrants (fall and spring) at Caswell and Mossdale in the following year. This total will not vary based on the ratio of spring-run to fall-run Chinook salmon spawners.

In addition to the YOY size-classes identified for fall-run Chinook salmon, the SEP Group expects that the existence of spring-run Chinook salmon spawning adults will correspond to production and detection of yearling outmigrants (Moyle 2002; Williams 2006). If yearling production rates or the ratio of spring-run to fall-run Chinook salmon adults is low, the total number of juveniles produced by the Chinook salmon spawning class should not be affected by this investment in the yearling life history strategy because yearlings will be a very small fraction of the total outmigrants resulting from any year-class of eggs. However, investment in yearlings may affect the total number of juveniles expected under the following conditions:

- Yearling production is much higher than the minimum specified in the life history size-class distribution objective, suggesting a substantial fraction of spring-run egg production is directed toward a yearling strategy and not a YOY strategy.
- Spring-run populations are a substantial fraction (greater than 33%) of the total spawning population such that spring-run Chinook salmon investment in a yearling life history strategy affects overall productivity estimates.

Under these conditions, the productivity objectives would credit the previous year's production of YOY juveniles as though three smolts had been produced in year "y" for each yearling-sized fish produced in year "y+1." This is based on expectations that the ratio of survival of smolt-sized spring-run Chinook salmon to yearling-sized fish would be approximately 33% (i.e., one yearling survives for every three smolt-sized fish that attempt a yearling strategy). The basis for this conversion is that a 50% overwintering mortality is commonly assumed for fall-run Chinook salmon fingerlings (Mullan 1990). Because spring-run Chinook salmon YOY juveniles would need to survive through summer months before emigrating as the following year's yearlings, the SEP Group assumed that additional mortality would occur. Therefore, the SEP Group increased the expected mortality of spring-run Chinook salmon YOY to the yearling life history stage to 66%.

##### *6.3.5.2.2 Adult Productivity*

In order to support the life history strategy of the spring-run phenotype and the productivity of this run, the majority of adult spring-run Chinook salmon that migrate into the Stanislaus River must survive until spawning commences. There is no reason to expect significant mortality of either spring-run or fall-run adult migrants in the river if there is suitable habitat (i.e., cover, temperature, DO) in which they can hold. Furthermore, holding spring-run (and migrating fall-run adult) females should experience conditions that facilitate spawning success; post-spawning egg retention should be low. Finally, the SEP Group expects that a very high proportion of redds constructed by spring-run migrants and by adult fall-run migrants will experience favorable growth conditions throughout the development period. Redd persistence will be indicated when redds are not superimposed on other redds; dewatered, scoured, or otherwise heavily disturbed; and when redds experience water quality conditions that are conducive to egg development and fry emergence. Attaining these objectives will require sufficient summer holding habitat for returning spring-run Chinook salmon adults as well as adequate spawning habitat for spring-run that can be isolated (temporally or physically or by temperature or flow conditions) from spawning fall-run Chinook salmon.

#### 6.3.5.3 Results: Productivity Objectives

##### *6.3.5.3.1 Juvenile Productivity Objectives*

Juvenile productivity objectives include the following:

- Rebuilding: Median eggs to Caswell survival greater than 8%
- Resilience: Median eggs to Caswell survival greater than 10.7%
- Sustainability: Median eggs to Caswell survival equal to 24.4%

Section 6.2.5.3 provides a more in-depth description of juvenile productivity objectives and supplemental guidance to support egg development success in the Stanislaus River.

##### *6.3.5.3.2 Adult Holding and Redd Success Objectives*

Adult holding and redd success objectives include the following for spring-run Chinook salmon:

- At least 90% of adult migrants that pass the weir through survive to spawning.
- Less than 10% of female carcasses retain 10% or more of eggs.

- The Chinook salmon redd viability rate is greater than 90% (as projected by monitoring of temperature, flow, and superimposition).

Spring-run Chinook salmon productivity Biological Objectives are summarized in Table 7.

#### 6.3.5.4 Rationale for Timing of Migration Life History Objective

The Watershed-Specific Goal is to support the fullest expression of spring-run Chinook salmon life history diversity in order to increase population stability, resilience, and productivity.

Size at date of migration was used as a proxy for the life history strategy. An objective that specifies a window for juvenile migration is necessary to ensure that river function is maintained during a normal migration period. Allowing for spring-run Chinook salmon migration throughout a broad migration window is intended to expose some spring-run Chinook salmon juveniles to supportive migration conditions (throughout their life cycle) whenever those supportive conditions occur (timing that is expected to vary unpredictably with the timing of hydrological, estuarine, and marine conditions across years).

#### 6.3.5.5 Methods for Timing of Migration Life History Objective

In other Central Valley watersheds where they co-occur, spring-run Chinook salmon spawning begins approximately 1 month (or more) earlier than fall-run Chinook salmon (Yoshiyama et al. 1998; Moyle 2002). Thus, the detection of migrating fry-sized spring-run Chinook salmon juveniles at least 3 weeks earlier than fall-run fry should be easily attained in a healthy river.

The migration timeframe for yearling-sized fish was based on yearling emigration data from Mill, Deer, and Butte creeks (Figure 25 of Lindley et al. 2004). The SEP Group investigated migration timing patterns in Sacramento River tributaries and determined that, among watersheds and across years, yearling emigration primarily occurred during a migration period that lasted weeks or months rather than during single, short-duration pulses that were more common for fry (Lindley et al. 2004; Ward et al. 2004; McReynolds et al. 2006, 2007; Garmin and McReynolds 2008, 2009). Collectively, these studies suggest that yearlings emigrate over a broader timeframe than fry.

The SEP Group recognizes that distinguishing between fall- and spring-run Chinook salmon juveniles in the field is challenging at this time. Thus, these life history objectives will be satisfied by detection of appropriately sized Chinook salmon juveniles, without regard to parentage, in the specified time window. If field techniques that allow distinction between juveniles of different runs become available, the SEP Group will consider how the objective should be implemented on a run-specific basis.

#### 6.3.5.6 Results: Timing of Migration Life History Objective

By year 15 of plan implementation, Chinook salmon monitoring will detect, in every year, migration of spring-run Chinook salmon juveniles as shown in Table 14.

**Table 14**
**Spring-run Chinook Salmon Timing of Migration Objectives at Caswell Rotary Screw Trap**

| Size/Life History Type | Frequency | Start | Fall-Run Start | End (Both Runs) |
|---|---|---|---|---|
| Yearling (to be measured two calendar years following parent cohort return [escapement]) | a) Detection in at least 50% of weeks between the second week of October to January, and<br><br>b) 50% of weeks February to April (The division between time periods is intentional and meant to ensure that some yearlings migrate in each of the time periods) | October | No Applicable Objective | April |
| YOY (Fry, Parr, and Smolt)[1] | Every week | First week of January | Last week of January | First week of June |

Note:
1. See Table 9 for definitions of fry, parr, and smolt size-classes.

This yearling migration timing objective will be in place any time spring-run Chinook salmon are spawning in the Stanislaus River. Because overall yearling abundance may be low, the SEP Group's only expectation is that yearling-sized Chinook salmon will be detected, at least once, in 50% of weeks between the second week of October and January and in 50% of weeks between February and April. However, it may only be a measurable objective when spring-run escapement and spawning are sufficient to produce a number of yearlings that can satisfy the objective. There are 30 weeks in the entire period, so at least 15 yearlings would need to be detected to meet the objective of at least one yearling detected in 50% of weeks in the two time periods.

The minimum number of yearlings needed to meet the objective implies that a total escapement of at least 16,700 spring-run Chinook salmon is needed. This is based on the following assumptions:

- At least 1.5 yearlings are produced per 1,000 returning adult females (i.e., 1.5 yearlings per 1,000 female spawners; see size at migration life history objective below).
- Sixty percent of the escaped fish are females (per current estimate for fall-run Chinook salmon; Appendix A).
- A sampling efficiency for yearlings is similar to that of Butte Creek, which is the system that the minimum yearling/spawner expectation is derived.

If the assumptions above are met and escapement is lower than this target, the yearling production objective can be revised to the following expectation: Roughly equal numbers of yearling are detected in each of the two time periods (mid-October to January and February to April).

As described in Section 6.3.5.9, the SEP Group believes it is likely that yearling production will be substantially greater than the 1.5 per 1,000 spawner rate identified in the size at migration life history objective. Additionally, the SEP Group believes that choosing the lowest documented yearling-to-spawner ratio known in the Central Valley (Butte Creek) is highly conservative, and this objective should be easily exceeded in a healthy river.

#### 6.3.5.7 Rationale for Size at Migration Life History Objective

Size at date of migration was used as a proxy for life history strategy. The timing of the migration objective (Section 6.3.5.6) establishes targets for the duration of the migration timing window, whereas this objective identifies a minimal distribution of size at migration among juvenile spring-run Chinook salmon. Production of a broad portfolio of spring-run Chinook salmon sizes during migration is intended to generate at least some spring-run Chinook salmon that are of supportive size to capitalize on conditions (throughout their freshwater migration) that exist in a given year. The SEP Group recognizes that the size-class that will perform best under a given year's set of environmental conditions is not knowable in advance and varies from year to year. Production of a wide portfolio of sizes at migration is needed so that some proportion of the population is appropriately sized to take advantage of conditions in each year (Satterthwaite et al. 2014).

#### 6.3.5.8 Methods for Size at Migration Life History Objective

For YOY migrants, the SEP Group found no reason to expect a different annual size-class distribution for spring-run Chinook salmon than was expected for fall-run. Run-specific size-class distributions may differ at any given time because the two populations spawn at different times; however, over the course of a migration season (the time step at which this objective is implemented), the overall distribution of size-classes should be similar across runs. These minima seem attainable based on the size-class distributions currently observed in the river (Figure 8; Table 8), and should capture intended benefits of anticipated habitat restoration activities. Furthermore, it would not be practical to attempt to measure differences in the annual size distribution at migration of spring-run Chinook salmon juveniles versus fall-run Chinook salmon juveniles. If field techniques that allow distinction between juveniles of different runs become available, the SEP Group will consider how this objective should be implemented on a run-specific basis.

The yearling production objective was calculated based on the expectation that at least 1.5 yearlings can be produced per 1,000 returning adult females, which is the minimum ratio detected for Butte Creek from 2001 to 2007 (Ward et al. 2004; McReynolds et al. 2006, 2007; Garman and McReynolds 2008, 2009). The rate of yearling production for spring-run Chinook salmon detected in Butte Creek is the lowest rate among the populations that have been studied on Sacramento River tributaries (Lindley et al. 2004; Ward et al. 2004; McReynolds et al. 2006, 2007; Johnson and Merrick 2012). For example, the percentage of yearlings among juvenile spring-run Chinook salmon on Butte Creek ranged from 0.01% to 0.05% during 2001 through 2006 (Ward et al. 2004; McReynolds et al. 2006, 2007). This compares to approximately 5% of all juveniles being yearlings on Deer and Mill creeks from 1994 to 2010 (Johnson and Merrick 2012). These numbers are believed to underestimate the true proportion of spring-run yearlings present. This is due to the following: 1) capture efficiency for yearling salmon is less than for YOY; and 2) the sampling location was downstream of redds that were built by fall-run Chinook salmon, which are generally expected to produce a much lower proportion of yearling migrants than spring-run Chinook salmon.

The SEP Group expects the yearling productivity objectives to be easily attainable in a restored Stanislaus River. Given the lack of information on yearling production rates for the Stanislaus River (spring-run escapement has only been sporadically monitored or documented; Franks 2012), there was no evidence to justify a higher yearling production rate. Failure to attain the objective will strongly suggest some impediment to yearling production in the Stanislaus River that should be investigated and addressed. If, over several years, the yearling to spawner ratio is higher than the level targeted here, the SEP Group recommends increasing the objective to account for the higher capacity to produce the yearling life history type.

This yearling production objective will be in place any time spring-run Chinook salmon are spawning in the Stanislaus River. However, it may only be a measurable objective when spring-run Chinook salmon escapement and spawning are sufficient to produce a number of yearlings that can be reliably detected. It is estimated that total escapement of approximately 5,600 spring-run Chinook salmon will be necessary to detect whether this objective is being met, assuming the following:

- Yearling production of at least 1.5 per 1,000 returning adult females and 60% of escapement are females (per the current estimate for fall-run Chinook salmon; Appendix A)
- A sampling efficiency for yearlings similar to that for Butte Creek (the system from which the minimum yearling per spawner expectation is derived)

When escapement is lower than 5,600 spring-run Chinook salmon, the objective should be revised such that at least one yearling is detected any time that spring-run escapement is greater than 1,100 fish. Yearling-sized fish are currently detected in the RSTs of the Stanislaus River (Watry et al. 2007), despite the fact that since the installation of the VAKI RiverWatcher weir run by FISHBIO, the cumulative number of spring-run Chinook salmon escapement (2007 to 2012) has not exceeded 70 individuals (Franks 2012).

#### 6.3.5.9 Results: Size at Migration Life History Objective

By year 15, generate a broad size-class distribution of emigrating juveniles such that the annual emigrant size-class distribution as measured at Caswell RST is as follows:

- For YOY migrants, same size distribution minima as for fall-run Chinook salmon objective
- For yearling migrants, minimum of 1.5 yearlings per 1,000 female spawners

Biological Objectives for spring-run Chinook salmon life history diversity are summarized in Table 12.

#### 6.3.5.10 Rationale for Genetic Objective

Central Valley spring-run Chinook salmon have a unique life history and physiology, which facilitate their abilities to ascend to higher elevation habitat than fall-run Chinook salmon and delay spawning for several months (Healey 1991; Yoshiyama et al. 2001). However, much of this high-elevation spawning habitat is no longer accessible to salmon due to the presence of dams, thus limiting the opportunity for differences in spawning locations between spring- and fall-run Chinook salmon (Lindley et al. 2006; Moyle et al. 2008). In rivers with dams blocking access to historic spawning habitat, such as the Sacramento and Feather rivers, hybridization between spring- and fall-run Chinook salmon has occurred (CDFG 1998; Banks et al. 2000). For creeks where access to historic spawning habitat is not blocked by dams (e.g., Mill and Deer creeks), genetic differences between spring- and fall-run Chinook salmon have been maintained and documented (Banks et al. 2000). Due to the genetic, life history, morphological, ecological, and behavioral differences between spring- and fall-run Chinook salmon, the two runs are designated as different ESUs and are managed based on these designations (Waples 1991; Smith et al. 1995; NMFS 2004).

One primary way to maintain distinct and heritable life history characteristics among ESUs is to limit gene flow among ESUs and allow for co-evolved gene complexes to be established and maintained through processes of local adaptation. Providing opportunities for spring-run Chinook salmon reproductive isolation is particularly important for the maintenance of these populations in rivers where high elevation habitat is blocked by dams.

The objective and rationale are not intended to prescribe or preclude the introduction of individuals with a spring-run Chinook salmon genetic lineage (e.g., from current spring-run ESU populations). Rather, it is possible that spring-run Chinook salmon that are genetically distinct from fall-run Chinook salmon are recolonizing San Joaquin River tributaries on their own or were never entirely extirpated. Spring-run Chinook salmon are also part of a large reintroduction effort on the mainstem San Joaquin River downstream of Friant Dam that may result in additional colonization of the San Joaquin tributaries in the future. The intent of this objective is to promote the recolonization of the San Joaquin River and its tributaries as well as the long-term success of individuals that exhibit spring-run life history characteristics independent of their near-term genetic origin.

#### 6.3.5.11 Methods for the Genetic Objective

Gene-flow criteria (less than 2% introgression) between ESUs have been proposed to achieve long-term genetic integrity and maintain a low extinction risk for natural populations (Lindley et al. 2007; HSRG 2014). Initial hybridization and introgression between runs should be avoided because, once gene flow between runs has occurred, it will be more difficult to establish and maintain genetic isolation between runs in the future. The SEP Group assumed that the general guidance for introgression between ESUs should apply to introgression between spring-run and fall-run in the Stanislaus River.

#### 6.3.5.12 Results: Genetic Objective

Immediately following plan implementation, conditions on the Stanislaus River will be established to support spring-run Chinook salmon spawning success and reinforcement of long-term genetic integrity as measured by greater than 98% of spring-running Chinook salmon spawning with other spring-running salmon (Table 13).

## 6.4 California Central Valley Steelhead

### *6.4.1 What is the Problem?*

Steelhead are listed as a threatened species under the federal ESA. Natural production is well below desired levels, survival rates are inadequate to achieve population growth and maintain population resilience, the populations express only a narrow range of the life history variants that are typical of this species, and hatchery influence on wild stocks compounds all of these problems.

Counts of steelhead in the San Joaquin River basin's three major tributaries—the Stanislaus, Tuolumne, and Merced rivers—are at very low levels (McEwan 2001). Unlike Chinook salmon, there is no dedicated escapement survey for steelhead. However, counts at weirs on these rivers show only a few adult steelhead returning in any given year and no fish returning in some years. The species exists in larger numbers as the resident rainbow life history form in the tailwaters below the major rim dams. However, the anadromous ESA-listed form of steelhead is extremely rare.

### *6.4.2 What Outcome(s) (Central Valley Goals) Will Solve the Problem?*

**Abundance**

Increasing abundance of steelhead is a goal of several policies governing Central Valley salmonids. The CVPIA (Section 3406 of the CVPIA, Title 34 of Public Law 102–575) calls for naturally spawning populations of anadromous fish that are double the 1967 to 1991 baseline within 10 years. State law (F&G Code § 6902(a)) and water quality regulations (SWRCB 2006) express the same target. In addition, increased abundance of this life history type will be required in order to recover the population (i.e., delist the population from the federal ESA). Furthermore, increased abundance of resident rainbow trout is believed to be necessary in order to support the following:

- Increased frequency of the anadromous phenotype
- Resilience of *O. mykiss* populations to the prolonged natural occurrence of conditions that render anadromy a poor strategy
- Local recreational fisheries

**Productivity and Life History Diversity**

Improvements in Central Valley productivity (measured as parr survival and smolt production) and increased life history diversity (i.e., more anadromous adults) are necessary for the following reasons:

- To achieve abundance targets for steelhead in the Central Valley
- To maintain fish "in good condition" (F&G Code § 5937)
- To achieve acceptable levels of the criteria NMFS uses to evaluate salmonid population viability (McElhany et al. 2000)
- To be consistent with other fisheries-related and water management-related policies

**Genetic Diversity**

For steelhead, as for salmon, concerns about genetic diversity and what is needed to sustain healthy and viable populations revolve around the influence of hatchery production and management (Williams 2006). In the Sacramento River basin, steelhead populations are dominated by hatchery fish, as there are hatcheries on Battle Creek, the Feather River, and the American River. However, since none of the three major San Joaquin River tributaries has a steelhead hatchery, straying of stocked steelhead is not currently a major concern in these rivers. The closest steelhead hatchery to the San Joaquin tributaries is on the Mokelumne River, an eastside tributary.

### *6.4.3 What Does Solving the Problem Look Like (Central Valley Objectives)?*

**Abundance**

Central Valley Objectives for resident rainbow trout abundance have not been determined. The AFRP (USFWS 2001) set an abundance objective of 13,000 naturally produced steelhead, but this only applied to the Sacramento River above the RBDD. This estimate was based on Mills and Fisher (1994), who calculated returns from a combination of RBDD ladder counts, hatchery returns, and estimates based on harvest rates. The NMFS Recovery Plan (NMFS 2014) has targets for the minimum number of viable steelhead populations needed for recovery by watershed and sub-region. A viable population at low risk of extinction is defined as having a minimum adult escapement of 2,500 individuals over 3 years, with a minimum effective population size of 500 fish in freshwater (NMFS 2014). This implies an average minimum escapement of 850 steelhead each year.

**Productivity**

The CVPIA and AFRP (USFWS 2001) inform Central Valley Objectives for population growth rates as these policies call for doubling of anadromous fish populations in 10 years. Current productivity is not sufficient to produce the Central Valley Objective (AFRP target) of 13,000 naturally produced steelhead in the upper Sacramento River or 850 adults (ESA recovery target) in most rivers in the Central Valley. Survival and population growth rates need to improve greatly to meet these system-wide objectives.

**Life History Diversity**

Existing policies inform Central Valley Objectives for life history diversity among *O. mykiss*, emphasizing the need to support the anadromous life history type (steelhead). The extensive loss of historic spawning and rearing habitat in the Central Valley has led to a near loss of steelhead in many watersheds. Currently, many rivers in the Central Valley are dominated by the freshwater fluvial, or resident, form of *O. mykiss*, also known as rainbow trout. Reversing this loss of life history diversity will require extensive habitat improvements in the rivers and Delta, which will allow for higher production of parr with faster growth rates, greater smolt survival, and higher adult survival. These changes should lead to increases in the proportion of *O. mykiss* population represented by the anadromous form.

**Genetic Diversity**

The steelhead population is currently dominated by hatchery fish, all of which are released as age-1 smolts. Hatchery fish tend to increasingly mature after only 1 year in the ocean and have low numbers of repeat spawners (Hankin et al. 2009). This has led to few age-classes of fish present in populations and an overall loss of diversity within the Central Valley population. Natural production of steelhead in Central Valley rivers and hatchery reforms are needed to reverse the genetic influence of hatchery-origin steelhead populations.

### *6.4.4 How will this Effort Contribute to Attainment of Central Valley Objectives (Watershed-Specific Goals)?*

The scope of the SEP Group's current effort is the Stanislaus River through the lower San Joaquin River to the Delta. Specific goals and objectives for the Stanislaus and lower San Joaquin rivers were developed to support the system-wide goals identified in Section 6.2.

**Abundance**

The Watershed-Specific Goal for steelhead abundance in the Stanislaus River is to increase steelhead escapement to delist and eventually permit a limited, regulated catch and release steelhead fishery.

**Productivity**

The SEP Group's goals for *O. mykiss* include producing riverine growth, density, and survival levels for *O. mykiss* that encourage production of sufficient numbers of anadromous smolt to support a viable steelhead population.

**Life History Diversity**

The Watershed-Specific Goal for life history diversity is to support the fullest expression of *O. mykiss* life history diversity in order to increase population stability, resiliency, and productivity. Currently, the San Joaquin River basin's tributaries are dominated by the resident rainbow trout. Increasing expression of the anadromous phenotype is necessary to meet NMFS recovery goals and the SEP's Watershed-Specific Goals for steelhead.

**Genetic Diversity**

The genetic Watershed-Specific Goal for *O. mykiss* on the Stanislaus River is to maintain an independent population that is largely free from the influence of steelhead hatchery strays.

### *6.4.5 What Suite of Species-Specific Outcomes (Biological Objectives) Characterize Success?*

The SEP Group has set Biological Objectives for *O. mykiss* that differ in many respects from those for Chinook salmon. This is partially due to *O. mykiss* displaying very different, complex life history strategies that are more diverse (within and across populations) and more plastic (within individuals) than those displayed by Chinook salmon. For example, *O. mykiss* populations display resident forms and anadromous forms, both of which must be protected in order to maintain population productivity and stability. In addition, the timing of the various migration and rearing periods for various *O. mykiss* life history stages and age-classes is highly variable, even within the same population (Figure 8).

Few data exist regarding steelhead demographics on the Stanislaus River, and no data exist on their age structure, growth rates, or survival rates. Results from snorkel surveys, RSTs, weir sampling, and otolith studies indicate that the anadromous form of *O. mykiss* is present in the Stanislaus River. Given the current expression of anadromy, it is likely that large improvements in river and Delta habitats are necessary to reach suitable levels of abundance, productivity, and diversity.

#### 6.4.5.1 Rationale for O. mykiss Abundance Objectives

Total abundance of rainbow trout is affected by conditions that are controllable solely on the Stanislaus River. As such, there is a Biological Objective for rainbow trout abundance, which is a significant difference from Chinook salmon Biological Objectives. Additionally, productivity and the balance between the anadromous and resident life history strategies are strongly influenced by resident rainbow trout density. Because abundance (density) is a specific, measurable, and desired outcome (Biological Objective) and a driver of other Biological Objectives, the SEP Group's Biological Objectives for rainbow trout abundance are described in report sections describing resident parr density (Section 6.4.5.4.1) and a range of life history objectives for the Stanislaus population (Section 6.4.5.8). Adult resident rainbow trout abundance Biological Objectives are provided in Table 18.

As with Chinook salmon, no specific Biological Objective is set for the number of steelhead that must return to the Stanislaus River. However, the inclusion of the Biological Objective for abundance for rainbow trout in the Stanislaus River will ultimately contribute to the attainment of the Central Valley Objectives for steelhead. Furthermore, combined with the Biological Objective for rainbow trout abundance, Central Valley Objectives for steelhead are essential to determining Environmental Objectives (e.g., physical, chemical, and biological conditions necessary to support juvenile rearing; see Section 7.2 for the Stanislaus River that will support attainment of larger goals and objectives. The CVPIA Final Restoration Plan (USFWS 2001) calls for Central Valley-wide escapement of steelhead of 13,000 fish. As seventh largest watershed (by watershed area) of the approximately 26 watersheds identified in the plan (USFWS 2001), the Stanislaus River could be expected to provide an escapement of between 500 (1/26) and 1,857 (1/7).

In order to qualify as one of the two independent, viable populations of steelhead in the San Joaquin River basin called for in the NMFS Recovery Plan (NMFS 2014), the steelhead population must be a naturally produced population at low risk of extinction. The NMFS Recovery Plan (NMFS 2014) states that a viable population at low risk of extinction should have a minimum adult escapement of 2,500 individuals over 3 years, with a minimum effective population size of 500 fish in freshwater (the census size of standing stock; for every one fish returning, two fish remain in ocean; 850 escapement in 1 year). The abundance objective would be measured as a minimum 3-year running average of 850 adult steelhead (not counting sexually immature fish, such as "half-pounders"), with a minimum effective population size of 500 in any given year.

Given the popularity of this species as a sportfish, it may be desirable in the future to allow a sport fishery on the recovered steelhead population of the Stanislaus River. Adult escapement beyond the recovery threshold would allow for a catch and release steelhead sport fishery in the Stanislaus River, assuming a low level of mortality from hooking and handling. If hooking mortality rates, defined as total catch and release fishing-related mortality up to outmigration as kelts, were an average of 15% (Ashbrook et al. 2010), then an escapement of 1,000 wild adult steelhead would allow for 850 fish to survive to the kelt stage. These figures imply that the final restoration target for steelhead in the Stanislaus River should be 1,000.

These levels of abundance are lower than the abundance levels anticipated for fall-run and spring-run Chinook populations (in Central Valley Objectives). Even in relatively healthy watersheds, steelhead are not typically as abundant as salmon populations. While salmon spawning runs often number in the hundreds of thousands to low millions, healthy wild steelhead runs typically reach hundreds in smaller coastal streams, thousands in larger rivers, and up to tens of thousands of fish in major river systems of the Northwest and northern California (Busby et al. 1996).

#### 6.4.5.2 Rationale for Productivity Objectives

Increasing smolt production levels while maintaining a strong resident rainbow trout population will require production of a larger number of age-0 *O. mykiss* and an increase in the somatic growth rate of *O. mykiss* on the Stanislaus River. Abundance (density) and growth rate affect the relative rate of anadromy in *O. mykiss* populations (McMillan et al. 2012; Kendall et al. 2014). Even at good smolt-to-adult return rates, a minimum number of smolts is needed to support Central Valley Goals and Objectives for steelhead abundance. High smolt production may also help swamp predators in the lower river and Delta and result in increased survival. Faster growing *O. mykiss* juveniles typically smolt at younger ages as long as they reach approximately 140 mm FL by the spring (Seelbach 1993). Large smolts have been shown to have higher survival to the adult stage (Ward et al. 1989).

The growth rates of juvenile *O. mykiss*, as well as the timing of growth, can vary greatly among watersheds in California. Sogard et al. (2012), using passive integrated transponder (PIT)-tag mark recapture methods, found that juveniles in two central coastal streams, Scott Creek and Soquel Creek, grew very slowly during the dry summer and fall months (0.11 mm/day [0.004 in/day] and 0.14 mm/day [0.006 in/day], respectively). These streams had faster growth rates for fish during the winter-spring months (0.24 mm/day [0.009 in/day] and 0.21 mm/day [0.008 in/day]) when flows were relatively high, even though water temperatures were colder. Lower American River juveniles grew 1.12 mm/day (0.044 in/day) in the summer-fall months, likely due to the warm water temperatures and high food production in that system, and those juveniles grew at 0.61 mm/day (0.024 in/day) in the winter-spring months (Sogard et al. 2012). Hence, stream flows, water temperatures, and food production can interact to produce wide-ranging growth rates in the same life history stage of this species in different seasons of the year.

#### 6.4.5.3 Methods for Productivity Objectives

In the near future, an *O. mykiss* population model for the Stanislaus River may be available, which would allow for the setting of age- and stage-specific survival rates for in-river and through-Delta reaches. A similar survival methodology for steelhead escapement could be used, as was developed for fall-run Chinook salmon escapement (Section 6.2.5.2). However, current data limitations present challenges for establishing Biological Objectives for *O. mykiss* productivity. For example, through-Delta survival rates of steelhead are not well known and have been assumed to be low (e.g., 10% in NMFS 2012). Recent acoustic tagging studies suggest that survival may be much higher—results from a recent 6-year study estimated through-Delta survival rates at 54% in 2011 (Buchanan 2013) and 32% in 2012 (Buchanan 2015).[8] In addition, steelhead smolts are more likely than Chinook salmon juveniles to avoid capture in RSTs because they are often larger and stronger swimmers than Chinook juveniles (Volkhardt et al. 2007).

[8] The Buchanan (2015) study used large hatchery steelhead, which might account for these relatively high rates, but they are much higher than survival rates from studies on Chinook salmon, which also used large hatchery smolts.

To overcome data limitations, alternative methods of measuring *O. mykiss* productivity have been proposed, including measures of parr density and growth rates, smolt size, and smolt production. Smolt production is a direct measurement of anadromy in the *O. mykiss* population. Higher growth and survival of *O. mykiss* parr (i.e., among the "resident" population) are believed to be correlated with a higher frequency of anadromy. Snorkel surveys on the Stanislaus River (Kennedy 2008) have shown very low densities (0 to 0.15 per square meter [$m^2$]) of age-0 *O. mykiss* in most locations, including a location near Goodwin Dam showing higher densities (0.3 per $m^2$). Bergman et al. (2014) estimated 0.63 to 2.13 fish per linear meter (3.28 feet [ft]) in the Stanislaus River in a reach just below Goodwin Dam. By comparison, Kozlowski (2004) electrofished 19 sites on the lower Yuba River and estimated that there was an average of approximately 0.4 age-0 *O. mykiss* per $m^2$. Even this density is very low compared to populations in coastal California streams where average densities of more than two fish per $m^2$ are common in electrofishing surveys (Sogard et al. 2012).

### 6.4.5.4 Results: Resident O. mykiss Productivity Objectives

#### *6.4.5.4.1 Parr Density*

The density of juvenile *O. mykiss* should increase over time to one age-0 individual per $m^2$ or 20,000 per river km (0.62 RM)[9] on average in specified reaches by year 15. This could be measured though snorkel surveys, electrofishing, or other appropriate sampling techniques.

#### *6.4.5.4.2 Parr Growth Rates*

The growth rates of individual age-0 and age-1 *O. mykiss* should increase over time to 0.60 mm/day (0.024 in/day) by year 15. An exception to this objective should be at age-0 densities over two individuals per $m^2$ on average or 2,000 per river km on average, at which time growth rates could be as low as 0.40 mm/day (0.016 in/day) to allow for lower growth rates at high juvenile densities. Growth rates could be measured by capturing, PIT tagging, or recapturing juvenile *O. mykiss* in the river, or the rates could be estimated by back-calculating lengths at age from scales.

This growth rate objective for *O. mykiss* is between growth rates observed in the lower Mokelumne River and the lower American River. The lower Mokelumne River has colder water temperatures and smaller invertebrates than the lower American River, which result in lower growth rates in the lower Mokelumne River. The American River has warm water temperatures and high invertebrate production, resulting in extremely fast growth.

Biological Objectives for productivity for *O. mykiss* are summarized in Table 15.

[9] One age-0 *O. mykiss* per $m^2$ translates to roughly 20,000 per river km (0.62 mile), assuming a river averaging 20 m (65.6 ft) wide.

**Table 15**
***O. mykiss* Productivity Objectives**

| Objective | | Productivity | |
|---|---|---|---|
| Life History Stage | | Juvenile Density | Juvenile Growth Rate |
| Description | Overview | Densities of *O. mykiss* that support the desired frequency of anadromy in the population | Average individual growth rates that support desired frequency of anadromy in the population |
| | Achieved by When? | Year 15 | Year 15 |
| | Measure What? | Population density (parr/river km$^2$) | Average growth rate (mm/day) |
| | Measured Where? | Upstream of Oakdale, in reaches identified as having high-quality *O. mykiss* holding habitat | Upstream of Oakdale, in reaches identified as having high-quality *O. mykiss* holding habitat |
| ***O. mykiss*** | | The minimum density of age-0 *O. mykiss* during the summer equals 1/m$^2$ on average | Minimum average growth of both age-0 and age-1 *O. mykiss*, averaged over an entire season, equals 0.60 mm/day |

Note:
km$^2$: square kilometer

### 6.4.5.5 Results: Anadromous O. mykiss (Steelhead) Productivity Objectives

#### *6.4.5.5.1 Smolt Size*

By year 15, at least 90% of the smolts (Stage 5 in Table 16) observed in the lower Stanislaus River should be 150 mm (5.9 in) FL or greater in length.

**Table 16**
**Life History Stage Numbering and Nomenclature for *O. mykiss*, with Special Reference to Steelhead Life History**

| Stage No. | Stage Name | Stage Description |
|---|---|---|
| 1 | Egg-sac fry | Newly emerged, still has egg yolk visible |
| 2 | Fry | Small parr, only a few weeks old |
| 3 | Parr | Distinct parr marks, scales not silvery |
| 4 | Silvery parr | Scales slightly silvery |
| 5 | Smolt | Bright silvery scales, dark edges on caudal fin |
| 6 | Adult | Sexually mature fish |

Current technology for measuring steelhead smolt production in large rivers is limited, especially in rivers with high and turbid spring flows. Steelhead smolts are believed to be strong enough swimmers that they can avoid capture in RSTs. The most successful methods for counting smolts have been inclined-screen traps and video cameras, which require some type of structure, such as a weir or low-head dam, to concentrate fish and allow individuals to be captured or filmed. Potential future technologies include next-generation Didson imaging sonar system cameras and mark-resight estimates based on PIT tagging of age-0 or age-1 fish prior to smolt emigration combined with mobile PIT-tag antennae.

###### *6.4.5.5.2 Parr and Smolt Production*

The number of naturally produced smolts (Stages 4 and 5 in Table 16) greater than 150 mm (5.9 in) FL per adult female steelhead should be at least 165 by year 15 of the implementation of habitat restoration. This could be measured at either Caswell or another suitable location further downstream, but prior to the confluence with the mainstem San Joaquin River. The methodology would be the same as smolt size methodology; but it would not necessarily require that smolts be captured, rather only be observed well enough to be identified and counted.

###### *6.4.5.5.3 Parr and Smolt Survival*

By year 15, 90% of all the silvery parr and smolts (Stages 4 and 5 in Table 16) counted at the lower end of the gravel bedded reach must be detected at the lower river or beginning of Delta.

###### *6.4.5.5.4 Adult Spawning*

By year 15, when adult steelhead are present and spawning, their eggs will have a minimum egg to emergence survival rate of 35% in the wild. See Section 6.2.5.4.2 (Supplemental Guidance to Support Productivity Objectives in the Stanislaus River) for further details regarding the identification, prioritization, monitoring, and adaptive management of this objective.

Biological Objectives for the productivity of the steelhead life history type are summarized in Table 17.

**Table 17**
**Steelhead Productivity Objectives**

<table>
<tr><th colspan="2">Objective</th><th colspan="8">Productivity</th></tr>
<tr><th colspan="2">Life History Stage</th><th colspan="2">Juvenile Smolt Size</th><th colspan="2">Juvenile Smolt Production</th><th colspan="3">Juvenile Smolt Survival</th><th>Adult</th></tr>
<tr><th rowspan="4">Description</th><th>Overview</th><td colspan="2">Proportion of smolts (Stages 4 and 5 in Table 16) observed should be of a size able to survive the ocean phase and return as anadromous adult</td><td colspan="2">Naturally produced smolts (Stages 4 and 5 in Table 16) per female spawner increase to levels consistent with other healthy steelhead populations</td><td colspan="3">Smolt survival – smolt (Stages 4 and 5 in Table 16) survival rate consistent with population resilience</td><td>Reproductive success of adult migrants and indicators of egg incubation success</td></tr>
<tr><th>Achieved by When?</th><td colspan="2">Year 15</td><td colspan="2">Year 15</td><td colspan="3">Year 15</td><td>Year 15</td></tr>
<tr><th>Measure What?</th><td colspan="2">FL</td><td colspan="2">Number of smolts per female spawner</td><td colspan="3">Survival through lower Stanislaus River</td><td>Egg-emergence survival of surrogates</td></tr>
<tr><th>Measured Where?</th><td colspan="2">Caswell (or other location prior to confluence with mainstem)</td><td colspan="2">Caswell (or other location prior to confluence with mainstem)</td><td>Lower end of gravel bedded reach</td><td></td><td>Delta entry</td><td>Spawning grounds</td></tr>
<tr><th colspan="2" rowspan="3">Steelhead</th><td>FL</td><td>150 mm (5.9 in)</td><td rowspan="2">3-year running average</td><td rowspan="2">Smolts per female spawner</td><td colspan="3" rowspan="3">> 90%</td><td rowspan="3">> 35%</td></tr>
<tr><td>Percentage</td><td>90%</td></tr>
<tr><td>Year type</td><td>All years</td><td>Minimum</td><td>165</td></tr>
</table>

#### 6.4.5.6 Rationale for Life History Objectives

Life history diversity in *O. mykiss* is partly defined by the duration of both freshwater and marine rearing (Hodge et al. 2016) and can be partially assessed as the proportion of juveniles emigrating at a particular age and/or size. For *O. mykiss*, this can encompass a temporal range of 1 to 3 years (McEwan 2001), but also includes the timing of migration within the emigration year. The proportion of anadromous adults in the Stanislaus River appears to be very low. Several factors are likely contributing to this low production of anadromous individuals. The river habitat may not be producing many age-0 *O. mykiss*. Those that are produced may be growing slowly or have poor survival. Delta habitat conditions may result in low survival of smolts. In rivers with healthy wild steelhead populations, the majority of juveniles tend to be produced by anadromous mothers, even if there are female resident rainbow trout present (Donohoe et al. 2008). The sex ratio of adult resident rainbow trout tends to be heavily biased toward males (Rundio et al. 2012). Genetic parentage analysis has shown that resident males contribute more to the next generation of steelhead than resident females (Christie et al. 2011). This is consistent with species that exhibit partial anadromy, where resident males are predicted to be more abundant (Jonsson and Jonsson 1993).

Age-0 *O. mykiss* have not yet selected an anadromous or resident life history pathway (Thorpe et al. 1998; Beakes et al. 2010). Tracking the proportion of those that eventually smolt is a measure of the life history diversity of the *O. mykiss* population. In a population dominated by the resident form, nearly all will choose to mature in the stream as residents due to any of the following (Satterthwaite et al. 2009):

- Generations of selective pressure against anadromy, likely from some combination of low smolt survival
- Large asymptotic size
- High survival rates of adult residents

In keeping with the Watershed-Specific Goal for life history (i.e., to support the fullest expression of *O. mykiss* life history diversity in order to increase population stability, resiliency, and productivity), Biological Objectives were established to provide for a balance between anadromous and resident *O. mykiss* life history types. These objectives also support the Watershed-Specific Goal for abundance, as they will maintain a minimum number of adult residents to allow the continuation of the popular sport fishery in the lower Stanislaus River. Finally, the life history Biological Objectives support population resilience by creating a “refuge population” of rainbow trout in the Stanislaus River that can potentially give rise to anadromous progeny.

#### 6.4.5.7 Methods for Life History Objectives

These Biological Objectives for steelhead use different metrics to measure, sometimes directly, sometimes indirectly, the proportion of the *O. mykiss* population that is anadromous versus resident.

The SEP Group acknowledges that there is no method available to determine the future migratory life history of individual *O. mykiss* parr in the Stanislaus River. Therefore, the general approach adopted was to increase overall productivity of juveniles, individual growth rates, and survival rates in the Stanislaus River. In concert with increased smolt to adult survival rates in the lower San Joaquin River and the Delta, these parameters should lead to higher numbers of juveniles following the anadromous life history strategy (Satterthwaite et al. 2010).

### 6.4.5.8 Results: Life History Objectives

#### *6.4.5.8.1 Anadromy – Juvenile Stage*

By year 15, a minimum of 150 steelhead outmigrants should be produced per female spawner in the poorest water years up to a minimum of 300 per female spawner in good water years. This will be tracked on a broodyear basis, as smolt years in steelhead do not necessarily match broodyears. Measurement of how well this objective has been achieved will require accurate estimates of adult escapement and smolt production each year for several years, plus ages of smolts in order to assign broodyears.

#### *6.4.5.8.2 Anadromy – Adult Stage*

By year 15, the proportion (as a 5-year running average) of all counted adult *O. mykiss* over a full season should be a minimum of 25% resident (less than 460 mm [18.1 in] FL) counted during the summer or fall and 20% anadromous (greater than 460 mm [18.1 in] FL) individuals counted during the spawning migration. Stream resident adults could be counted by snorkel surveys or estimated by mark and recapture through hook and line sampling. Anadromous adults could be estimated at a weir or using snorkel or redd surveys.

#### *6.4.5.8.3 Anadromy – Maternal Origin*

The proportion of age-0 *O. mykiss* that are the progeny of anadromous mothers should increase to a minimum of 45% by year 15. This percentage could be met with approximately 10 times more resident adults (approximately age 3 and older) than adult steelhead.

This objective is measurable and should be monitored using otolith microchemistry studies. Several published papers have used otolith microchemistry to determine the maternal origin of individual *O. mykiss* (Donohoe et al. 2008; Zimmerman et al. 2008). For this type of study, it is best to take otoliths from age-0 fish to avoid biases from sampling older fish that have decided to become resident, as it is known that anadromy in *O. mykiss* has some genetic heritability.

#### *6.4.5.8.4 Anadromy – Balance*

The objective for anadromy - balance is as follows: by year 15, attain and maintain a minimum abundance of resident adults (as defined by a combination of year-round presence, size at age, and scale analysis) that at least meets the lower end of the abundance range (i.e., a superpopulation of 1,492 to 7,873 age 1+ or 3 to 9 age 1+ per 100 $m^2$ (1,076 square feet [$ft^2$]) as specified by Bergman et al. (2014). Resident adult numbers can be estimated by mark recapture studies, snorkel surveys, or electrofishing.

#### *6.4.5.8.5 Anadromy – Smolt Emigration*

In most *O. mykiss* populations that produce steelhead, the largest, oldest smolts (often age 3) emigrate first, followed by the smaller, younger smolts (age 2 and age 1) as the emigration progresses. In order to maintain this age-class diversity among smolts, environmental conditions should be suitable for smolt emigration for several months of the year. Steelhead smolts have been detected emigrating from the Stanislaus River anywhere from December through June, based on data from the Caswell and Oakdale RSTs, though the abundance of smolts is usually greatest from January through April. Thus, by year 15, the Stanislaus River RSTs should detect emigrating steelhead smolts (Stages 4 [silvery parr] and 5 [smolt] of at least 150 mm [5.9 in] FL in a minimum of 4 months of each emigration season [October through September]).

Biological Objectives for life history diversity for *O. mykiss* on the Stanislaus River are summarized in Table 18.

**Table 18**
***O. mykiss* Life History Diversity Objectives**

| **Objective** | | **Life History Diversity (Anadromy)** | | | | |
|---|---|---|---|---|---|---|
| **Life History Stage** | | **Juvenile** | | | **Adult** | |
| **Description** | **Overview** | Smolts produced per female spawner indicative of healthy spawner | Supports anadromy via a sufficient proportion of juveniles with anadromous *O. mykiss* mothers | Supports a range of outmigration dates for life history diversity | Support viable levels of both life history types | Support viable levels of both life history types |
| | **Achieved by When?** | Year 15 | Year 15 | Year 15 | Year 15 | Year 15 |
| | **Measure What?** | Smolts per female spawner | Proportion of age-0 juveniles with anadromous maternal origin in otolith | Smolt (Stages 4 and 5; at least 150 mm [5.9 in] FL) detection | Proportion of adult *O. mykiss* | Resident adult abundance |
| | **Measured Where?** | Spawning reach | Age-0 *O. mykiss* collected in rearing areas | Caswell RST | Entire River | Reach just downstream of Goodwin Dam |
| ***O. mykiss*** | | This should be tracked on a brood year basis | | | N/A | Age 1+ fish superpopulation > 1,492 to 7,873 |
| | | Annual hydrology > 50% exceedance: > 300 | > 45% | Minimum of 4 months of the year | > 25% resident – summer | 3 to 9 age 1+ resident fish per 100 m² (1,076 ft²) |
| | | Annual hydrology ≤ 50% exceedance: > 150 | | N/A | > 20% anadromous – immigrating adults | |

# 7 Environmental Objectives

The Environmental Objectives developed by the SEP Group are intended to represent physical and chemical conditions needed to support the Biological Objectives for Chinook salmon populations and the *O. mykiss* population (including resident and anadromous life history types) within the Stanislaus River. They define the physical and chemical conditions needed to attain the Biological Objectives. They also provide life history stage-specific guidance that should be used in the development, prioritization, and adaptive management of Conservation Actions.

The confluence of conditions that, in any specific instance, comprise suitable habitat as experienced by an individual organism are often the product of processes and dynamics operating at a broad range of spatial and temporal scales. Processes like sediment transport, large wood deposition, and flow fluctuations may be impacted or constrained to a range of degrees in altered or managed systems like the Stanislaus River. Similarly, the potential outcomes of those processes, in terms of their effect on habitat quality, may be more or less achievable through management interventions or other alternative means (e.g., gravel augmentation, large wood deposition) in different cases or under different circumstances. In response to this—and to avoid being prescriptive about what actions are necessary to achieve a desired outcome—Environmental Objectives are quantified at the scale and in terms of the specific conditions experienced by an individual organism at a given increment of time and space (e.g., temperature of X degrees 7-day average of daily maximum temperatures [7DADM], spawning substrate X size, for Y area, during months Q-Z) as opposed to processes or dynamics that may mechanistically lead to those conditions (e.g., flow magnitude, sediment transport). It is important to note, however, that some combination of processes and actions will invariably be required to achieve and maintain the suitable habitat conditions quantified in the Environmental Objectives. Additionally, a poor understanding of watershed-scale processes that influence more localized projects could result in projects failing to achieve and or maintain objective conditions. As such, the conditions quantified in the Environmental Objectives, and any action to achieve or maintain them, should be considered in the context of the range of landscape dynamics and processes that created them under unimpaired or historic conditions in addition to what might govern them under current or future conditions.

Attainment of Watershed-Specific Goals and Biological Objectives is unlikely until Environmental Objectives are met; thus, the speed with which Environmental Objectives are met is important. In addition, producing these necessary environmental conditions is not a substitute for attaining the Biological Objectives. In other words, attainment of the Biological Objectives is the intent; attainment of Environmental Objectives should result in achievement of Biological Objectives, but adjustment of the Environmental Objectives may be necessary to ensure full attainment of the desired biological outcomes. Environmental Objectives are considered hypotheses of the conditions necessary to support the Biological Objectives; thus, they should be implemented within an adaptive management framework that allows for modification, if necessary, to achieve desired biological outcomes.

Environmental objectives have been developed to support the following life history stages:

- Adult upstream migration
- Adult holding
- Spawning
- Egg development
- Juvenile rearing and migration

The specific criteria for each Environmental Objective and category are detailed in this section and summarized in Appendix B. Temperature, DO, and contaminants are critical to all life history stages; these parameters are discussed by life history stage in this section. A more integrated discussion of temperature, DO, and contaminants is provided in Appendix C. A general approach for, and the intended application of, the Environmental Objectives as well as descriptions of key variables are also presented below.

## 7.1 General Approach for, and Intended Application of, Environmental Objectives

Environmental Objectives are intended to quantify the desired habitat and ecosystem conditions in the planning area (e.g., Stanislaus River) necessary to achieve and sustain the Biological Objectives. Environmental Objectives are defined in terms of a range of specific measurable parameters that together make up suitable environmental conditions for the species in question. Because habitat and ecosystem condition needs vary across species as well as among different life history stages within a single species, Environmental Objectives are defined separately for each species and life history stage combination.

In general—and specifically in the application of Environmental Objectives to the identification and prioritization of Stressors and the subsequent development of conservation actions—it is important to note that Watershed-Specific Goals and Biological Objectives can only be attained if all of the target species' life history stages are successful. As a result, though Environmental Objectives are specified by distinct life history stages, attaining the Biological Objectives related to each life history stage will require that Environmental Objectives for all life history stages for the species be achieved.

Environmental Objectives for each species and life history stage have been assigned a timing window indicating the months of the calendar year during which the conditions described by the objectives should be maintained, and a geographic range (defined by reach) where the objectives are applicable.

It is important to note that Environmental Objectives do not necessarily need to be met across the specified geographic range in order to achieve Biological Objectives. Rather, the geographic range merely indicates those reaches where sufficient spatial habitat extent (quantified as a component of Environmental Objectives where applicable) can be achieved, given inherent characteristics of the system (e.g., geologic, topographic, and geomorphic). Geographic ranges have been defined as broadly as possible to allow for maximum flexibility in the attainment of Environmental Objectives, given the inherent constraints of the system.

In some cases, for some portion of the applicable timing window or during some years, only a subset of the supportive conditions for a given species or life history stage may be attainable. However, this does not necessarily indicate that an individual or cohort experiencing those stressful conditions will not contribute to population success or the attainment of Biological Objectives. For this reason, Environmental Objectives have been defined in three categories of conditions for all applicable parameters:

- Supportive conditions
  - Contribute to the health and growth of individuals and the population without harmful effects
  - Support the attainment of the Biological Objectives
- Stressful conditions
  - Associated with some degree of impact at the individual or population level (e.g., observable or measurable stress, increased vulnerability to disease, reduced growth, reduced survival)
  - May or may not support attainment of the Biological Objectives
    - Where likelihood of detriment increases with lower suitability (relative to supportive range), or decreased occurrence (frequency or duration) of suitable conditions
- Detrimental conditions
  - Associated with a significant level of harm at the individual or population level
  - Will not support the attainment of one or multiple Biological Objectives

Supportive conditions are expected to fully support individual and population health as well as fitness. Stressful conditions, by contrast, if maintained for an extended period or experienced across multiple parameters, should be considered harmful and will inhibit the potential for the species or life history stage experiencing them to contribute to the attainment of the Biological Objectives for that year-class.

When looked at in their totality, the complete set of Environmental Objectives provides a spatial and temporal depiction of the system that will support the attainment and maintenance of the Biological Objectives. Therefore, Environmental Objectives are intended to serve as the basis for the development and evaluation of conservation actions designed to create the habitat and ecosystem conditions necessary to support Biological Objectives. Achieving the Biological Objectives will therefore require a suite of conservation actions that together address Environmental Objectives. In cases where it has been provided, the required spatial extent of the habitat conditions specified in the Environmental Objectives is a function of population size and fish density relative to habitat area relationships and has been calculated based on the target population size.

Due to temporal differences in their life history stages, it is anticipated that some habitats may be used by fall-run after spring-run, and the total areal habitat needs for both runs may not be equal to the sum of each run's individual need. However, the use by subsequent life history stages must also be considered (e.g., spawning timing between fall-run and spring-run have minimal overlap, but egg development occurs in the same location as spawning and has considerable temporal overlap), and the total habitat needs must be able to accommodate both. Future monitoring data can be used to determine the extent of habitat that can be re-used by fall-run without causing adverse impacts to spring-run productivity. If the data suggest that habitats can be re-used, then environmental objectives can be modified.

Additionally, prior to achieving desired Environmental Conditions, habitat conditions may be less optimal for certain species and life history stages than for others. Resolving the conditions for one life history stage may therefore have a disproportionately large effect on the ability to advance Biological Objectives for other or all of that species' life history stages. To inform prioritization of conservation actions, the SEP Group identified, described, and prioritized stressors to provide guidance on the relative impact of existing stressors on life history stages (Section 8).

Given the dynamics and needs necessary to achieve Biological Objectives, the SEP Group anticipates the need for a conservation plan that encompasses the following:

- A suite of conservation actions designed to achieve all Environmental Objectives
- A phased implementation approach for those objectives through time
- Prioritized sequences for implementation based, in part, on the relative needs of different life history stages and the evolving habitat extent of the growing population

## 7.2 Environmental Objectives and Supporting Rationale for each Life History Stage

### *7.2.1 Adult Upstream Migration*

Chinook salmon and steelhead return from the ocean to freshwater to spawn in the rivers of the Central Valley. Fall-run Chinook salmon return to San Joaquin River tributaries, including the Stanislaus River, between late September and December (Figure 8). Spring-run Chinook salmon have been observed in San Joaquin Tributaries in recent years and are being restored to the mainstem

San Joaquin under the SJRRP. These fish are expected to migrate to their spawning grounds between March and June (Figure 8; SJRRP 2010). Steelhead migrate upstream from September through April (Figure 8).

After spawning, Chinook salmon adults die, whereas steelhead may attempt to return to the Estuary and Pacific Ocean for possible repeat spawning in subsequent years. Both Chinook salmon and steelhead cease to eat during their spawning migrations; somatic energy reserves and nutrients are used to complete the upstream journey, the processes of attaining and defending nest sites and mates, and spawning. Nutrients and energy are also allocated to production of gametes. Adult migration and gametogenesis are energy-intensive and time-sensitive activities; thus, delays caused by barriers or disorientation can result in death, lost opportunities to spawn, or other forms of reduced reproductive success.

Chinook salmon and steelhead typically return to their natal streams to reproduce, a process called homing, and its opposite (i.e., returning to a non-natal stream to spawn) is called straying. Several modes of orientation play a role in successful homing. However, once adult fish enter freshwater, olfactory identification of water emanating from the natal stream is the dominant cue driving salmonid orientation (Healey 1991; Quinn 2005). In highly managed watersheds like those of the Central Valley where large fractions of a river's flow may be diverted at one or more locations along the migration path, homing success can be influenced by the amount of flow from a particular spawning stream that reaches migrating adult salmon and the ratio of flow from various source streams in a watershed (Marston et al. 2012). The magnitude of pulse flows or attraction flows to facilitate adult migrations, and the ratio of flows from various San Joaquin River tributaries that must reach any point along the migratory corridor, are not addressed as Environmental Objectives because establishing such San Joaquin River basin-wide objectives will require completion of Environmental and Biological Objectives for all the major San Joaquin River tributaries and the mainstem. Likewise, base flow conditions in the Stanislaus River as well as the mainstem San Joaquin below its confluence with the Stanislaus River are not identified here.

Environmental Objectives that are required for successful completion of adult migrations (from freshwater entry to arrival at holding sites for spring-run Chinook salmon) or to spawning grounds (for fall-run Chinook salmon and steelhead) include those for temperature, DO, minimum channel depth at critical riffles, and contaminants (metals and pesticides). Contaminants can interfere with migration success and subsequent reproductive success; therefore, maximum tolerable levels of these compounds are also included. Although adult Chinook salmon and steelhead may have different environmental requirements for optimal performance, the literature did not support the ability of the SEP Group to develop separate species-specific Environmental Objectives for migration. Thus, all Environmental Objectives for adult migration apply to runs of Chinook salmon and steelhead.

Poor environmental conditions may result in the delay of spawning migrations rather than outright mortality. Delayed migrations are expected to negatively affect reproductive success. Consistent with this expectation are the observations that adult (sockeye) salmon migrate at speeds much faster than those that would be energetically optimal (Brett 1983) and that fat reserves are largely depleted by the time fish spawn and die (as reviewed in Quinn 2005). This report assumes that supportive conditions for adult migration are those that result in no delay (i.e., 0-hours delay) in the migration process, and stressful conditions will result in delays that are less than 24 hours. Environmental conditions that result in migration delays greater than 24 hours are considered detrimental. Delays of greater than 24 hours may result in the reduced ability to acquire and defend spawning territory, mates, or completed redds. In addition, environmental conditions that result in extended delay of migration are likely to be associated with stresses that affect fecundity (e.g., egg or sperm viability).

A summary of the Environmental Objectives detailed below for the adult upstream migration life history stage is provided in Table B-1 of Appendix B.

### 7.2.1.1 Temperature

#### *7.2.1.1.1 Temperature Objective Rationale (Adult Upstream Migration)*

Water temperature affects all aspects of salmonid metabolism and physiology. Low water temperatures are not likely to be a problem for migrating Central Valley salmonids. High water temperatures approaching physiological limits occur with some frequency in most of the larger Central Valley rivers (Williams 2006). These temperatures result in high metabolic rates and increased susceptibility to disease (USEPA 1999, 2003; NRC 2004). In addition, increases in temperature reduce the ability of water to hold DO, which may stress migrating salmonids. Finally, development and maintenance of gametes appear to be negatively affected by prolonged exposure to elevated temperatures (Berman and Quinn 1990 as cited by USEPA 1999).

#### *7.2.1.1.2 Temperature Approach (Adult Upstream Migration)*

Several literature reviews provide insight into temperature levels that are supportive, stressful, or detrimental to the success of migrating adult Chinook salmon and steelhead. The SEP Group relied primarily on USEPA (1999, 2003) guidance for temperature effects on Pacific salmon and supplemented that information when newer information and studies specific to Central Valley salmon were available.

Wherever possible, temperature thresholds are reported as both a daily average (corresponding roughly to the temperature thresholds reported from studies using constant temperature conditions) and 7DADM, as per the practice of the USEPA (2003). The 7DADM that corresponds to a daily threshold was calculated by adding half of the difference between daily average and daily maximum temperatures (USEPA 2003) to the daily threshold reported in the literature. For the Stanislaus River, the average difference during the summer and fall months between daily average and daily maximum temperatures was approximately 3°C (5.4 °F) at the Orange Blossom Bridge gage. So, a conversion factor of 1.5°C (2.7°F) was added to daily recommended temperature thresholds to estimate the "midpoint" temperature for the corresponding 7DADM. For some temperature-related effects, other temperature metrics are reported when the effect occurs on a shorter or longer timeframe.

#### *7.2.1.1.3 Temperature Objectives (Adult Upstream Migration)*

Raleigh et al. (1986) identified weekly average optimal temperatures of 8°C to 12°C (46.4°F to 53.6°F) for Chinook salmon; however, USEPA (1999, 2003) identified no stressful impacts at constant temperatures lower than 14°C (57.2°F). Supportive temperatures range from 9.5°C to 15.5°C (49.1°F to 59.9°F) as a 7DADM (accounting for the typical difference between daily average and daily maximum temperatures in the Stanislaus River).

Stressful temperatures (those associated with negative sub-lethal effects) ranged from constant laboratory temperatures of 14°C to 19°C (57.2°F to 66.2°F) or 15.5°C to 20.5°C (59.9°F to 68.9°F) as a 7DADM. Exposure to high water temperatures facilitates infection among migrating adult salmonids (Noga 1996). The USEPA (2001) identified an elevated risk of disease spread at weekly average temperatures between 14°C to 17°C (57.2°F to 62.6°F) and a high risk of infection at prolonged exposure to temperatures greater than 18°C (64.4°F; USEPA 2003). The USEPA (2003) reported reduction in migration fitness due to cumulative stresses associated with prolonged exposure to temperatures 17°C to 18°C (62.6°F to 64.4°F). Swimming performance is reduced at temperatures greater than 20°C (68°F; USEPA 2003); however, Williams (2006) and Richter and Kolmes (2005) indicate that migration may be impeded when temperatures are as low as 19°C (66.2°F). Many sources recommend maintaining temperatures lower than 20°C to 21°C (68°F to 69.8°F) to prevent direct impairment of Chinook salmon migrations (USEPA 1999, 2003; Richter and Kolmes 2005). Furthermore, although the impact of water temperatures on developing embryos is not well understood, there is evidence that developing reproductive tissues exposed to high temperature may be less viable than those that are formed under cooler temperatures. The USEPA (2003) indicates that eggs in holding females exposed to constant temperatures greater than 13°C (55.4°F) suffer reduced viability. Berman and Quinn (1990) found that offspring of adult Chinook salmon that had been held for 2 weeks at temperatures between 17.5°C to 19°C (63.5°F to 66.2°F) had higher pre-hatch mortality as well as developmental abnormality rates and lower weight than a control group. The SEP Group's 7DADM of 15.5°C to 20.5°C (59.9°F to 68.9°F) reflects the thresholds for stressful conditions, including delays in adult migration that would exceed 24 hours.

Detrimental temperatures are those that will tend to prohibit attainment of Biological Objectives for the Stanislaus River. The Incipient Upper Lethal Temperature (IULT) for Chinook salmon may be as low as 21°C to 22°C (69.8°F to 71.6°F) for adult Chinook salmon and steelhead during migration

(USEPA 1999, 2003; Richter and Kolmes 2005). Williams (2006) reported that salmon returning to the Stanislaus River in 2003 endured water temperatures greater than 21°C (69.8°F) on their migration; however, there is no information regarding the fate of adults that experienced these temperatures or their offspring.

Given the range of detrimental effects to migrating adult salmon and steelhead and their future offspring, and the different exposure timesteps in which these negative effects would be expected to occur, the SEP Group provides several thresholds for detrimental temperature effects. Weekly mean temperatures greater than 18°C (64.4°F) expose migrating salmonids to a high risk of disease, which could lead to catastrophic failure of a year-class (e.g., NRC 2004). On a 7DADM basis, temperatures greater than 20.5°C (68.9°F) must be avoided in the migration corridor. Instantaneous temperatures (e.g., daily maxima) must be below 22°C (71.6°F) to avoid detrimental effects to migrating adult salmon.

Table 19 summarizes the temperature objectives for adult upstream migration for Chinook salmon and steelhead.

**Table 19**
**Temperature Objectives for Chinook Salmon and Steelhead Adult Upstream Migration**

| Habitat Type | Temporal Extent | Condition | Range (Metric) |
|---|---|---|---|
| Delta to Holding/ Spawning Grounds | Fall-run: Late September to December<br><br>Spring-run: March to June<br><br>Steelhead: September to April | Supportive | 8°C to 14°C (46.4°F to 57.2°F) (Daily Average) |
| | | | 9.5°C to 15.5°C (49.1°F to 59.9°F) (7DADM) |
| | | Stressful | 14°C to 19°C (57.2°F to 66.2°F) (Daily Average) |
| | | | 15.5°C to 20.5°C (59.9°F to 68.9°F) (7DADM) |
| | | Detrimental | > 18°C (64.4°F) (Weekly Average) |
| | | | > 19°C (66.2°F) (Daily Average) |
| | | | > 20.5°C (68.9°F) (7DADM) |
| | | | > 22°C (71.6°F) (Instantaneous) |

## 7.2.1.2 Dissolved Oxygen

### *7.2.1.2.1 Dissolved Oxygen Rationale (Adult Upstream Migration)*

The DO is critical to producing the energy adult salmonids need to complete their upstream migrations. Oxygen consumption increases exponentially with increased swimming velocity (Brett 1964), and adult salmon tend to migrate at speeds approaching their physiological maxima. The capacity of water to hold DO varies inversely with temperature, and the organic material in the water can decrease DO through biological oxygen demand (BOD; Tetra Tech 2006; USEPA 2006). High temperatures and high BOD contribute to periodically low levels of DO in the San Joaquin mainstem.[10] As a result, areas of the lower San Joaquin River and Delta are listed as being impaired on the USEPA Clean Water Act Section 303(d) list for not meeting water quality standards due to low DO (USEPA 2011). These low levels of DO have been observed to delay or block adult salmon migrations into the San Joaquin River basin during some years.

#### *7.2.1.2.2 Dissolved Oxygen Approach (Adult Upstream Migration)*

The SEP Group relied on DO criteria established by the USEPA (1986), the Central Valley Regional Water Quality Control Board (CVRWQCB; 2018), and other technical literature to identify DO objectives that are supportive (no negative effects), stressful (observably negative sub-lethal effects), and detrimental (preventing attainment of Biological Objectives) ranges for migrating adult salmonids. The Washington State Department of Ecology (WDOE; 2002) reported that DO concentrations above 8 to 9 milligrams per liter (mg/L) are needed for maximum swimming performance in salmon. Several researchers report decreased swimming efficiency at DO levels that are less than 7 mg/L (Dahlberg et al. 1968; WDOE 2002). The DO levels below 5 to 6 mg/L elicited avoidance (WDOE 2002). Davis (1975) reported a "distress" response when adult salmon were exposed to DO less than 6 mg/L.

Hallock et al. (1970) found that adult Chinook salmon migrating up the San Joaquin River avoided DO concentrations below 5 mg/L. However, their observation that these fish began to migrate when DO increased above 5 mg/L is not conclusive evidence that DO levels between 5 to 6 mg/L are acceptable. First, these fish had already suffered an extended delay while avoiding DO levels below 5 mg/L, so this is not an indication that the fish Hallock et al. (1970) observed would not have been delayed had they initially encountered DO levels between 5 to 6 mg/L. Second, the final fates and reproductive successes of the fish Hallock et al. (1970) observed were not recorded. Therefore, it is not known if the eventual migration through waters with low DO had negative fitness consequences.

The regulatory limit for DO in the Stockton Deep Water Ship Channel (DWSC) is 6 mg/L during months when fall-run Chinook salmon migrate; however, that standard applies only to the DWSC, not other waters that San Joaquin River basin fall-run Chinook salmon might migrate through. The standard in other stretches of the fall-run migratory pathway is 5 mg/L. Similarly, the standard is only 5 mg/L during the spring (CVRWQCB 2018). Spring-run Chinook salmon adults (which were not known to be present in the San Joaquin River basin when the regulatory standard was implemented) require the same levels of DO as do fall-run Chinook salmon, and steelhead are believed to require similar DO levels to complete migration. Therefore, the 6 mg/L boundary between stressful and detrimental conditions must apply during the spring migration season as well. DO concentrations above 8 mg/L were assumed to represent supportive conditions, and concentrations below 6 mg/L were detrimental. Between 6 and 8 mg/L was identified as stressful for migrating and holding adults.

[10] See http://www.sjrdotmdl.org/concept_model/about.htm and sources cited there.

#### *7.2.1.2.3 Dissolved Oxygen Objectives (Adult Upstream Migration)*

Table 20 provides a summary of DO objectives for adult upstream migration for Chinook salmon and steelhead.

**Table 20**
**Dissolved Oxygen Objectives for Chinook Salmon and Steelhead Adult Upstream Migration**

| Habitat Type | Temporal Extent | Condition | Range (Metric) |
|---|---|---|---|
| Delta to Holding/ Spawning Grounds (Main Channel) | Fall-run: Late September to December<br><br>Spring-run: March to June<br><br>Steelhead: September to April | Supportive | > 8 mg/L (Daily Minimum) |
| | | Stressful | 6 to 8 mg/L (Daily Minimum) |
| | | Detrimental | < 6 mg/L (Daily Minimum) |

### 7.2.1.3 Channel Depth

#### *7.2.1.3.1 Channel Depth Rationale (Adult Upstream Migration)*

Migrating adult salmonids require water of sufficient depth to facilitate upstream passage. Although migrating salmonids can transit areas with water that is less than their body depth, such conditions are not desirable as they cause stresses associated with the following:

- Increased drag and reduced swimming efficiency
- Low oxygen availability (if gills are exposed)
- Exposure to predators and poachers
- Abrasion on the riverbed
- Crowding
- Cumulative effect of these negative conditions

#### *7.2.1.3.2 Channel Depth Approach (Adult Upstream Migration)*

Riffles that do not provide depths greater than the body depth of an adult salmon between adjacent pools impede salmon migration. For many decades, the CDFW (2013) has used a protocol for determining minimum depth of the critical (most shallow) riffle, which is applied in higher-elevation waterways to determine necessary instream flows (depth increases with increased flow). The methodology for calculating necessary flows from estimates of critical riffle depth may not be applicable to low gradient, mainstem rivers. However, the criteria for estimating minimum depths and minimum extent of those depths in the shallowest riffle are relevant and likely conservative estimates for mainstem rivers. Indeed, to account for the long distances that migrating salmon must travel in mainstem rivers, the SEP Group has modified the CDFW criteria to include a longitudinal minimum depth (i.e., addressing depths in riffles up and downstream of the critical [shallowest] riffle).

The critical riffle methodology (as modified by the SEP Group) describes the boundary between stressful and detrimental conditions. In other words, this Environmental Objective describes the minimum allowable depth of the Stanislaus and lower San Joaquin rivers. A supportive depth distribution (in cross-section and longitudinally) has yet to be determined and would likely depend on factors, such as water temperature, clarity, DO, and velocity, and the density of salmon migrating during any particular period.

##### *7.2.1.3.3 Channel Depth Objectives (Adult Upstream Migration)*

The SEP Group developed the following depth objectives for adult upstream migration:

- Shallowest riffle (critical riffle):
  - At least 25% of the entire transect (perpendicular to flow) of the shallowest riffle in the migratory corridor will be deeper than or equal to 0.3 m (1 ft).
  - At least 10% of the entire transect will be contiguously greater than or equal to 0.3 m (1 ft; CDFW 2013).
- Frequency of shallow riffles:
  - 90% of the riffles in the migratory corridor must satisfy the requirements of the critical riffle for depths greater than or equal to 0.46 m (1.5 ft) instead of greater than or equal to 0.3 m (1 ft).

#### 7.2.1.4 Contaminants

##### *7.2.1.4.1 Contaminants Rationale (Adult Upstream Migration)*

The Stanislaus River, San Joaquin River, Delta, and San Francisco Bay have been identified as impaired for pesticides on the USEPA Clean Water Act Section 303(d) list (SWRCB 2010; USEPA 2011). In addition, mercury, selenium, and nutrients have been identified as impairing beneficial uses in the Stanislaus River, San Joaquin River, Delta, and San Francisco Bay (SWRCB 2010; USEPA 2011).

Contaminants have a high potential to adversely impact the successful completion of adult migration throughout the migratory corridor. However, mercury and selenium bioaccumulation in the ocean is likely low, and returning adults cease to eat during their migration, so there are low risks to adult salmonid migration from mercury and selenium (CEDEN 2014; though exposure earlier in the life cycle may impair adult performance). There is some evidence that other contaminants (e.g., hydrocarbons, metals, and automobile tire leachate) from urban runoff have caused pre-spawn mortality in salmonids in the Pacific Northwest (Scholz et al. 2011; McIntyre et al. 2015; Peter et al. 2018). However, there are no data that suggest a high occurrence of prespawn mortality or that these contaminants are at the levels that would impact up-migrating salmonids to the Stanislaus River. Therefore, pesticides and nutrients are the only contaminants that were analyzed by the SEP Group for direct impacts on adult salmon migration to and in the Stanislaus River.

Adult fish are typically less sensitive to pollutants than juveniles; however, pre-spawn adult salmonids are likely less tolerant of chemical stressors because they have used most of their accumulated fat stores for gamete production (NMFS 2008, 2010, 2013b). It is probable that some pre-spawn migrating adults will die because of short-term exposures to pesticides or nutrients (i.e., ammonia, nitrate, or nitrite), especially when subjected to additional stressors such as elevated temperatures. Pre-spawn mortality is a particularly important factor in the recovery of salmonid populations with low abundance because every adult is crucial to the population's reproductive potential and viability (NMFS 2013b).

Successful migration of adult fish may also be impeded by exposures to sub-lethal concentrations of pesticides and nutrients or indirect ecological impairments caused by excessive nutrients. For example, most pesticides—in addition to other chemical contaminants like metals—have been found to disrupt fish olfaction (Hansen et al. 2009; Scholz et al. 2000; Moore and Waring 2001). This disruption of the olfactory sense can eliminate the detection of natal waters or disrupt orientation in adult migrants, which can increase straying (Potter and Dare 2003; Scott and Sloman 2004). Pollutants have also been found to alter migration patterns and delay timing in adult migrating Atlantic salmon in the Maramichi River, Canada (Elson et al. 1972). Furthermore, contaminant exposures have been found to result in metabolic costs in fish that may decrease salmonids' ability to complete subsequent life history stages (Beyers et al. 1999; Coghlan and Ringler 2005).

Nutrients occur naturally; however, anthropogenic activities may elevate levels of certain nutrients or change the ratios among different nutrients, which can result in impairments to aquatic life. For example, ammonia, nitrite, and nitrate (to a lesser extent) have been found to be toxic to fish via disruption of oxygen transport by the blood (Russo et al. 1974; Camargo et al. 2005; USEPA 2013). Anthropogenic sources of nutrients (e.g., nitrogen and phosphorus) from activities like agriculture, urbanization, sewage treatment, and livestock operation have been shown to cause eutrophication in Central Valley rivers (Gowdy and Grober 2005; CVRWQCB 2018; Schlegel and Domagalski 2015). Detrimental impacts from eutrophication include increased temperatures, hypoxia, disrupted migratory corridors, and reduced habitat associated with macrophytes or the release of biotoxins by cyanobacteria or other phytoplankton (Gowdy and Grober 2005; Berg and Sutula 2015; Boyer and Sutula 2015; Schlegel and Domagalski 2015).

For more information on the rationale, approach, or objectives for contaminants, see Appendix C, Section 1.3.

#### 7.2.1.4.2 Contaminants Approach (Adult Upstream Migration)

The SEP Group relied on adopted numeric water quality objectives for pesticides from the Sacramento and San Joaquin River Water Quality Control Plan and proposed pesticide water quality objectives from developing pesticide control programs (CVRWQCB 2018) to determine pesticide levels that would not cause adverse impacts to adult migration. In addition, for pesticides that do not have state or federally promulgated objectives or criteria, the SEP Group used the USEPA Office of Pesticide Programs aquatic-life benchmarks with a level of concern for impacts to endangered and threatened species as the safe level for pesticides.

Unfortunately, no pesticide monitoring program exists throughout the migratory corridor for Stanislaus River salmonids, nor is there likely a program that will exist in the future that will be able to monitor all possible pesticides that may adversely impact adult salmonids during their migration to the Stanislaus River spawning area. Furthermore, the multitude of possible pesticide combinations, differing biochemical interactions of pesticides, and variations of direct and indirect effects preclude the possibility of quantifying the true impact of pesticides on salmonids in the Central Valley (e.g., the combined effect of direct and indirect impacts of all contaminants on the growth rates and survival of salmonids).

The SEP Group has relied on a pesticide prediction model (Hoogeweg et al. 2011) to estimate the current frequency of pesticide water quality objective or benchmark exceedances to categorize supportive, stressful, and detrimental conditions for adult migration pesticide Environmental Objectives. That is, the categories are an evaluation of the risks that a species is exposed to pesticide concentrations that could cause harm in a river reach; pesticide conditions were estimated and categorized for each month of the year. The categories assume that, while zero occurrences of pesticides are preferred, such low levels of exposure may not be achievable considering the amount of urban and agricultural development in the Central Valley. The SEP Group used this approach (i.e., frequency of water quality criteria or benchmark exceedances) for all Chinook and steelhead life history stages because data from this model are currently available, and the model can be readily updated with current pesticide use data. For more information or rationale for this approach, see Appendix C, Section 1.3.

Alternately, other models, monitoring, toxicity bioassays, or other information can be developed, conducted, or gathered in the future to determine if pesticide concentrations are adversely impacting salmonid migration (or other life history stages) to the Stanislaus River. For example, the CVRWQCB’s Delta Regional Monitoring Program pesticide monitoring includes the analyses for 150 current-use pesticides. Individual pesticide detections and concentrations can be compared to water quality objectives or other benchmarks to estimate detriments to different life history stages. However, other screening tools that incorporate the combined presence of pesticides, such as the Pesticide Toxicity Index (Nowell et al. 2014, 2018) or Species at Risk ($SPEAR_{pesticide}$) Index (Beketov et al. 2009; Hunt et al. 2017), would likely estimate ecological impacts more accurately. Both indices have been found to correlate with invertebrate community condition as well as other toxicity indicators.

Additionally, techniques currently used elsewhere for constituents of emerging concern could be used to predict toxicological impacts from traditional and emerging pesticides, unknown toxicants, mixtures of contaminants, etc. Bioanalytical screening assays and toxicity testing could be used to detect adverse biological effects during each life history stage (Anderson et al. 2012). When biological effects are observed, non-targeted chemical analyses can be used to identify the chemical or multiple chemicals that may be causing the effect. If these types of monitoring are conducted, then the pesticide or other contaminant environmental objectives can be developed and implemented (e.g., no detection of adverse biological effects or no toxics in toxic amounts) or these types of monitoring can verify expected decreases in toxicity as a result of reduced occurrences of pesticides in the river.

Nutrient imbalances can impair salmonid adult migration through direct toxicity and ecological use impairments, so the SEP Group used two approaches to develop nutrient Environmental Objectives. To evaluate the possible direct toxicity of ammonia, nitrite, and nitrate to salmonids in the Stanislaus River, the SEP Group relied on promulgated USEPA (2013) aquatic-life criteria for toxicological effects from ammonia and literature benchmarks for protective concentrations for nitrate and nitrite exposures. Phosphate does not appear to have direct toxicological impacts to fish or daphnids at ecologically relevant concentrations (Kim et al. 2013), so it is not considered further for this evaluation.

The second category of nutrient Environmental Objectives is ecological use impairments (e.g., migratory corridors), which would include nutrient imbalances that result in a reduction of beneficial habitat for salmonids. Recent efforts for evaluating environmental impacts from nutrients have moved away from the strict application of a single nutrient concentration criterion across broad landscapes or watersheds (USEPA 2000; Tetra Tech 2006). These efforts were developed, in part, because predefined nutrient limits could result in eutrophication in all waterbodies. The evaluation of appropriate nutrient levels requires the evaluation of aquatic beneficial uses needing protection, classification of waterbodies by type and trophic status, and consideration of other external environmental factors (USEPA 2000; Tetra Tech 2006). For example, an indirect way to evaluate possible nutrient impairments is to examine some of the detrimental outcomes of nutrient impairments (e.g., depressed DO, excessive macrophytes, or chlorophyll-a concentrations).

#### *7.2.1.4.3 Contaminants Objectives (Adult Upstream Migration)*

Pesticide water quality objectives and benchmark concentrations are displayed in Tables 21 and 22. Pesticide concentrations necessary to protect Chinook salmon and steelhead migration are expected to be similar. The supportive condition for pesticide occurrence is less than 1% chance of a pesticide exposure or exposure to a combination of pesticides that exceed water quality objectives or aquatic-life benchmarks in a given day of a month (Bin 1, Table 23). This frequency corresponds to the allowed frequency of exceedances to protect aquatic beneficial uses for current water quality objectives and criteria (40 Code of Federal Regulations [CFR] Part 131; CVRWQCB 2018).

**Table 21**
**Central Valley Regional Water Quality Control Board Adopted Water Quality Objectives and Triggers for Current Use Pesticides**

| Pesticide | Acute (µg/L) | Chronic (µg/L) |
|---|---|---|
| Adopted Water Quality Objectives[1] | | |
| Diazinon | 0.16 | 0.1 |
| Chlorpyrifos | 0.025 | 0.015 |
| Carbofuran | 40 | 40 |
| Simazine | 4 | 4 |
| Thiobencarb | 1 | 1 |
| Pentachlorophenol | 5.3 | 4 |
| Copper | 5.7 | 4.1 |
| Adopted Water Quality Triggers[1] | | |
| Bifenthrin | 0.0008 | 0.0001 |
| Cyfluthrin | 0.0008 | 0.0002 |
| Lambda cyhalothrin | 0.0007 | 0.0003 |
| Cypermethrin | 0.001 | 0.0003 |
| Esfenvalerate | 0.002 | 0.0003 |
| Permethrin | 0.006 | 0.001 |

Notes:
1. CVRWQCB 2018
µg/L: micrograms per liter

**Table 22**

**U.S. Environmental Protection Agency Office of Pesticide Programs' Aquatic-Life Benchmarks for the 40 Pesticides that Pose the Greatest Risk in the Central Valley Region**

| Pesticide | Pesticide Type | Acute Benchmark (µg/L) | Endangered and Threatened Acute Benchmark (µg/L) | Chronic Benchmark (µg/L) | Source of Acute/ Chronic Value[1] |
|---|---|---|---|---|---|
| Abamectin | Insecticide | 0.17 | 0.017 | 0.006 | IA/IC |
| Bifenthrin | Insecticide | 0.075 | 0.0075 | 0.0013 | FA/IC |
| Bromacil | Herbicide | 6.8 | 0.68 | 3000 | AA/FC |
| Captan | Fungicide | 13.1 | 1.31 | 16.5 | FA/FC |
| Carbaryl | Insecticide | 0.85 | 0.085 | 0.5 | IA/IC |
| Chlorothalonil | Fungicide | 1.8 | 0.18 | 0.6 | IA/IC |
| Chlorpyrifos | Insecticide | 0.05 | 0.005 | 0.04 | IA/IC |
| Clomazone | Herbicide | 167 | 16.7 | 350 | AA/FC |
| Copper hydroxide | Fungicide | 5.9 | 0.59 | 4.3 | IA/IC |
| Copper sulphide | Insecticide/Algaecide | 5.9 | 0.59 | 4.3 | IA/IC |
| Cyfluthrin | Insecticide | 0.0125 | 0.00125 | 0.007 | IA/IC |
| Cyhalofop butyl | Herbicide | 245 | 24.5 | 134 | FA/FC |
| Cypermethrin | Insecticide | 0.195 | 0.0195 | 0.069 | FA/IC |
| Deltamethrin | Insecticide | 0.055 | 0.0055 | 0.0041 | IA/IC |
| Diazinon | Insecticide | 0.11 | 0.011 | 0.17 | IA/IC |
| Dimethoate | Insecticide | 21.5 | 2.15 | 0.5 | IA/IC |
| Diuron | Herbicide | 2.4 | 0.24 | 26 | AA/FC |
| Esfenvalerate | Insecticide | 0.025 | 0.0025 | 0.017 | IA/IC |
| Hexazinone | Herbicide | 7 | 0.7 | 17000 | AA/FC |
| Imidacloprid | Insecticide | 35 | 3.5 | 1.05 | IA/IC |
| Indoxacarb | Insecticide | 12 | 1.2 | 3.6 | FA/IC |
| Lambda cyhalothrin | Insecticide | 0.0035 | 0.00035 | 0.002 | IA/IC |
| Malathion | Insecticide | 0.3 | 0.03 | 0.035 | IA/IC |
| Mancozeb | Fungicide | 47 | 4.7 | N/A | AA/na |
| Maneb | Fungicide | 13.4 | 1.34 | N/A | AA/na |
| Methomyl | Insecticide | 2.5 | 0.25 | 0.7 | IA/IC |
| (s)-Metolachlor | Herbicide | 8 | 0.8 | 30 | AA/FC |
| Naled | Insecticide | 25 | 2.5 | 0.045 | AA/IC |
| Oxyfluorfen | Herbicide | 0.29 | 0.029 | 1.3 | AA/FC |
| Paraquat | Herbicide | 0.396 | 0.0396 | N/A | AA/na |
| Pendimethalin | Herbicide | 5.2 | 0.52 | 6.3 | AA/FC |
| Permethrin | Insecticide | 0.01 | 0.001 | 0.0014 | IA/IC |
| Propanil | Herbicide | 16 | 1.6 | 9.1 | AA/FC |
| Propargite | Insecticide | 37 | 3.7 | 9 | IA/IC |
| Pyraclostrobin | Fungicide | 0.0015 | 0.00015 | 0.002 | FA/FC |
| Simazine | Herbicide | 36 | 3.6 | 960 | AA/FC |
| Thiobencarb | Herbicide | 17 | 1.7 | 1 | AA/IC |

| Pesticide | Pesticide Type | Acute Benchmark (µg/L) | Endangered and Threatened Acute Benchmark (µg/L) | Chronic Benchmark (µg/L) | Source of Acute/ Chronic Value[1] |
|---|---|---|---|---|---|
| Tralomethrin | Insecticide | 0.055 | 0.0055 | 0.0041 | IA/IC |
| Trifluralin | Herbicide | 7.52 | 0.752 | 1.14 | AA/FC |
| Ziram | Fungicide | 9.7 | 0.97 | 39 | FA/IC |

Notes:

1. Identifies which taxa was the most sensitive to the pesticide from available toxicity evaluations defined as FA = fish acute; IA = invertebrate acute; AA = Algae Acute; FC = fish chronic; IC = invertebrate chronic; na = not available.

Sources: USEPA Office of Pesticide Programs. Table modified from Hoogeweg et al. (2011).

Aquatic-life benchmarks are used by the USEPA Office of Pesticide Programs for risk assessments in the registration of pesticides. To assess a pesticide not listed, the entire list of nearly 500 pesticide benchmarks can be acquired at https://www.epa.gov/pesticide-science-and-assessing-pesticide-risks/aquatic-life-benchmarks-pesticide-registration

**Table 23**

**Categories of Predicted Pesticide Aquatic-Life Benchmark Exceedances**

| Bin Category | Condition | Range of the Frequency of Benchmark Exceedances | | |
|---|---|---|---|---|
| 1 | Supportive | 0 | – | 0.017 |
| 2 | Stressful | 0.018 | – | 0.055 |
| 3 | | 0.056 | – | 0.1 |
| 4 | | 0.101 | – | 0.153 |
| 5 | | 0.154 | – | 0.206 |
| 6 | | 0.207 | – | 0.303 |
| 7 | Detrimental | 0.304 | – | 0.447 |
| 8 | | 0.448 | – | 0.5 |
| 9 | | 0.501 | – | 0.589 |
| 10 | | 0.59 | – | 0.994 |

Note:

Frequencies were calculated from the total number of predicted exceedance days for each month from 2000 to 2009. Any day that had at least one pesticide that exceeded benchmarks was counted as an exceedance day.

Source: Adapted from Hoogeweg et al. 2011

It is estimated that exposure of salmon to pesticides 30% of the time would impede olfaction enough to reduce the intrinsic population growth by 2% (1.08 versus the 1.1 control; Baldwin et al. 2009). Furthermore, a 2% reduction in intrinsic population growth is estimated to reduce salmon population more than 30% over 20 years. Assuming that the frequency of pesticide exposures has a similar impact on salmonid physiology and responses across all life history stages, exposures of pesticides greater than 30% (Bins 7 – 10, Table 23) would represent detrimental conditions. Accordingly, stressful conditions would include Bins 2 – 6, Table 23. See Appendix C, Section 1.3.3.1 for more information.

Environmental Objectives for ammonia, nitrate, and nitrite toxicity (nutrient toxicity) are provided in Table 24. The USEPA (2013) has promulgated aquatic-life ambient water quality criteria for ammonia for the protection of sensitive species, including salmonids. The USEPA has not developed water quality criteria for protection from direct toxicity to fish or other aquatic life for nitrate or nitrite, so the SEP relied on literature benchmarks for these constituents. The toxicity of ammonia, nitrate, and nitrite are highly dependent on other environmental factors (e.g., pH, temperature, and DO). Therefore, an evaluation of the environmental conditions will require a consideration of these other factors.

**Table 24**
**Nutrient Toxicity Objectives for All Life History Stages of Chinook Salmon and *O. mykiss***

| Nitrogen Species | Maximum Average Continuous Concentration |
|---|---|
| Ammonia[1] | 2.8 mg total $NH_3$-N/L @ pH 7 and 14°C (57°F) |
| Nitrate[2] | 2 mg $NO_3$-N/L |
| Nitrite[3] | 0.06 mg $NO_2$-N/L |

Notes:

1. USEPA (2013) *Aquatic Life Ambient Water Quality Criteria for Ammonia – Freshwater 2013.* Ammonia toxicity is temperature- and pH-dependent. Actual ammonia limits can be calculated using the following equation:

$$CCC = 0.8876 \times \left(\frac{0.0278}{1 + 10^{7.688-pH}} + \frac{1.1994}{1 + 10^{pH-7.688}}\right) \times \left(2.126 \times 10^{0.028 \times (20-MAX(T,7))}\right)$$

2. Camargo et al. (2005)
3. Russo et al. (1974)

– (Ammonia) $NH_3$ -N/L = milligrams of ammonium as nitrogen per liter
– (Nitrite) $NO_2$-N/L = milligrams of nitrite as nitrogen per liter
– (Nitrate) $NO_3$ – N/L = milligrams of nitrate as nitrogen per liter

The USEPA (2000) has provided guidance for developing nutrient criteria for rivers and streams. The generalized environmental conditions that define oligotrophic, mesotrophic, and eutrophic lotic systems are displayed in Table 25. The San Diego Regional Water Quality Control Board adopted water quality objectives for nitrate (10 mg/L), total nitrogen (1 mg/L), and total phosphorus (0.1 mg/L)—not to be exceeded 10% of the time—as part of a Rainbow Creek nutrient total maximum daily load (SDRWQCB 2006). These objectives are waterbody-specific, but they can be used as a general level of nutrients that may cause impairments to aquatic life beneficial uses. Nutrient concentrations and other environmental conditions (e.g., DO and primary productivity metrics) should be assessed in combination to determine ecological support for adult upstream migration.

**Table 25**
**Suggested Boundaries for Trophic Classifications of Lotic Systems**

| Variable (Units) | Oligotrophic to Mesotrophic Boundary | Mesotrophic to Eutrophic Boundary |
|---|---|---|
| Mean benthic chlorophyll ($mg/m^2$) | 20 | 70 |
| Maximum benthic chlorophyll ($mg/m^2$) | 60 | 200 |
| Sestonic chlorophyll (µg/L) | 10 | 30 |
| Total nitrogen (µg/L) | 700 | 1,500 |
| Total phosphorus (µg/L) | 25 | 75 |

Note:
$mg/m^2$: milligrams per square meter
Source: USEPA 2000

## 7.2.2 Adult Holding

Spring-run Chinook salmon migrate upstream in the spring and require deep, cool, well-oxygenated water during the summer months while they rest and wait to spawn in the early fall. Adult *O. mykiss* also require cool, well-oxygenated water in which to hold as they await the spawning period during the summer months. The holding behavior among fall-run Chinook salmon is abbreviated, relative to the length of the holding period for spring-run and *O. mykiss*; however, fall-run may spawn days to weeks after arriving on the spawning grounds, so they too require adequate holding conditions. During these resting periods, salmonids seek to minimize energy expenditures by avoiding high temperatures, high velocities, low oxygen, and disturbances from predators or people.

Environmental objectives for the adult holding life history stage were established for temperature, DO, water depth and velocity, and contaminants. No objectives were developed for potential disturbance (people and predators) or distribution of holding habitat as these parameters seem unlikely to adversely impact oversummering adult salmonids in the current and future states of the Stanislaus River. The objectives and supporting rationale for each of these parameters are discussed below. A summary of Environmental Objectives is provided in Table B-2 of Appendix B.

### 7.2.2.1 Temperature (Adult Holding)

#### *7.2.2.1.1 Temperature Rationale (Adult Holding)*

Supportive water temperatures during the holding stage will allow adult salmon to maintain a low metabolic rate. High temperatures during holding can increase their metabolic rate to a point where sufficient energy reserves will not be available for the rigors of digging redds, spawning, and nest guarding. Elevated pre-spawn mortality can occur if water temperatures are too high during the holding period (McCullough 1999).

#### *7.2.2.1.2 Temperature Approach (Adult Holding)*

As described in detail in Appendix C (Section 1.1.2), the SEP Group relied primarily on USEPA (2003) guidance for temperature effects on Pacific salmon.

#### *7.2.2.1.3 Temperature Objectives (Adult Holding)*

The USEPA (2003) reports reduced viability of gametes in holding adult salmonids at constant temperatures in excess of 13°C (55.4°F). While lethal temperatures (1-week constant exposure) range from 23°C to 26°C (73.4°F to 78.8°F), disease risk is high at 18°C to 20°C (64.4°F to 68°F). Sustained water temperatures above 27°C (80.6°F) are lethal to adult spring-run Chinook salmon (Moyle et al. 1995). Temperature objectives are provided in Table 26.

**Table 26**
**Temperature Objectives for Chinook Salmon and *O. mykiss* Adult Holding**

| Habitat Type | Temporal Extent | Condition | Range (Metric) |
|---|---|---|---|
| Main Channel | April through September | Supportive | < 13°C (55.4°F) (Daily Average) |
| | | | < 14.5°C (58.1°F) (7DADM) |
| | | Stressful | 13°C to 17°C (55.4°F to 62.6°F) (Daily Average) |
| | | | 14.5°C to 18.5°C (58.1°F to 65.3°F) (7DADM) |
| | | Detrimental | > 18°C (64.4°F) (Weekly Average) |
| | | | > 19°C (66.2°F) (Daily Average) |
| | | | 20.5°C (68.9°F) (7DADM) |
| | | | > 22°C (71.6°F) (Instantaneous) |

### 7.2.2.2 Dissolved Oxygen (Adult Holding)

#### *7.2.2.2.1 Dissolved Oxygen Rationale (Adult Holding)*

Low levels of DO can result in adverse physiological effects on salmonids, up to and including death. Low DO levels can be associated with high nutrient inputs; contaminated runoff from urban, industrial, or agricultural lands; or mass die-offs of algal species.

#### *7.2.2.2.2 Dissolved Oxygen Approach (Adult Holding)*

The SEP Group used the same approach for holding habitat as was used for upstream migration (Section 7.2.1.2.2).

#### *7.2.2.2.3 Dissolved Oxygen Objectives (Adult Holding)*

The SEP Group used the same objectives for holding habitat as was used for upstream migration (Section 7.2.1.2.3); however, these objectives are applied only to habitats upstream of Oakdale (Table 27).

**Table 27**
**Dissolved Oxygen Objectives for Chinook Salmon and *O. mykiss* Adult Holding**

| Habitat Type | Temporal Extent | Condition | Range (Metric) |
|---|---|---|---|
| Main Channel | April through September | Supportive | > 8 mg/L (Daily Minimum) |
| | | Stressful | 6 to 8 mg/L (Daily Minimum) |
| | | Detrimental | < 6 mg/L (Daily Minimum) |

## 7.2.2.3 Water Depth and Velocity (Adult Holding)

Water velocity experienced by adults during holding should be low enough so that little energy is expended. Spring-run Chinook salmon may hold for several months in a stream prior to spawning, so it is essential that they limit how much energy they use during this period. Water depth should be sufficient to provide cover and refuge from predators and human disturbance.

### *7.2.2.3.1 Water Depth and Velocity Rationale (Adult Holding)*

Holding adult salmon seek to maximize energy reserves through occupying habitats with minimal nonzero velocities. Energy expended to hold position is energy not available for redd construction, spawning, and redd defense. Disturbance by predators or humans result in flight response of fish seeking to escape, using additional energy beyond that necessary to hold position.

### *7.2.2.3.2 Water Depth and Velocity Approach (Adult Holding)*

The depth of the river should provide sufficient cover to hide from predators. Spring-run Chinook salmon hold in pools that are at least 1 m to 3 m (3.3 ft to 9.8 ft) deep (Moyle et al. 1995) and usually greater than 2 m (6.6 ft) deep (Moyle 2002).

Holding pools for adult spring-run Chinook salmon have been characterized as having moderate water velocities ranging from 0.15 meter per second (m/s) to 0.4 m/s (0.5 feet per second [ft/s] to 1.3 ft/s; DWR et al. 2000). According to Moyle (2002), the adults prefer mean water column velocities of 0.15 m/s to 0.8 m/s (0.49 ft/s to 2.6 ft/s).

Holding pools usually have a large bubble curtain at the head, underwater rocky ledges, and shade cover throughout the day. Adult spring-run Chinook salmon also seek cover in smaller “pocket” water behind large rocks in fast water (Moyle et al. 1995).

### *7.2.2.3.3 Water Depth and Velocity Objectives (Adult Holding)*

Targets for depth and velocity are presented in Table 28.

**Table 28**
**Depth and Velocity Objectives for Chinook Salmon Adult Holding**

| Habitat Type | Temporal Extent | Variable | Supportive Condition |
|---|---|---|---|
| Main Channel | April through September | Depth | ≥ 1.5 m (4.9 ft) |
| | | Velocity | < 0.37 m/s (1.2 ft/s) |

### 7.2.2.4 Contaminants (Adult Holding)

#### *7.2.2.4.1 Contaminants Rationale (Adult Holding)*

Water quality conditions can impact survival during the salmonid holding period. Studies in the Pacific Northwest have shown high pre-spawn mortality in Coho salmon due to urban contaminants such as in stormwater runoff (Feist et al. 2011; Scholz et al. 2011). In addition to pesticides, urban runoff contaminants often include metals, petroleum, and other compounds. However, unlike pesticides, there is no evidence that these other types of contaminants are currently causing an adverse impact in the holding reaches in the Stanislaus River. Consequently, no Environmental Objectives for these other contaminants are addressed in this report. However, contaminant exposures have been found to result in metabolic costs in fish that may decrease the ability of salmonids to complete subsequent life history stages (Beyers et al. 1999; Coghlan and Ringler 2005). Thus, urban runoff and other non-point discharges should occasionally be assessed in the future to confirm that there are no adverse impacts to salmonids.

Nutrient constituents (i.e., ammonia, nitrate, and nitrite) can cause direct toxicity to holding salmonids. Similar to adult migration, excessive nutrients can result in adverse environmental conditions that reduce the fitness and survival of holding adults (e.g., low DO or elevated temperatures).

#### *7.2.2.4.2 Contaminants Approach (Adult Holding)*

For a discussion of the SEP Group's approach to setting pesticide objectives and objectives for concentrations of nitrogen-based nutrients, see Section 7.2.1.4.2.

#### *7.2.2.4.3 Contaminants Objectives (Adult Holding)*

Pesticide water quality objectives and benchmark concentrations are displayed in Tables 21 and 22. Pesticide concentrations necessary to protect Chinook salmon and *O. mykiss* holding are expected to be similar. Based on the described approach of pesticide Environmental Objectives, the supportive condition for pesticide occurrence would be less than a 1% chance (Bin 1, Table 23) of a pesticide exposure, or exposure to a combination of pesticides that exceed water quality objectives, or aquatic-life benchmarks in a given day of a month. This frequency corresponds to the allowed frequency of exceedances to protect aquatic beneficial uses for current water quality objectives and criteria (40 CFR Part 131; CVRWQCB 2018).

It is estimated that salmon exposed to pesticides at a frequency 30% of the time would impede olfaction enough to reduce the intrinsic population growth by 2% (1.08 versus the 1.10 control; Baldwin et al. 2009). Furthermore, a 2% reduction in intrinsic population growth is estimated to reduce salmon population more than 30% over 20 years. Assuming that the frequency of pesticide exposures has a similar impact on salmonid physiology and responses across all life history stages, exposures of pesticides greater than 30% (Bins 7 – 10, Table 23) would represent detrimental conditions. Accordingly, stressful conditions would include Bins 2 – 6, Table 23. See Appendix C, Section 1.3.3.1 for more information.

Ammonia, nitrate, and nitrite concentrations necessary to protect holding adult salmonids are provided in Table 24.

### *7.2.3 Spawning*

Salmonids in the Pacific portion of North America have evolved a life history that requires rivers and streams with relatively high gradients for reproduction and rearing. These waterways are cold, low in trace elements, low in nutrients, and high in DO. Movement within the sediment is adequate to disperse fine materials to lower elevations and larger pools more quickly than the larger sediments, resulting in sorting of sediment differentially in low and high velocity waters. Factors, such as high water temperatures, high spawner densities, and presence of pathogens, can contribute to prespawn mortality or high rates of egg retention in females (Quinn et al. 2007).

The extensive building of large dams resulted in alteration of spawning habitats (Ligon et al. 1995). The dams impede migration of adult salmonids to high elevation spawning areas. At the same time, dams alter a river’s hydrograph and sediment supply, reducing movement and availability of large sediment downstream of the dam and allowing fine sediment to settle into interstitial spaces among gravel and cobble. This altered geomorphology reduces the suitability of any remaining spawning habitat downstream of a dam. Studies often focus on changes in the purely structural aspects of spawning habitat downstream of dams (i.e., habitat quantity). For example, Hanrahan et al. (2004) evaluated spawning habitat in a large drainage area in the Columbia River system. The spawning habitat parameters Hanrahan et al. (2004) considered were typical: depth, velocity, substrate, and channel-bed slope.

Dams also alter water quality aspects of salmon spawning habitat. Water retained behind the dam for extended periods can have high levels of nutrients and trace elements that are toxic to various salmonid life history stages. Water stored behind a dam also absorbs heat, causing temperatures to rise and DO levels to drop when it is released downstream. These changes in water quality caused by dams often create physiological stress on the salmonids using the river below the dam.

The structure of redds requires specific characteristics for sediment, water quality, and placement of the redd within the river's geomorphology (Tonina and Buffington 2009). Free-flowing rivers develop an alternating pool/riffle sequence structure that gives a non-uniform distribution of sediment within the river. The faster moving riffles have coarser sediment than the slower flowing pool areas. Redds are generally built in the faster moving water that occurs in the coarse sediment areas, at the top and bottom of the riffles. The distribution of sediment sizes, along with water velocity and depth, are essential components of spawning habitat. Redd distribution in a river is patchy, reflecting the non-uniform distribution of sediment. Availability of coarse substrate (up to 10% of body length), swift water flow, and the structure of a redd are important to maintaining water quality in the nest for egg development (Tonina and Buffington 2009; Merz et al. 2013). In addition, redd placement at the top or bottom of the riffles increases the percolation of water through the redd, thus improving water quality and increasing survival of eggs over the 1.5 to 3 months of development. Stressful conditions can negatively affect spawning success.

There is evidence that salmon production in the Stanislaus River is limited by carrying capacity constraints, particularly in dry years (Figure 4). The apparent limit on juvenile production in dry years suggests that limited available habitat constrains success in spawning and egg development, or juvenile rearing, or both.

Parameters considered important in this review of spawning habitat are quantity and quality of available habitat, as defined by temperature, DO, water flow (depth and velocity), availability of coarse sediment (sediment size distribution), habitat quantity and distribution, and contaminants (pesticides and trace elements). Supportive levels of some of these parameters vary between species (gravel particle size distribution, depth, velocity, and temperature), while the criteria for DO, pesticides, and trace element contaminants are the same for both species. Most of the variation between species is a result of differences in body size, which has often been identified as the primary factor affecting variance in salmonid spawning habitat (Kondolf 2000; Zeug et al. 2013). Body size determines the preferred particle size distribution that makes up quality spawning habitat.

### 7.2.3.1 Temperature (Spawning)

#### *7.2.3.1.1 Temperature Rationale (Spawning)*

The background and development of these temperature objectives are discussed in Appendix B, Section 1.1. Adult spawning Chinook salmon and *O. mykiss* temperature needs are generally similar to their eggs. Considerations specific to spawning habitat include temperature triggers for spawning and potential thermal stress that could lead to high rates of prespawn mortality and egg retention. In general, the temperature criteria for eggs are protective of spawning and the subsequent egg development phase.

#### *7.2.3.1.2 Temperature Approach (Spawning)*

Salmonid eggs and larvae require cold water to successfully complete development. With the construction of impassable dams, Chinook salmon spawning in the San Joaquin Valley became dependent on releases of coldwater from reservoirs to provide sufficient conditions to protect their developing eggs. The accessible supply of coldwater in reservoirs limits successful spawning habitat for Chinook salmon populations in the Central Valley in general, and the San Joaquin River basin in particular.

USEPA (2003) found that constant temperatures between 4°C to 12°C (39.2°F to 53.6°F) result in good egg survival and that a narrower range (6°C to 10°C [42.8°F to 50°F]) is supportive; a 7DADM of less than 13°C (55.4°F) is recommended (Table 29 in Section 7.2.3.1.3). In a review, Myrick and Cech (2004) concluded that temperature-related egg mortality in Chinook salmon increased at temperatures above 13.3°C (55.9°F), and this is the limit applied in most regulatory arenas (e.g., NMFS 2009b; SWRCB Order 90-05). A review of research on different populations of Chinook salmon from within and outside of the Central Valley indicated that temperatures between 6°C and 12°C (42.8°F to 53.6°F) were supportive for Central Valley Chinook salmon (Myrick and Cech 2004).

As with Chinook salmon, *O. mykiss* eggs and larvae require cold water to successfully complete development. With the construction of impassable dams, *O. mykiss* eggs developing in the San Joaquin Valley became dependent on coldwater releases from reservoirs. The accessible supply of coldwater storage limits successful spawning habitat for *O. mykiss* populations in the southern Central Valley. Additional study of temperature impacts on *O. mykiss* eggs is needed (Myrick and Cech 2004).

Supportive egg development temperatures for *O. mykiss* occur in a narrower range than those for Chinook salmon. Indeed, Myrick and Cech (2004) warned against managing water temperatures for the upper end of the Chinook salmon thermal tolerance range in waterways and during periods when *O. mykiss* eggs are also developing because developing *O. mykiss* cannot tolerate such high temperatures. Richter and Kolmes (2005) concluded that egg mortality increased as development temperatures exceeded 10°C (50°F), and substantial mortality may occur when temperatures exceed 13.5°C to 14.5°C (56.3°F to 58.1°F). Based on experience at hatcheries in the Central Valley, supportive egg development temperatures appear to be in the 7°C to 10°C (44.6°F to 50°F) range (Myrick and Cech 2004). California's steelhead management plan (McEwan and Jackson 1996) suggests a slightly higher temperature range (from 9°C to 11°C [48.2°F to 51.8°F]).

### 7.2.3.1.3 Temperature Objectives (Spawning)

Temperature objectives for Chinook salmon and *O. mykiss* spawning are provided in Tables 29 and 30.

**Table 29**
**Temperature Objectives for Chinook Salmon Spawning**

| Habitat Type | Temporal Extent | Condition | Range (Metric) |
|---|---|---|---|
| Spawning Gravel | Fall-run: Late October to March<br><br>Spring-run: Late August to March | Supportive | 6°C to 12°C (42.8°F to 53.6°F) (Daily Average) |
| | | | < 12.5°C (< 54.5°F) (7DADM) |
| | | Stressful | 4°C to 6°C (39.2°F to 42.8°F) (Daily Average)) |
| | | | 12°C to 13.3°C (53.6°F to 55.9°F) (Daily Average) |
| | | | 12.5°C to 13.8°C (54.5°F to 56.8°F) (7DADM) |
| | | Detrimental | > 13.3°C (55.9°F) (Daily Average) |
| | | | > 13.8°C (56.8°F) (7DADM) |

**Table 30**
**Temperature Objectives for *O. mykiss* Spawning**

| Habitat Type | Temporal Extent | Condition | Range (Metric) |
|---|---|---|---|
| Spawning Gravel | December to June | Supportive | 7°C to 10°C (44.6°F to 50°F) (Daily Average) |
| | | | 10.5°C (50.9°F) (7DADM) |
| | | Stressful | 4°C to 7°C (39.2°F to 44.6°F) (Daily Average) |
| | | | 10°C to 13.5°C (50°F to 56.3°F) (Daily Average) |
| | | | 10.5°C to 14.0°C (50.9°F to 57.2°F) (7DADM) |
| | | Detrimental | > 13.5°C (56.3°F) (Daily Average) |
| | | | > 14.0°C (57.2°F) (7DADM) |

## 7.2.3.2 Dissolved Oxygen (Spawning)

### 7.2.3.2.1 Dissolved Oxygen Rationale (Spawning)

The background and development of these DO objectives are discussed in Appendix B, Section 1.2. Adult spawning Chinook salmon and *O. mykiss* DO needs are generally similar to their eggs. However, the eggs are more sensitive to oxygen minima. Since the result of spawning is the production of eggs, the DO criteria for eggs becomes the limiting factor for spawning. Therefore, the spawning DO objective in Section 7.2.3.2.3 is the same as the DO objective identified for egg development.

#### 7.2.3.2.2 *Dissolved Oxygen Approach (Spawning)*

The summaries of egg development mortality through hatching and development growth rates (Section 7.2.4.1.2) provide rationale for the DO objectives identified in Section 7.2.3.2.3.

#### 7.2.3.2.3 *Dissolved Oxygen Objectives (Spawning)*

The DO objectives for Chinook salmon and *O. mykiss* spawning are provided in Table 31.

**Table 31**
**Dissolved Oxygen Objectives for Chinook Salmon and *O. mykiss* Spawning**

| Habitat Type | Temporal Extent | Condition | Range (Metric) |
|---|---|---|---|
| Gravel (measurement must occur in gravel, not water column) | Fall-run: Late October to March<br><br>Spring-run: Late August to March<br><br>*O. mykiss*: December to June | Supportive | > 8 mg/L (Daily Minimum) |
| | | Stressful | 6 to 8 mg/L (Daily Minimum) |
| | | Detrimental | < 6 mg/L (Daily Minimum) |

### 7.2.3.3 Depth and Velocity (Spawning)

#### 7.2.3.3.1 *Depth and Velocity Rationale (Spawning)*

Depth and velocity of water are two components of salmonid spawning habitat that salmonids can detect. As such, these parameters are considered core components of spawning habitat for salmon and *O. mykiss* (Hanrahan et al. 2004). These two habitat features have been part of the definition of salmonid spawning habitat for more than 50 years (Wickett 1958; Thompson 1972; Bovee 1978). As a result, these habitat features have become important to a form of river habitat evaluation called IFIM/PHABSIM (for early work on Stanislaus River, see Aceituno 1993). Recent work has been performed on the Stanislaus River modeling discharge-habitat relationships for rearing salmonids (Bowen et al. 2012).

#### 7.2.3.3.2 *Depth and Velocity Approach (Spawning)*

The tool used to describe depth and velocity is referred to as the habitat suitability index (HSI) or habitat suitability criteria. Both refer to a curve that represents the relative usefulness of particular depth (y-axis) or velocity (x-axis) for spawning by ascribing an index value of 0 to 1 (0 = useless, 1 = most preferred). These HSI charts are developed from measurements of actual redd locations (e.g., Gard 2006), which are then used to produce a probability curve with the x-axis representing the increments of the measured component that were used (such as depth) and the y-axis showing the percent of redds that fell in that increment. If a large sample of redd measurements is made, the probability curves for the depths and velocities can become the HSI by making the highest probability equal to 1 and adjusting all other values equally (essentially dividing by maximum probability). The depth and velocity spawning criteria are based on the assumptions that an HSI greater than 0.6 is supportive, all other values of habitat used are stressful ($0 < \text{HSI} \leq 0.6$), and all values outside of the range used by salmonids are considered detrimental (which is essentially habitat that cannot be used for spawning). In this context, "non-habitat" is a better term than "detrimental."

Chinook salmon have been observed spawning in a broad range of water depths (0.15 m to 4.6 m [0.5 ft to 15 ft]), although the preferred range is approximately 0.61 m (2 ft) deep for fall-run (Gard 2006). Using these data, supportive habitat is 0.3 m to 0.76 m (1 ft to 2.5 ft) in depth, with stressful ranging from 0.15 m to 0.3 m (0.5 ft to 1 ft) on the shallow end and 0.76 m to 3.05 m (10 ft) in deeper water. Although spawning has been observed to depths of nearly 4.6 m (15 ft), very few observations of spawning have been made in water greater than 3.05 m (10 ft) deep.

Gard (2006) found that supportive water velocity ranged from 0.3 m/s to 1.2 m/s (1 ft/s to 4 ft/s). Outside of that range, velocities down to 0.12 m/s (0.4 ft/s) and up to 1.5 m/s (5 ft/s) could support some spawning, but should be considered stressful. Gard (2006) had few observations of spawning at velocities greater than 1.2 m/s (4 ft/s); thus, 1.2 m/s (4 ft/s) should be considered the upper limit of spawning.

For *O. mykiss*, depth and velocity requirements are slightly lower than those requirements for Chinook salmon due to the smaller average size of adult *O. mykiss*. Bovee (1978) indicated depths of 0.36 m (1.17 ft) on average (range of 0.15 m to 0.61 m [0.5 ft to 2 ft]) were satisfactory, and these results are supported by more recent literature (Hannon 2015, pers. comm.). As with Chinook salmon, *O. mykiss* are more sensitive to water velocity than depth when selecting redd locations.

Velocities during spawning of 0.3 m/s to 1.1 m/s (1 ft/s to 3.6 ft/s) are recommended for the Central Valley (Hannon 2015, pers. comm.). Bovee (1978 as cited by McEwan and Jackson 1996 and USFWS 1995) found 0.61 m/s (2 ft/s) was the preferred velocity, and Reynolds et al. (1993) found 0.46 m/s (1.5 ft/s) was preferred. Stressful velocities are identified as a very small range at the lower end of the velocities; flows outside that overall range are considered to be detrimental or "non-habitat."

#### *7.2.3.3.3 Depth and Velocity Objectives (Spawning)*

Depth and velocity objectives for Chinook salmon and *O. mykiss* spawning (eggs and larvae) are provided in Tables 32 and 33.

**Table 32**
**Depth and Velocity Objectives for Chinook Salmon Spawning**

| Habitat Type | Temporal Extent | Condition | Range (metric) |
|---|---|---|---|
| Spawning Gravel | Fall-run: Late October to December<br><br>Spring-run: Late August to October | Supportive | Depth: 0.3 m to 0.76 m (1 ft to 2.5 ft) |
| | | | Velocity: 0.3 m/s to 1.2 m/s (1 ft/s to 4 ft/s) |
| | | Stressful | Depth: 0.15 m to 0.3 m (0.5 ft to 1 ft) and 0.76 m to 3.05 m (2.5 ft to 10 ft) |
| | | | Velocity: 0.12 m/s to 0.3 m/s (0.4 ft/s to 1 ft/s) |
| | | Detrimental | Depth: < 0.15 m (< 0.5 ft) or > 3.05 m (> 10 ft) |
| | | | Velocity: < 0.12 m/s (< 0.4 ft/s) or > 1.5 m/s (> 5 ft/s) |

**Table 33**
**Depth and Velocity Objectives for *O. mykiss* Spawning**

| Habitat Type | Temporal Extent | Condition | Range (metric) |
|---|---|---|---|
| Spawning Gravel | December to April | Supportive | Depth: 0.15 m to 0.61 m (0.5 ft to 2 ft) |
| | | | Velocity: 0.5 m/s to 1.1 m/s (1.6 ft/s to 3.6 ft/s) |
| | | Stressful | Depth: 0.08 m to 0.15 m (0.26 ft to 0.5 ft) and 0.61 m to 1 m (2 ft to 3.3 ft) |
| | | | Velocity: 0.32 m/s to 0.4 m/s (1.1 ft/s to 1.3 ft/s) |
| | | Detrimental | Depth: < 0.08 m (0.26 ft) or > 1 m (> 3.3 ft) |
| | | | Velocity: < 0.3 m/s (< 0.98 ft/s) or > 1.2 m/s (> 4 ft/s) |

### 7.2.3.4 Sediment Size Distribution

#### *7.2.3.4.1 Sediment Size Distribution Rationale Sediment Size Distribution*

Sediment size is an important consideration in the construction of redds. The female fish must be able to move most of the coarse sediments at the chosen site with a fanning of her tail. There is a long history and a large number of evaluations of coarse sediment available for review (Reiser and Bjornn 1979; Barnhart and Parsons 1986; Healey 1991; Williams 2006). These evaluations indicate a large variation in the extent sizes of gravel considered appropriate by salmon for spawning. Much of this variation is a result of varying size of the females.

#### *7.2.3.4.2 Sediment Size Distribution Approach (Spawning)*

Coarse gravel is essential for holding salmonid eggs in the redd without blocking the water flow necessary to provide oxygen to developing eggs. Kondolf and Wolman (1993) give an extensive review of studies to identify characteristics of gravel that are chosen by salmonids (also see

Kondolf 2000; Riebe et al. 2014). Kondolf and Wolman (1993) looked at a variety of gravel size metrics and species. The two species were differentiated based on size. Supportive grain size for a salmon redd varied with the size of the female. The largest size of a female for *O. mykiss* was assumed to be 600 mm (23.6 in). The largest assumed size for Chinook salmon was assumed to be 1,000 mm (39.4 in). For the purposes of this report, the D50 metric (median grain diameter) was used to determine appropriate grain sizes, as reported by Kondolf and Wolman (1993) and Kondolf (2000).

Based on reports by Kondolf and Wolman (1993) and Kondolf (2000), average values for D50 were abstracted in two ways. Kondolf and Wolman (1993) presented box-and-whisker plots that summarized the distribution of gravel sizes used for spawning by salmonids from a large number of studies for each species. Using these plots, the supportive level for each species was defined as the interquartile range, or that from the lower 25% (D25) to the upper 75% (D75) of the distribution of gravel sizes. For Chinook, this gives a range from 48 mm to 22 mm (1.89 in to 0.87 in). For *O. mykiss*, the range is from 25 mm to 15 mm (0.98 in to 0.59 in). The full range of the distribution of gravel sizes used for spawning by salmonids was then used to define the stressful ranges: Chinook salmon run from 80 mm to 10 mm (3.15 in to 0.39 in) and *O. mykiss* from 48 mm to 10 mm (1.89 in to 0.39 in).

The second method for determining the supportive and stressful values was derived from the relationship between female size and D50 of sediment, as presented in Figure 5 by Kondolf (2000). The optimum range was defined as the values between the best fit line (average for all values) and half the distance between the best fit line and upper envelope curve limit line. The full range is from the lowest value recorded for females of a given size to the upper envelope curve limit line. Stressful values are all the values in the full range that are outside the optimum range. Using this method, the *O. mykiss* optimum range was 35 mm to 20 mm (1.38 in to 0.79 in; full range was 55 mm to 5 mm [2.2 in to 0.2 in]), and the Chinook optimum range was 60 mm to 30 mm (2.36 in to 1.18 in; full range was 85 mm to 25 mm [3.35 in to 0.98 in]). Riebe et al. (2014) suggest a broader range of grain sizes may define the optimum range, depending on the fish size distribution for a watershed.

Averaging these two assessments (using data from many studies) gives an *O. mykiss* supportive range of 30 mm to 15 mm (1.18 in to 0.59 in) and a full useable range of 50 mm to 10 mm (1.97 in to 0.39 in). The Chinook salmon optimum with this same averaging technique results in an optimum range from 55 mm to 25 mm (2.2 in to 0.98 in) and a full useable range of 80 mm to 10 mm (3.15 in to 0.39 in). Detrimental values are anything outside the full range of observed spawning (it is detrimental in the sense that it is, by definition, not spawning habitat). The detrimental range includes coarse sediment that is too large for a female to move and too large of a proportion of fine sediment relative to larger gravel (greater than 10 mm), which may plug interstitial spaces between gravel and small cobble, thus reducing water flow.

#### 7.2.3.4.3 *Sediment Size Distribution Objectives (Spawning)*

Coarse sediment objectives for Chinook salmon and *O. mykiss* spawning are provided in Tables 34 and 35.

**Table 34**
**Sediment Size Distribution Objectives for Chinook Salmon Spawning**

| Habitat Type | Temporal Extent | Condition | Range (Metric) |
|---|---|---|---|
| Spawning Gravel | Fall-run: Late October to December<br><br>Spring-run: Late August to October | Supportive | D50 55 mm to 25 mm (2.2 in to 0.98 in) |
| | | Stressful | D50 80 mm to 56 mm (3.15 in to 2.2 in) and 24 mm to 10 mm (0. 94 in to 0.39 in) |
| | | Detrimental | Not spawning habitat<br>D50 < 9 mm (0.35 in) or > 81 mm (3.19 in) |

**Table 35**
**Sediment Size Distribution Objectives for *O. mykiss* Spawning**

| Habitat Type | Temporal Extent | Condition | Range (Metric) |
|---|---|---|---|
| Spawning Gravel | December to April | Supportive | D50 30 mm to 15 mm (1.18 in to 0.59 in) |
| | | Stressful | D50 50 mm to 30 mm (1.97 in to 1.18 in) and<br>D50 15 mm to 10 mm (0.59 in to 0.39 in) |
| | | Detrimental | Not spawning habitat<br>D50 < 9 mm (< 0.35 in) or D50 > 51 mm (> 2 in) |

### 7.2.3.5 Habitat Quantity and Distribution Objectives (Spawning)

Several objectives associated with spawning habitat do not fit into a supportive or stressful framework. They will be dealt with in this subsection as a group and will not have a table of values. The first of these objectives addresses the question of how much habitat Chinook salmon and *O. mykiss* need for spawning. Other subsections describe the quality of the habitat needed, but do not address the quantity of that habitat. Appendix A provides a spreadsheet model that was developed and used to estimate the number of female Chinook salmon that would be needed to reach the population goal that has been identified for the Stanislaus River.

The fall-run Chinook salmon minimum suitable spawning habitat area target was identified as 14.7 acres, assuming attainment of the AFRP (USFWS 2001) production target (i.e., 22,000 natural production in the ocean) for the Stanislaus River. This habitat would be located particularly at the tail of holding pools. The calculations used to set the suitable spawning habitat area target are based on an average redd size for Chinook salmon of 10 $m^2$ (107.6 $ft^2$; Hannon 2015, pers. comm.) and the fact that an escapement of 9,942 salmon (for 5,965 female spawners) would be necessary to achieve the AFRP target for a natural production of fall-run Chinook salmon from the Stanislaus River, with the following assumptions:

- The population is 60% female.
- Average fecundity is 5,813 eggs.
- Egg to age-2 survival rates are those identified in the rebuilding objective (the first three bullets on this list are SEP population model assumptions; Appendix A).
- Mean redd size for fall-run and spring-run Chinook salmon on the Stanislaus is 10 $m^2$.
- Minimum spawning habitat would be the space needed to support one redd for each spawning female, with no overlap among redds or open space (i.e., territory buffer) between redds.

The spawning habitat needed for 5,965 female spawners equals a minimum of 14.7 acres, as demonstrated in the following equation:

$$10\ m^2\ \frac{[107.6\ ft^2]}{female\ \ \times 5{,}965\ females = 59{,}650\ m^2\ [641{,}855\ ft^2]} = 14.7\ acres$$

There is no evidence that spring-run Chinook salmon would have different redd sizes than fall-run Chinook salmon in the Stanislaus River. The spring-run production target, survival rates from egg to age 2, fecundity, and the ratio of males to females were assumed to be the same as those for fall-run. Therefore, the amount of spawning habitat needed for spring-run would be the same as fall-run at 14.7 acres.

The *O. mykiss* target was identified as 2.7 acres. The *O. mykiss* redd size used to arrive at this value is 5.43 $m^2$ (58.4 $ft^2$; Orcutt et al. 1968) and a territory buffer of 50% (just over 2.5 $m^2$ [26.9 $ft^2$]), resulting in a value of 8 $m^2$ (86.1 $ft^2$) per female. The population size would be an average of 600 female spawners. The calculation for *O. mykiss* spawning habitat is demonstrated in the following equation:

$$600\ females\ \times 8\ m^2\ [86.1\ ft^2]\ per\ female = 4{,}800\ m^2\ = 1.19\ acres$$

In addition, spawning habitat is needed for resident rainbow trout to meet the *O. mykiss* objective. For resident rainbow trout, 1.35 $m^2$ (14.5 $ft^2$) per redd was used, plus a territory buffer of 50%, for a total of approximately 2 $m^2$ (21.5 $ft^2$) per redd (Hannon 2015, pers. comm.). The target population size for resident rainbows is 3,000 adult females. The calculation is demonstrated in the following equation:

$$3{,}000\ females\ \times 2\ m^2\ [21.5\ ft^2]\ per\ female = 6{,}000\ m^2\ = 1.48\ acres$$

Thus, the total amount of spawning habitat needed for *O. mykiss* is 1.2 acres for *O. mykiss* plus 1.5 acres for resident rainbow trout, for a total of 2.7 acres.

Additional considerations for qualifying suitable spawning habitat for Chinook and *O. mykiss* include the need for cover or feeding areas adjacent to spawning areas such as holding pools, undercut banks, overhanging vegetation, large wood, and boulders. Physical habitat attributes and hydrologic conditions work to uphold the habitat-forming processes that create and maintain suitable habitat (Beechie and Bolton 1999; Buffington et al. 2004). Spawning habitat may need to be increased in locations in the river that address the specific needs of spring-run Chinook salmon and *O. mykiss*, in addition to fall-run depending on spatial or temporal overlap between runs. A possible action would be to provide additional spawning habitat in the canyon downstream of Goodwin Dam where temperatures are generally low and fall-run are less likely to spawn. Likewise, the future maintenance of suitable spawning habitat may need to include bar and wood roughness to retain suitable gravel for spawning (Buffington et al. 2004).

### 7.2.3.6 Contaminants (Spawning)

#### *7.2.3.6.1 Contaminants Rationale (Spawning)*

The background and development of these contaminant objectives are discussed in Appendix C, Section 1.3. Adult spawning Chinook salmon and *O. mykiss* likely have some differences in sensitivities to the various contaminants; however, the SEP Group found no studies that supported separate Environmental Objectives for contaminants. Therefore, the contaminant objectives will be applicable to all species during their period of spawning.

Mercury and selenium toxicity were not considered in setting objectives for spawning salmonids. Mercury and selenium bioaccumulation in the ocean are likely low, and returning adults cease to eat during their spawning period, so there are low risks to adult salmonid spawning from mercury and selenium. Therefore, pesticides and nutrients are the only contaminants that have perceived direct impacts on adult spawning in the Stanislaus River.

Pesticides can have lethal and sub-lethal impacts to salmonid spawners. Pre-spawn mortality of adult salmonids from pesticide exposures is discussed in Section 7.2.1.4.1; there is some evidence that salmonids will die from exposure prior to spawning. However, the studies of the causes of prespawn mortality did not specify whether mortality occurred during the acts of migration, holding, or spawning (Scholz et al. 2011).

Sub-lethal impacts of pesticides are more likely than direct mortality of spawners. Most pesticides, in addition to other chemical contaminants such as metals, have been found to disrupt fish olfaction (Hansen et al. 2009; Scholz et al. 2000; Moore and Waring 2001). Disruption in olfaction has been linked to the elimination of fish behaviors important for reproduction (Potter and Dare 2003; Scott and Sloman 2004). For example, the pyrethroid insecticide cypermethrin inhibited male Atlantic salmon from detecting and responding to the reproduction priming pheromone prostaglandin, which is released by ovulating females (Moore and Waring 2001). The males exposed to cypermethrin did not respond to prostaglandin with the expected increased levels of plasma sex steroids and expressible milt. The disruption of spawning synchronization would likely result in an increase in the number of unfertilized eggs in the river (NMFS 2009c).

Pesticide exposures have been found to decrease the number of viable fertilized eggs. For example, Moore and Waring (2001) found that salmon egg and milt exposed to cypermethrin resulted in a greater proportion of unfertilized eggs. Adult zebrafish exposed to low doses of deltamethrin for 3 months showed reduced fecundity in females, and the number of unhatched fertilized eggs increased when compared to the control (Sharma and Ansari 2010). Furthermore, even short adult exposures to pesticides have been shown to impair fish reproduction. For instance, Brander et al. (2016) observed that 21-day exposures to bifenthrin caused significant differential expression of genes related to reproduction and immune function at sub-lethal concentrations to *Menidia beryllina* (inland silversides). Additionally, Brander et al. (2016) reported a statistically significant 30% reduction in fertilized eggs from the adult *M. beryllina*, and their population dynamic modeling predicted that these reductions in reproductive success would cause a significant decline in fish population over time.

Nutrient constituents (i.e., ammonia, nitrate, and nitrite) can also cause direct toxicity to spawning adults. Similar to the previous life history stages, excessive nutrients can result in adverse environmental conditions that reduce the fitness and survival of spawning adults (e.g., low DO or elevated temperatures).

#### *7.2.3.6.2 Contaminants Approach (Spawning)*

For a discussion of the SEP Group's approach to setting pesticide objectives and objectives for concentrations of nitrogen-based nutrients, see Section 7.2.1.4.2.

#### *7.2.3.6.3 Contaminants Objectives (Spawning)*

Pesticide water quality objectives and benchmark concentrations are displayed in Tables 21 and 22. Pesticide concentrations necessary to protect Chinook salmon and *O. mykiss* spawning are expected to be similar. Based on the described approach of pesticide Environmental Objectives, the supportive condition for pesticide occurrence would be less than a 1% chance (Bin 1, Table 23) of a pesticide exposure or exposure to a combination of pesticides that exceed water quality objectives or aquatic-life benchmarks in a given day of a month. This frequency corresponds to the allowed frequency of exceedances to protect aquatic beneficial uses for current water quality objectives and criteria (40 CFR Part 131; CVRWQCB 2018).

It is estimated that salmon exposed to pesticides at a frequency 30% of the time would impede olfaction enough to reduce the intrinsic population growth by 2% (1.08 versus the 1.10 control; Baldwin et al. 2009). Furthermore, a 2% reduction in intrinsic population growth is estimated to reduce salmon population more than 30% over 20 years. Assuming that the frequency of pesticide exposures has similar impact on salmonid physiology and responses across all life history stages, then exposures of pesticides greater than 30% (Bin 7 – 10, Table 23) would represent detrimental conditions. Accordingly, stressful conditions would include Bins 2 – 6, Table 23. See Appendix C, Section 1.3.3.1 for more information.

Ammonia, nitrate, and nitrite concentrations necessary to protect spawning adult salmonids are provided in Table 24.

### *7.2.4 Egg Development*

The egg development life history stage takes place in the gravel, beginning when the female salmon or *O. mykiss* deposits her eggs in a redd and ending when fry swim up out of the river bottom. The time period from egg deposition to fry emergence from the redd for a particular egg lasts roughly 3 to 5 months, depending on egg and alevins developmental rates, which are determined by water temperature. Egg development in the Stanislaus River generally occurs from late October through March for fall-run Chinook salmon and from December through June for *O. mykiss.* For spring-run Chinook salmon in the Sacramento River basin, egg development generally occurs from September through March; it is assumed that that timeframe would apply for spring-run Chinook salmon in the Stanislaus River should a population become reestablished there.

Salmon and *O. mykiss* eggs developing in the gravel are vulnerable to low DO, warm water temperatures, poor water quality, physical disturbance (e.g., people walking on redds), redd scour from high flows, and low flows that result in redd dewatering or insufficient water velocity to maintain water quality. The eggs require clean, cold, well-oxygenated water. Without enough swift water moving through the redd to sweep out fine sediment and metabolic waste, the eggs cannot receive sufficient clean, oxygenated water for proper development and mortality often results. In order to evaluate whether the Stanislaus River is providing conditions during egg development that will support attainment of the Biological Objectives, Environmental Objectives for water temperature, DO, fine sediment, and contaminants were established. The objectives and supporting rationale for each of these parameters are discussed below. The objectives for water temperature are species-specific, but the objectives for DO and water quality do not vary by species. Therefore, one set of objectives is presented for all three species. A summary of Environmental Objectives is provided in Table B-4 of Appendix B.

### 7.2.4.1 Temperature (Egg Development)

#### *7.2.4.1.1 Temperature Rationale (Egg Development)*

Suitable water temperature is necessary for normal behavior, growth, and viability of all life history stages of salmonids, including the egg development stage. Water temperature and developmental rate are tightly and positively correlated in salmonids (Healey 1991; Quinn 2005); however, above certain temperatures, enzymatic function is compromised and food resources are utilized inefficiently. For example, eggs and alevins that develop at temperatures that are either too cold or too warm produce smaller fry than would be produced at supportive temperatures (USEPA 2001). Hatching and emergence success decrease as temperatures rise above the threshold for optimum development. Direct egg mortality due to elevated temperatures occurs in the Central Valley (Williams 2006). Temperature-related mortality and habitat limitation will likely become serious problems for Central Valley salmonids in the future because of global climate change (Lindley et al. 2007).

#### *7.2.4.1.2 Temperature Approach (Egg Development)*

The SEP Group relied on water temperature criteria established by in the USEPA Region 10 Guidance for Pacific Northwest State and Tribal Temperature Water Quality Standards (USEPA 2003) to identify supportive, stressful, and detrimental water temperature conditions for Chinook salmon. The USEPA (2003) recommends using the 7DADM metric for evaluating temperature impacts on salmonid life history stages. The 7DADM metric is the 7DADM. The SEP Group used water temperature ranges for supportive, stressful, and detrimental to describe the objectives for Chinook salmon and *O. mykiss*.

**Chinook Salmon**

Salmonid eggs and larvae require suitable water temperatures to complete development. The length of time it takes for eggs to hatch depends mostly on water temperature. In addition, warm water temperatures can decrease egg survival. The USEPA (2003) found that constant temperatures between 4°C to 12°C (39.2°F to 53.6°F) result in good egg survival and that a narrower range (6°C to 10°C [42.8°F to 50°F]) is supportive. In a review, the USFWS (1999 cited by Myrick and Cech 2004) concluded that temperature-related egg mortality in Chinook salmon increased at temperatures above 13.3°C (55.9°F); this is the limit applied in most regulatory arenas (e.g., NMFS 2009b; SWRCB Order 90-05). A review of research on different populations of Chinook salmon from within and outside of the Central Valley indicated that temperatures between 6°C and 12°C (42.8°F to 53.6°F) were optimal for Central Valley Chinook salmon (Myrick and Cech 2004).

***O. mykiss***

As with Chinook salmon, *O. mykiss* eggs and larvae require cold water to successfully complete development. With the construction of impassable dams, *O. mykiss* eggs developing in the

San Joaquin Valley became dependent on coldwater releases from reservoirs. The accessible supply of coldwater storage limits successful spawning habitat for *O. mykiss* populations in the southern Central Valley. There is a lack of peer-reviewed studies on the temperature tolerances of Central Valley anadromous *O. mykiss* eggs, and additional study of temperature impacts on this species' eggs is needed (Myrick and Cech 2004). Supportive egg development temperatures for *O. mykiss* occur in a narrower range than those for Chinook salmon. Indeed, Myrick and Cech (2004) warned against managing water temperatures for the upper end of the Chinook salmon thermal tolerance range in waterways and during periods when *O. mykiss* eggs are also developing because developing *O. mykiss* cannot tolerate such high temperatures. Richter and Kolmes (2005) concluded that egg mortality increased as development temperatures exceeded 10°C (50°F), and substantial mortality may occur when temperatures exceed 13.5°C to 14.5°C (56.3°F to 58.1°F). Based on experience at hatcheries in the Central Valley, supportive egg development temperatures appear to be in the 7°C to 10°C (44.6°F to 50°F) range (Myrick and Cech 2004). California's steelhead management plan (McEwan and Jackson 1996) suggests a slightly higher temperature range (from 9°C to 11°C [48.2°F to 51.8°F]).

#### *7.2.4.1.3 Temperature Objectives (Egg Development)*

Egg development temperature objectives are described in Table 36 for Chinook salmon and Table 37 for *O. mykiss*.

**Table 36**
**Temperature Objectives for Chinook Salmon Egg Development**

| Habitat Type | Temporal Extent | Condition | Range (Metric) |
|---|---|---|---|
| Gravel | Fall-run: Late October to March<br><br>Spring-run: Late August to March | Supportive | 6°C to 12°C (42.8°F to 53.6°F) (Daily Average) |
| | | | < 12.5°C (< 54.5°F) (7DADM) |
| | | Stressful | 4°C to 6°C (39.2°F to 42.8°F) (Daily Average) |
| | | | 12°C to 13.3°C (53.6°F to 55.9°F) (Daily Average) |
| | | | 12.5°C to 13.8°C (54.5°F to 56.8°F) (7DADM) |
| | | Detrimental | > 13.3°C (55.9°F) (Daily Average) |
| | | | > 13.8°C (56.8°F) (7DADM) |

**Table 37**
**Temperature Objectives for *O. mykiss* Egg Development**

| Habitat Type | Temporal Extent | Condition | Range (Metric) |
|---|---|---|---|
| Gravel | December to June | Supportive | 7°C to 10°C (44.6°F to 50°F) (Daily Average) |
| | | | < 10.5°C (50.9°F) (7DADM) |
| | | Stressful | 4°C to 6.9°C (39.2°F to 44.4°F) (Daily Average) |
| | | | 10°C to 13.5°C (50°F to 56.3°F) (Daily Average) |
| | | | 10.5°C to 14.0°C (50.9°F to 57.2°F) (7DADM) |
| | | Detrimental | > 13.5°C (> 56.3°F) (Daily Average) |
| | | | > 14.0°C (> 57.2°F) (7DADM) |

## 7.2.4.2 Dissolved Oxygen (Egg Development)

### *7.2.4.2.1 Dissolved Oxygen Rationale (Egg Development)*

Adequate concentrations of DO in water are critical for salmon and *O. mykiss* survival. In freshwater streams, hypoxia can impact the growth and development of salmon and *O. mykiss* eggs, alevins, and fry as well as the swimming, feeding, and reproductive ability of juveniles and adults. If salmonids are exposed to hypoxic conditions for too long, mortality can result (Carter 2005). Without achieving supportive or some combination of supportive and stressful Environmental Objectives for DO (described in Section 7.2.4.2.2, the Biological Objectives for Chinook salmon and *O. mykiss* productivity will likely not be met.

### *7.2.4.2.2 Dissolved Oxygen Approach (Egg Development)*

The SEP Group relied on DO criteria established by the USEPA (1986) and the CVRWQCB (2018), as well as relevant technical literature (e.g., WDOE 2002), to identify DO objectives that are supportive (no negative effects), stressful (observably negative, though not significantly harmful), and detrimental (clearly harmful) ranges for various salmonid life history stages and transitions.

The criteria established by the USEPA (1986) and CVRWQCB (2018) covered coldwater species in one category; separate criteria for Chinook salmon and *O. mykiss* were not provided. This blanket approach of protecting salmon and *O. mykiss* with one set of DO criteria is supported by the available literature; thus, the SEP Group followed that approach.

The summaries of egg development mortality through hatching and development growth rates provide rationale for the DO objectives identified in Table 38.

**Egg Development Mortality through Hatching**

The effect of low DO on salmon egg mortality largely depends on development temperatures. Under laboratory conditions at favorable development temperatures, mortality rates when DO levels greater than or equal to 9 mg/L should be less than 1%, less than 2% at a concentration of 7 mg/L, and between 2% and 6% at a concentration of 6 mg/L (WDOE 2002). Survival rates at oxygen concentrations below 4 mg/L are highly variable. All tests at concentrations below 1.7 mg/L resulted in 100% mortality (WDOE 2002).

Mortality rates related to low DO concentrations increase substantially at temperatures that are warmer than ideal. In water at 13.4°C (56.1°F), a decrease in DO from 11 mg/L to 10 mg/L caused a 4% reduction in survival through hatching. At 7 mg/L, egg survival decreased by 19%. Furthermore, in the laboratory studies that produced these results (WDOE 2002), post-hatch salmon larvae (alevin) did not need to push their way up through gravel substrate to emerge as would wild fish. Supportive fitness will likely be required for optimal emergence from the gravel in natural environments. Thus, the effect of depleted oxygen levels on egg development success may be more profound than revealed by simple laboratory studies of egg hatching success. Sub-lethal impacts of high temperatures probably play an important role in overall egg development success rates.

Any decrease in the mean oxygen concentration during the development period appears to directly reduce the size of newly hatched salmonids (WDOE 2002). At favorable development temperatures, the level of this size reduction remained slight (less than or equal to 5%) when mean oxygen concentrations were 10 mg/L or more. At DO concentrations of 9 mg/L, the size of hatched fry was reduced by approximately 8%. Mean concentrations of 7 mg/L and 6 mg/L were associated with 18% and 25% reductions in emergent fry size, respectively.

### *7.2.4.2.3 Dissolved Oxygen Objectives (Egg Development)*

DO objectives for egg development for Chinook salmon and *O. mykiss* are presented in Table 38.

**Table 38**
**Dissolved Oxygen Objectives for Chinook Salmon and *O. mykiss* Egg Development**

| Habitat Type | Temporal Extent | Condition | Range (Metric) |
|---|---|---|---|
| Gravel (measurement must occur in gravel, not water column) | Fall-run: Late October to March<br><br>Spring-run: Late August to March<br><br>*O. mykiss*: December to June | Supportive | > 8 mg/L (Daily Minimum) |
| | | Stressful | 6 to 8 mg/L (Daily Minimum) |
| | | Detrimental | < 6 mg/L (Daily Minimum) |

### 7.2.4.3 Fine Sediment (Egg Development)

#### *7.2.4.3.1 Fine Sediment Rationale (Egg Development)*

High levels of fine sediment in spawning gravels are known to negatively affect spawning success (Kondolf 2000) through suffocation and entrapment (Jensen et al. 2009). High proportions of fine sediment may reduce the flow of oxygenated water to eggs, thus reducing the removal of metabolic wastes and potentially slowing embryo development (Greig et al. 2005; Jensen et al. 2009). Fine sediment may also entomb the egg and provide a physical barrier to hatching and fry emergence (Frannen et al. 2012). Studies of the effects of fines have often compared levels of fines with percent survival of eggs (e.g., Tappel and Bjornn 1983). There is a great deal of variation in the relationship of fine sediment to egg survival, but Jensen et al. (2009) evaluated many of the studies in an attempt to get a common assessment of the information available. This meta-analysis found that egg survival greatly declined when the proportion of sediment less than 0.85 mm (0.033 in) was greater than 10%. Relationships between egg survival and percent fines were also observed for slightly larger sediment size-classes, but the effect was less pronounced. For example, the proportion of sediment less than 4.8 mm (0.189 in) was negatively correlated with survival of eyed eggs; however, the effect threshold was higher at 50% proportion of sediment of less than 4.8 mm. The data Jensen et al. (2009) provide for a fine sediment upper limit of 6.4 mm is largely from Tappel and Bjornn (1983). With the enormous scatter in survival values, it does not appear to improve the evaluation of limits to define optimum conditions. Combining the data from previous studies, Jensen et al. (2009) were able to produce curves for several species, including Chinook salmon and *O. mykiss*. The data have a large amount of variation in them, but the relationships will allow the development of criteria for maintaining gravel quality for spawning.

#### *7.2.4.3.2 Fine Sediment Approach (Egg Development)*

The values for fine sediment are largely developed from Jensen et al. (2009). It is important to note that data for very low fine sediment values do not support 100% survival of eggs. The y-intercepts of the relationships given in Jensen et al. (2009) indicate the average survival of between 80% and 95% when fines less than 0.85 mm (0.033 in) are at extremely low values. The y-intercepts for the 4.8 mm (0.189 in) fines also are not at 100% and, in fact, are lower than the values for 0.85 mm (0.033 in), which seems counterintuitive. Variation in egg survival is enormous at those low levels of fines, ranging from approximately 20% to nearly 100%. Using the data, 80% was set as a baseline value for egg survival under a “no fine sediment” condition. It was assumed that no more than a 10% decline from the baseline should be allowed under supportive conditions; thus, fine sediment that allows for greater than or equal to 70% egg survival is considered supportive. Stressful conditions are assumed to be between 50% and 70% egg survival. Conditions that are equal to or less than 50% survival are assumed to be detrimental.

Using the percent survival above, fine sediment values were extracted from the graphs using direct inspection. The curve for all species egg survival versus fine sediment less than 0.85 mm (0.033 in) that was used as the curve includes a 95% confidence interval. The lower 95% bound was used to provide the most conservative (minimum) estimate for percent fines. The inspection results in a 5% fines limit for optimum habitat and a 10% fines limit for stressful habitat. Any higher percentage of fines smaller than 0.85 mm (0.033 in) would be considered detrimental.

The data for sediment smaller than 4.8 mm (0.189 in) are less clear. There are results from studies using green eggs and eyed eggs. The results indicate a very different response by the green and eyed eggs; the eyed eggs exhibit higher survival rates, likely because of their more advanced developmental stage. It is likely that green eggs have lower survival overall because the early developmental stage increases sensitivity to stressful conditions. The effect of fine sediment on overall egg survival mostly occurs during the sensitive green egg stage; thus, the green egg curve was used to set fine sediment thresholds for the 4.8 mm (0.189 in) sediment size-class. In addition to variation in egg survival due to the developmental stage, egg survival for green and eyed eggs varied among studies conducted using different salmonid species. *O. mykiss* green eggs show higher survival than Chinook green eggs; however, Chinook eyed eggs show higher survival than *O. mykiss*. This was interpreted to mean that the data were highly variable; there is little evidence to support using different survival rates for Chinook and *O. mykiss*. Thus, the *O. mykiss* curve from the green eggs graph was used, giving 5% fines as the upper limit for supportive conditions and 15% as the upper limit for stressful conditions. Anything greater than 15% fines (less than 4.8 mm [0.189 in]) is considered detrimental.

#### *7.2.4.3.3 Fine Sediment Objectives (Egg Development)*

Table 39 provides fine sediment objectives for Chinook salmon and *O. mykiss* egg development.

**Table 39**
**Fine Sediment Objectives for Chinook Salmon and *O. mykiss* Egg Development**

| Habitat Type | Temporal Extent | Condition | Range (Metric) |
|---|---|---|---|
| Gravel (measurement must occur in gravel, not water column) | Fall-run: Late October to March<br><br>Spring-run: Late August to March<br><br>*O. mykiss*: December to June | Supportive | < 5% smaller than 4.8 mm (0.189 in) |
| | | Stressful | 5% to 15% finer than 4.8 mm (0.189 in) or<br>5% to 10% finer than 0.85 mm (0.033 in) |
| | | Detrimental | > 15% smaller than 4.8 mm (0.189 in) or<br>> 10% smaller than 0.85 mm (0.033 in) |

### 7.2.4.4 Contaminants (Egg Development)

#### *7.2.4.4.1 Contaminants Rationale (Egg Development)*

Poor water quality has a high potential of impacting the survival and recovery of salmonids. Pesticides, mercury, and selenium have the ability to impact all life history stages of salmonids, including the egg development stage. Exposure to these contaminants can occur through transfer from the maternal parent or through direct contact in the water or gravel. For example, mercury and selenium exposure to eggs and early-life history stages (ELS) will be from maternal transfer because eggs are fairly resistant to these contaminants, and toxicity to mercury and selenium typically occurs from long-term bioaccumulation (Appendix C, Section 1.3.1). Effects to ELS fish from mercury and selenium include developmental deformities, reduced hatch, increased pre-swimup mortality, and behavior abnormalities.

Contrary to mercury and selenium, current-use pesticides do not typically bioaccumulate to the same extent, and toxicity to eggs and ELS salmonids can occur from river exposures. In addition to a reduction in fertilized eggs, further evidence supports the theory that pesticides impact salmonid egg to fry development. For example, Du Gas (2008) observed that exposures to the herbicides atrazine and chlorothalonil in gravel-bed flume incubators resulted in reduced survival to hatch, increased finfold deformities, reduced condition factors at emergence, and premature emergence in sockeye salmon. Furthermore, another laboratory study that exposed Chinook eyed eggs and alevins to dinoseb (herbicide), diazinon (organophosphate insecticide), and esfenvalerate (pyrethroid insecticide) resulted in abnormal swimming behavior, myoskeletal abnormalities, and metabolic disruptions as well as mortality at high concentrations (Viant et al. 2006). Alevins were much more sensitive to pesticide exposures than the eyed eggs, which emphasizes the important dangers of pesticide exposures to the critical life history stages of alevin development and emergence (Viant et al. 2006; Finn 2007; Du Gas 2008).

Nutrient constituents (i.e., ammonia, nitrate, and nitrite) can also cause direct toxicity to developing eggs. Similar to the previous life history stages, excessive nutrients can result in adverse environmental conditions that reduce the fitness and survival of developing eggs (e.g., low DO or elevated temperatures).

#### *7.2.4.4.2 Contaminants Approach (Egg Development)*

For discussion of the SEP Group’s approach to setting pesticide objectives and objectives for concentrations of nitrogen-based nutrients, see Section 7.2.1.4.2.

Unlike the evaluation for adult salmonids, selenium and mercury may impact the success of developing eggs. The SEP Group relied on the USEPA National Freshwater Selenium Ambient Water Quality Criterion for Aquatic Life (2016) for the Environmental Objectives to protect salmonid species in the Stanislaus River against adverse effects. The criteria have yet to be promulgated; however, the criteria are consistent with the relevant technical literature on selenium toxicology. The Environmental Objective should be reevaluated once the USEPA selenium criteria are finalized. No criteria have been promulgated for the protection of fish from mercury impacts. However, in recent literature, researchers have developed fish tissue mercury concentration benchmarks that are estimated to be protective of adult and ELS fish (Appendix C, Section 1.3.2.2). The SEP Group relied on these benchmark concentrations as the level that would be fully protective of salmonids during their egg development stage. Furthermore, selenium and mercury objectives are presented as the maximum contaminant concentration to be found in eggs and ELS fish tissue as well as the maximum tissue concentration allowable in maternal salmonids to prevent the toxicological transfer of mercury and selenium. This is because egg and ELS fish exposure to mercury and selenium is through maternal transfer (Wiener and Spry 1996; Presser and Luoma 2013; USEPA 2015).

#### *7.2.4.4.3 Contaminants Objectives (Egg Development)*

Pesticide water quality objectives and benchmark concentrations are displayed in Tables 21 and 22. Pesticide concentrations necessary to protect Chinook salmon and *O. mykiss* egg development are expected to be similar. Based on the described approach of pesticide Environmental Objectives, the supportive condition for pesticide occurrence would be less than a 1% chance (Bin 1, Table 23) of a pesticide exposure or exposure to a combination of pesticides that exceed water quality objectives or aquatic-life benchmarks in a given day of a month. This frequency corresponds to the allowed frequency of exceedances to protect aquatic beneficial uses for current water quality objectives and criteria (40 CFR Part 131; CVRWQCB 2018).

It is estimated that salmon exposed to pesticides at a frequency of 30% of the time would impede olfaction enough to reduce the intrinsic population growth by 2% (1.08 versus the 1.10 control; Baldwin et al. 2009). Furthermore, a 2% reduction in intrinsic population growth is estimated to reduce salmon population more than 30% over 20 years. Assuming that the frequency of pesticide exposures has a similar impact on salmonid physiology and responses across all life history stages, then exposures of pesticides greater than 30% (Bin 7 – 10, Table 23) would represent stressful conditions. Accordingly, stressful conditions would include Bins 2 – 6, Table 23. See Appendix C, Section 1.3.3.1 for more information.

Mercury objectives for the egg development life history stage are presented in Table 40. The objectives apply to the mercury concentrations in the eggs themselves as well as the concentrations in the maternal fish to prevent the transfer of mercury at toxicological levels.

**Table 40**

**Mercury Objectives for Chinook Salmon and *O. mykiss* during the Egg Development Life History Stage**

| Condition | Egg and Maternal Ovary mg/kg (wet weight) | Maternal Fish mg/kg whole body (wet weight) |
|---|---|---|
| Supportive | < 0.02 | < 0.20 |
| Stressful | 0.02 to 0.10 | 0.20 to 1.0 |
| Detrimental[1] | > 0.1 | > 1.0 |

Note:

1. Sub-lethal impacts to fish are estimated to occur above supportive conditions. Detrimental impacts are assumed to occur at mercury tissue concentrations that are expected to create 25% or greater injury to the fish. An EC25 metric is a consistent threshold to determine chronic toxicity assessments for regulatory compliance (SWRCB 2012).

Selenium objectives for the egg development life history stage are presented in Table 41. The objectives apply to the selenium concentrations in the eggs themselves as well as the concentrations in the maternal fish to prevent the transfer of selenium at toxicological levels. In addition, aqueous selenium objectives are presented for lentic and lotic systems to protect aquatic life from bioaccumulating toxic levels of selenium.

**Table 41**

**U.S. Environmental Protection Agency National Freshwater Selenium Ambient Water Quality Criterion for Aquatic Life**

| Media Type | Fish Tissue | | Water Column | |
|---|---|---|---|---|
| **Criterion Element** | **Egg/Ovary** | **Fish Whole Body or Muscle** | **Monthly Average Exposure** | **Intermittent Exposure** |
| Magnitude | 15.1 mg/kg (dry weight) | 8.5 mg/kg whole body or 11.3 mg/kg muscle (skinless, boneless filet; dry weight) | 1.5 micrograms per liter (µg/L) in lentic aquatic systems<br>3.1 µg/L in lotic aquatic systems | $WQC_{int} = \frac{WQC_{30\text{-}day} - C_{bkgrnd}(1 - f_{int})}{f_{int}}$ |
| Duration | Instantaneous measurement | Instantaneous measurement | 30 days | Number of days per month with an elevated concentration |
| Frequency | Never to be exceeded | Never to be exceeded | Not more than once in 3 years on average | Not more than once in 3 years on average |

Notes:

Source: USEPA 2016

WQC: water quality criterion

Ammonia, nitrate, and nitrite concentrations necessary to protect salmonid developing eggs are provided in Table 24.

### 7.2.5 Juvenile Rearing and Migration

The juvenile rearing and migration life history stage encompasses all of those developmental stages, life history strategies, and associated behaviors and phenotypic expressions that occur subsequent to emergence and prior to either ocean entry (for anadromous forms) or sexual maturation (for resident forms; principally applicable to *O. mykiss*). Depending on the species, these may include the following:

- Fry, parr, smolt, and yearling developmental stages
- Anadromous, resident, and estuarine migratory behaviors
- Habitat areas
  - Within the bank-full channel (in-channel)
  - Adjacent to the bank-full channel on higher gradient, shorter inundation off-channel floodplains, floodplain terraces, backwaters, and intermittent side channels (short-inundation floodplains)
  - Lower gradient, longer inundation valley floodplains and wetlands (long-inundation floodplains)

There is evidence that salmon production in the Stanislaus River is limited by carrying capacity constraints, particularly in dry years (Figure 4). The apparent limit on juvenile production in dry years may indicate that the Stanislaus River currently only provides enough high-quality juvenile rearing habitat to support production of a limited number of juveniles. Rearing habitat limitation is consistent with the observation that the number of juveniles produced per spawner increases dramatically in years with higher winter-spring flows (Figure 4).

Generally, supportive conditions for juvenile salmonid rearing involve a balance of the following—a) water quality conditions (e.g., temperature, DO, contaminant concentrations); b) physical attributes of habitat (water depth, suitable cover, and substrate); c) extent of available habitat relative to fish territory size (as a function of fish size, fish density, prey density, and habitat structure); d) ecosystem and food web conditions (e.g., prey availability, predator density, and competition); and e) activity levels (as a function of the interaction of a, b, c, and d with water velocity)—such that juvenile salmonids can sustain metabolic needs while maximizing growth (Quinn 2005). However, these conditions vary across a range of sub-habitat types within the riverine landscape used by juvenile salmonids. Various sub-habitats may also be used differently by each salmonid species, specific life history stages of a given salmonid species (Roper et al. 1994; Bradford and Higgins 2001; Merz et al. 2015), and individuals within a life history stage that are developing at different rates (e.g., "young," small smolts may utilize habitats differently than older, larger ones). In the San Joaquin River basin's Mokelumne River, juvenile Chinook salmon have been shown to prefer off-channel floodplain habitat for rearing, while juvenile *O. mykiss* prefer in-channel riffle habitat (Merz et al. 2015).

For a given species, the interaction of different life history stages with different sub-habitats can additionally reinforce cohort and population-level life history diversity and associated resilience (McClure et al. 2008; Zimmerman et al. 2015). For example, juvenile Chinook salmon rearing on floodplains can experience greater maximum size, diversity in growth, and exposure to environmental pollutants than juvenile salmon reared in the associated river channel (Sommer et al. 2001a, 2005; Jeffres et al. 2008; Henery et al. 2010). For juvenile *O. mykiss*, in-channel rearing habitat with more variable flow has been associated with higher levels of anadromy (Pearsons et al. 2008; Kendall et al. 2014). In characterizing optimal rearing habitat conditions, it is appropriate to do so by sub-habitat and species.

Depending on the salmonid species and life history stage, there may not be a clear delineation between those sub-habitats used for rearing and for migration. For example, the same channel reach may theoretically be used by juvenile *O. mykiss* for rearing at the same time as it is being used for juvenile Chinook salmon as a migration corridor. Similarly, the same valley floodplain area may be used as a migration pathway by an outmigrating juvenile Chinook salmon smolt and a primary rearing area for a Chinook salmon parr. Juvenile Chinook salmon and *O. mykiss* may also continue to rear as they move downstream, whereas steelhead seem to move downstream relatively quickly once they begin their emigration from upstream rearing areas.

For the purposes of Environmental Objectives development, the SEP Group characterizes migration as downstream movement in outmigrating anadromous or estuarine juveniles. Migration objectives include physical habitat conditions (e.g., temperature) that support smoltification, allow for passage (e.g., depth and free-flowing rivers not obstructed by barriers, partial barriers, or water diversions), and facilitate movement (e.g., velocity) as well as habitat heterogeneity and distribution that support distributed velocity refugia, downstream rearing behavior, and predator avoidance (e.g., turbidity). Rearing and migration habitat are differentiated based on the primary function it is serving to a given individual or species during the time they are occupying it. In cases where a habitat is serving rearing and migration functions simultaneously for a given species, optimal conditions for rearing are prioritized. The SEP Group recognizes that the natural, historic overlap in these functions speaks to their inherent alignment. Within the appropriate range, diversity in conditions within a given sub-habitat type supports life history diversity and resilience in the population.

#### 7.2.5.1 Temperature

##### *7.2.5.1.1 Temperature Rationale (Juvenile Rearing and Migration)*

Juvenile salmonid growth, life history stage duration, and metabolic efficiency are directly influenced by water temperature (Quinn 2005). Several authors have hypothesized that Central Valley populations of Chinook salmon and *O. mykiss* may tolerate warmer temperatures than those of other populations (e.g., Myrick and Cech 2004). In the San Joaquin River basin's Tuolumne River, there is limited evidence of this warm temperature tolerance in *O. mykiss* populations (Farrell et al. 2015). For juvenile salmonids who are actively feeding over a certain range of temperatures, growth increases with increasing temperatures as long as food is readily available; increasing temperatures may lead to decreased growth or death when food supplies are not sufficient to support increases in metabolic rate. Temperatures ultimately limit growth and survival at thresholds that are species-, population-, and individual-specific.

Temperatures that produce mortality among Pacific salmon depend, to some extent, on acclimation temperatures—higher acclimation temperatures produce higher IULT (Myrick and Cech 2004). Various sources indicate an IULT for Chinook salmon in the range of 24°C to 25°C (75.2°F to 77°F; e.g., Myrick and Cech 2004). Baker et al. (1995) found that Central Valley Chinook salmon had an IULT between approximately 22°C to 24°C (71.6°F to 75.2°F). Negative sub-lethal effects (those that may increase susceptibility to other mortality mechanisms) begin to occur at temperatures lower than the IULT. In the laboratory, when fish have access to full rations, growth of juvenile salmonids increases with temperature up to their physiological limits; however, when food supply is limited (as it often is under normal conditions in the field), supportive and stressful growth and mortality occur at lower temperatures. For example, Mesa et al. (2002) detected increased levels of heat shock proteins (an indicator of stress) after several hours of exposure to 20°C (68°F) for Columbia River fall-run Chinook salmon.

#### *7.2.5.1.2 Temperature Approach (Juvenile Rearing and Migration)*

**Chinook Salmon**

Among juvenile fall-run Chinook salmon from California's Central Valley population, Marine and Cech (2004) found decreased growth, reduced smoltification success, and impaired ability to avoid predation at temperatures above 20°C (68°F). They also reported that fish reared at temperatures of 17°C to 20°C (62.6°F to 68°F) experienced increased predation relative to fish raised at 13°C to 16°C (55.4°F to 60.8°F), although they found no difference in growth rate among fish reared in these two temperature ranges (Marine and Cech 2004). Similarly, Kuehne et al. (2012) found that warm temperatures (e.g., 20°C [68°F] versus 15°C [59°F]) acted additively with predator presence to increase behavior responses and to reduce growth in juvenile Chinook salmon. The finding of decreased performance at temperatures above 17°C (62.6°F) is consistent with several studies that suggest, when food supplies are not super-abundant, optimal growth and survival among Chinook salmon occurs at temperatures somewhat lower than 17°C (62.6°F). The USEPA (2003) identifies constant temperatures of 10°C to 17°C (50°F to 62.6°F) and 7DADM less than 18°C (64.4°F) as being supportive conditions for juvenile Chinook salmon when food supplies are limiting. The USEPA (2003) recommends 16°C (60.8°F) 7DADM as a maximum criterion for the following:

- Protecting juvenile salmon and trout from lethal temperatures
- Providing upper optimal conditions for juvenile growth under limited food during the period of summer maximum temperatures and optimal temperatures for other times of the growth season
- Avoiding temperatures where juvenile salmon and trout are at a competitive disadvantage with other fish
- Protecting against temperature-induced elevated disease rates
- Providing temperatures that studies show juvenile salmon and trout prefer and are found in high densities

Based on this recommendation, 16°C (60.8°F) 7DADM or less has been established as the supportive water temperature for juvenile rearing and migration in the river channel.

As indicated, the temperatures that can be tolerated by rearing juvenile Chinook salmon depend largely on food availability. The USEPA (2003) indicates that, when food supplies are unlimited, temperatures from 13°C to 20°C (55.4°F to 68°F; constant) may be optimal. Recent studies on Central Valley Chinook salmon rearing on inundated floodplains reveal excellent survival and growth rates at even higher temperatures. Growth and survival for limited periods have been recorded at temperatures as high as approximately 25°C (77°F) (Katz, unpublished data; Jeffres, unpublished data). The increased tolerance for high temperatures in these fish is believed to be related to the high prey densities and food quality available on floodplains, coupled with low activity costs (Sommer et al. 2001b; Henery, unpublished data) and suggests that when food is not limiting, Chinook salmon can tolerate and even thrive at temperatures approaching the physiological limits observed in the laboratory (i.e., IULT). As a result, the SEP Group assumed that following successful restoration of floodplain habitats (and during periods when juvenile Chinook salmon actually occupy inundated floodplains), rearing Chinook juvenile salmon could survive temperatures approaching 25°C (77°F) for limited periods of time. Based on these distinctions, temperatures greater than 25°C (77°F) were established as detrimental for salmon rearing on long-inundation floodplains only. However, the SEP Group also recognizes that exposure to such warm water temperatures greatly increases disease risk, and stress from other water quality factors (e.g., DO or contaminants) likely reduces thermal tolerance. When Chinook salmon are not in habitats that support superabundant food resources (e.g., in-channel habitats), lower temperatures are required to avoid negative sub-lethal effects.

Elevated water temperatures can inhibit the parr-smolt metamorphosis (smoltification) in salmonids. Chinook salmon can smolt at temperatures ranging from 6°C to 20°C (42.8°F to 68°F; Myrick and Cech 2004). However, salmon that undergo smoltification at higher temperatures (greater than 16°C

[60.8°F]) tend to display impaired smoltification patterns and reduced saltwater survival (Myrick and Cech 2004). Marine and Cech (2004) found that Central Valley Chinook salmon rearing in temperatures greater than or equal to 20°C (68°F) suffered altered smolt physiology. Other studies from within this ecosystem suggest that negative effects of temperature on the parr-smolt transition may occur at temperatures less than 20°C (68°F). Richter and Kolmes (2005) cite two studies that indicated negative impacts on Chinook salmon smoltification success at temperatures greater than 17°C (62.6°F). The USEPA (2003) indicates that smoltification impairment may occur at temperatures between 12°C to 15°C (53.6°F to 59°F).

***O. mykiss***

Laboratory studies show that incipient lethal temperatures for juvenile *O. mykiss* occur in a range between 27.5°C to 29.6°C (81.5°F to 85.3°F), depending on acclimation temperatures (Myrick and Cech 2005). Temperature influences growth and lipid content in *O. mykiss* (McMillan et al. 2012). Supportive temperatures for *O. mykiss* juvenile growth occur between 15°C to 19°C (59°F to 66.2°F; Moyle 2002; Richter and Kolmes 2005).

In addition to growth, temperature may also influence *O. mykiss* ecological interactions and life history (Reese and Harvey 2002; Kendall et al. 2014). For example, *O. mykiss* juveniles suffer adverse impacts of competition with pikeminnow at temperatures greater than 20°C (68°F), though no competitive impact is detectable at lower temperatures (Reese and Harvey 2002). Temperature has been correlated with anadromy versus residency in juvenile *O. mykiss* (Kendall et al. 2014), with warmer temperatures associated with anadromy in some cases (Sogard et al. 2012; Benjamin et al. 2013; Doctor et al. 2014). The variable nature of these correlations does not support the use of temperature objectives in isolation as a mechanism for promoting anadromy.

Steelhead may be particularly sensitive to high temperatures during the smoltification process. The USEPA (2003) indicates that temperatures greater than 12°C (53.6°F) inhibit steelhead metamorphosis into smolt. Richter and Kolmes (2005) and USEPA (1999) cited studies that presented a range of temperatures between 11°C to 14°C (51.8°F to 57.2°F) that may inhibit steelhead smoltification. Myrick and Cech (2005) cautioned that smolting steelhead in the Central Valley must experience temperatures less than 11°C (51.8°F) to successfully complete this metamorphosis. The critical temperature at which smoltification becomes inhibited may vary from run to run (Richter and Kolmes 2005).

#### *7.2.5.1.3 Temperature Objectives (Juvenile Rearing and Migration)*

Temperature objectives for juvenile rearing and migration life history stages for Chinook salmon and *O. mykiss* are provided in Table 42.

**Table 42**
**Temperature Objectives for Chinook Salmon and *O. mykiss* Juvenile Rearing, Migration, and Smoltification**

| Habitat Type | Temporal Extent | Condition | Range (Metric) |
|---|---|---|---|
| Channel | Fall-run: Last week of January to second week of June | Supportive | 6°C to 16°C (42.8°F to 60.8°F) (7DADM) |
| | | Stressful | 16°C to 20°C (60.8°F to 68°F) (7DADM) |
| | | Detrimental | > 20°C (> 68°F) (7DADM) |
| Floodplain – Short Inundation | Spring-run: Last week of December to second week of June | Supportive | 10°C to 18°C (50°F to 64.4°F) (7DADM) |
| | | Stressful | 18°C to 20°C (64.4°F to 68°F) (7DADM) |
| | | Detrimental | > 20°C (> 68°F) (7DADM) |
| Mainstem | *O. mykiss*: January to December (year-round) | Supportive | 15°C to 19°C (59°F to 66.2°F) (Daily Average) |
| | | | 16.5°C to 21.5°C (61.7°F to 70.7°F) (7DADM) |
| | | Stressful | 20°C to 25°C (68°F to 77°F) (Daily Average) |
| | | | 21.5°C to 26.5°C (70.7°F to 79.7°F) (7DADM) |
| | | Detrimental | > 25°C (> 77°F) (Daily Average) |
| | | | 26.5°C (79.7°F) (7DADM) |
| | | | > 27.5°C (> 81.5°F) (Instantaneous) |

## 7.2.5.2 Dissolved Oxygen (Juvenile Rearing and Migration)

### *7.2.5.2.1 Dissolved Oxygen Rationale (Juvenile Rearing and Migration)*

Adequate concentrations of DO in water are critical for salmon and *O. mykiss* survival. In freshwater streams, hypoxia can impact the growth and development of salmon and *O. mykiss* fry as well as the swimming, feeding, and reproductive ability of juveniles. If salmonids are exposed to hypoxic conditions for too long, mortality can result (Carter 2005). Factors affecting DO levels may vary among sub-habitats used during juvenile rearing and migration. On floodplains, DO levels may be spatially variable and driven by factors such as temperature, wind mixing, and BOD. In channels, DO is typically less spatially heterogeneous (relative to salmonid needs) and presumed to be driven principally by temperature, with potential influences from groundwater, mixing, and BOD lower in the system.

### *7.2.5.2.2 Dissolved Oxygen Approach (Juvenile Rearing and Migration)*

Salmonids may be able to survive when DO concentrations are low (less than 5 mg/L), but growth, food conversion efficiency, and swimming performance will be adversely affected (Bjornn and Reiser 1991). Davis (1975) reviewed numerous studies and reported no impairment to rearing salmonids if DO concentrations averaged 9 mg/L, while at oxygen levels of 6.5 mg/L, "the average member of the community will exhibit symptoms of oxygen distress," and at 4 mg/L, a large portion of salmonids may be affected. The WDOE (2002) concluded that a monthly or weekly average concentration of 9 mg/L and a monthly average of the daily minimum concentrations should be at or above 8 to 8.5 mg/L to have a negligible effect (5% or less) on growth and support healthy growth rates. The USEPA (1986) stated that due to the variability inherent in growth studies, the reductions in growth rates seen above 6 mg/L are not usually statistically significant, while reductions in growth at DO levels below 4 mg/L are considered severe. The WDOE (2002) recommended that DO levels below 5 to 6 mg/L should be considered a potential barrier to the movement and habitat selection of juvenile salmonids. Given that recommendation, the SEP Group has established that DO levels below 6 mg/L are detrimental for juvenile salmon.

#### *7.2.5.2.3 Dissolved Oxygen Objectives (Juvenile Rearing and Migration)*

The DO objectives for Chinook salmon and *O. mykiss* juvenile rearing and migration are provided in Table 43. It is not necessary to separate DO objectives by habitat type because juvenile salmon and *O. mykiss* are affected by DO the same whether they are in the main river channel or in the floodplain.

**Table 43**
**Dissolved Oxygen Objectives for Chinook Salmon and *O. mykiss* Juvenile Rearing and Migration**

| Habitat Type | Temporal Extent | Condition | Range (Metric) |
|---|---|---|---|
| River channel or Floodplain (water column measurement) | Fall-run: Last week of January to second week of June<br>Spring-run: Last week of December to second week of June<br>*O. mykiss*: January to December (year-round) | Supportive | > 8 mg/L (Daily Minimum) |
| | | Stressful | 6 to 8 mg/L (Daily Minimum) |
| | | Detrimental | < 6 mg/L (Daily Minimum) |

### 7.2.5.3 Contaminants (Juvenile Rearing and Migration)

#### *7.2.5.3.1 Contaminants Rationale (Juvenile Rearing and Migration)*

Like the other life history stages, contaminants have the high potential to impact juvenile rearing and migration. In fact, the greatest impact that contaminants may have is to the health and survival of the juvenile rearing and migration life history stages. For example, herbicides and insecticides are designed to target the organisms at the base of the food web that rearing salmonids rely on. In addition, pesticides have been found to disrupt fish behaviors and biochemistry necessary for survival at this life history stage (e.g., predator avoidance, feeding, metabolism, growth, osmoregulation, and orientation) (Beyers et al. 1999; Coghlan and Ringler 2005; Potter and Dare 2003; Scott and Sloman 2004). Furthermore, the nearshore, low-flow habitats that provide the greatest benefit to rearing and migratory juveniles typically have higher concentrations and loads of pesticides, which compounds the impact on salmonids in their preferred habitat (NMFS 2008, 2009c, 2011c). Finally, juvenile salmonids exposed to pesticides and other olfactory inhibiting contaminants during development may fail to imprint to their natal waters, which can lead to increased adulthood straying (NMFS 2009c).

Because of the short time period and the type of food web that juvenile salmonids use during rearing and migration, there is typically low risk to mercury and selenium toxicity. However, there are some instances where environmental conditions may stimulate methylmercury production and pose toxicological risks to rearing and migrating juveniles. For example, in 2006, episodic flooding in the San Joaquin River watershed, Delta, and other Central Valley river basins created conditions where YOY fish methylmercury concentrations increased 4- to 5-fold higher than typical concentrations and to levels that could pose risks to fish health (Slotton et al. 2007).

Nutrient constituents (i.e., ammonia, nitrate, and nitrite) can also cause direct toxicity to rearing and migrating juveniles. Similar to the previous life history stages, excessive nutrients can result in adverse environmental conditions that reduce the fitness and survival of developing eggs (e.g., low DO or elevated temperatures). (See Appendix C, Section 1.3 for more detailed information on the effects of pesticides, nutrients, mercury, and selenium.)

#### *7.2.5.3.2 Contaminants Approach (Juvenile Rearing and Migration)*

For discussion of the SEP Group's approach to setting pesticide objectives and objectives for concentrations of nitrogen-based nutrients, see Section 7.2.1.4.2 (Contaminants Approach, Adult Upstream Migration). The approaches for selenium and mercury Environmental Objectives are similar to egg development life history stages (Section 7.2.4.4.2).

#### *7.2.5.3.3 Contaminants Objectives (Juvenile Rearing and Migration)*

Pesticide water quality objectives and benchmark concentrations are displayed in Tables 21 and 22. Pesticide concentrations necessary to protect Chinook salmon and *O. mykiss* juvenile rearing and migration are expected to be similar. Based on the described approach for pesticide Environmental Objectives, the supportive condition for pesticide occurrence would be less than a 1% chance (Bin 1, Table 23) of a pesticide exposure or exposure to a combination of pesticides that exceed water quality objectives or aquatic-life benchmarks in a given day of a month. This frequency corresponds to the allowed frequency of exceedances to protect aquatic beneficial uses for current water quality objectives and criteria (40 CFR Part 131; CVRWQCB 2018).

It is estimated that salmon exposed to pesticides at a frequency of 30% of the time would reduce juvenile growth through olfaction disruption enough to reduce intrinsic population growth by 2% (1.08 versus the 1.10 control; Baldwin et al. 2009). Furthermore, a 2% reduction in intrinsic population growth is estimated to reduce salmon population more than 30% over 20 years. Consequently, exposures to pesticides greater than 30% (Bin 7 – 10, Table 23) would represent detrimental conditions. Accordingly, stressful conditions would include Bins 2 – 6, Table 23. (See Appendix C, Section 1.3.3.1 for more information.)

Mercury objectives for juvenile rearing and migration for Chinook salmon and *O. mykiss* are presented in Table 44. (See Appendix C, Section 1.3.3.2 for more information.)

**Table 44**
**Mercury Objectives for Chinook Salmon and *O. mykiss* for Juvenile Rearing and Migration**

| Condition | Juvenile Fish<br>mg/kg whole body (wet weight) |
|---|---|
| Supportive | < 0.20 |
| Stressful | 0.20 to 1.0 |
| Detrimental [1] | > 1.0 |

Note:

1. Sub-lethal impacts to fish are estimated to occur above supportive conditions. Detrimental impacts are assumed to occur at mercury tissue concentrations that are expected to create 25% or greater injury to the fish. An EC25 metric is a consistent threshold to determine chronic toxicity assessments for regulatory compliance (SWRCB 2012).

Selenium objectives for the rearing and migration life history stage are presented in Table 41. The objectives apply to the selenium concentrations in the juvenile fish tissue. In addition, aqueous selenium objectives are presented for lentic and lotic systems to protect rearing and migrating juvenile salmonids from bioaccumulating toxic levels of selenium.

Ammonia, nitrate, and nitrite concentrations necessary to protect salmonid juveniles are provided in Table 24.

### 7.2.5.4 Physical Characteristics of Rearing Habitat (Juvenile Rearing and Migration)

Physical attributes of rearing habitat include the following:

- Water depth and velocity
- Cover, structure, and substrate

The rationale and approach to defining objectives for attributes in each of these groups are described separately below, and objectives are summarized in Table 45.

**Table 45**
**Physical Rearing Habitat Objectives (Including Metrics for Cover, Substrate, Depth, and Velocity) for Juvenile Chinook Salmon and *O. mykiss***

| Habitat Type | Parameter | Condition | Range (Metric) |
|---|---|---|---|
| Floodplain–Short Inundation | Substrate | Supportive | > 5% fines to support vegetation recruitment |
| | Cover | Supportive | Average HSI score of ≥ 0.5 for all cover types<br>Or:<br>HSI for individual cover types:<br>Woody debris ≥ 0.9<br>Cobble boulder ≥ 0.5<br>Overhanging vegetation ≥ 0.8<br>Root wad ≥ 1 |
| | Depth | Supportive | 0.15 m to 1.22 m (0.5 ft to 4 ft)<br>Averaged spatially |
| | | Stressful | 1.23 m to 2.13 m (4 ft to 7 ft)<br>Averaged spatially |
| | Velocity | Supportive | 0 m/s to 0.9 m/s (0 ft/s to 3 ft/s) |
| | | Stressful | > 0.9 m/s (> 3 ft/s) |
| Floodplain–Long Inundation | Substrate | Supportive | > 5% fines to support vegetation recruitment |
| | Cover | Supportive | Average HSI score of ≥ 0.5 for all cover types |
| | Depth | Supportive | 0.15 m to 1.22 m (0.5 ft to 4 ft)<br>Averaged spatially |
| | | Stressful | 1.23 m to 2.13 m (4 ft to 7 ft)<br>Averaged spatially |
| | Velocity | Supportive | 0 m/s to 0.9 m/s (0 ft/s to 3 ft/s) s |
| | | Stressful | > 0.9 m/s (> 3 ft/s) |
| Channel | Substrate | Supportive | See spawning habitat requirements |
| | Cover | Supportive | Average HSI score of ≥ 0.5 for all cover types<br>Or:<br>HSI for individual cover types:<br>Woody debris ≥ 0.9<br>Cobble boulder ≥ 0.5<br>Overhanging vegetation ≥ 0.8<br>Root wad ≥ 1 |
| | Flow variability | Supportive | Summer flow variability that mimics the natural hydrograph; intended to contribute to the expression of anadromy |

Notes:
Cover metrics are defined by HSI values for various cover types (averaged either across cover types or for individual cover types).
Rearing habitat objectives apply year-round for *O. mykiss*, the last week of January to second week of June for fall-run Chinook salmon, and the last week of December to second week of June for spring-run Chinook.

#### *7.2.5.4.1 Water Depth and Velocity Rationale (Juvenile Rearing and Migration)*

Depth and velocity of flow play a critical role in habitat quality for juvenile salmonids. Water depth and water velocity are parameters commonly applied to habitat suitability models for juvenile salmonids, and different combinations of water velocity and depth can contribute to habitat physical and ecological functions as well as heterogeneity within and across habitat types. For juvenile salmonids, water velocity is a key driver of activity level, which interacts with temperature, DO, and prey availability-driven consumption rate to affect growth rate (Section 1.3.5.3), and suitable depths support foraging behavior and predator avoidance (Gregory 1993). Optimal depth and velocity for juvenile salmonids can vary significantly between systems and for fish of different sizes (Figure 9). Research on juvenile Chinook salmon rearing on flooded rice fields in the Yolo Bypass found no significant correlation between depth and growth for depth ranges of approximately 0.15 m to 0.61 m (6 in to 2 ft) at low velocities and a consistent prey density (Katz, unpublished data).

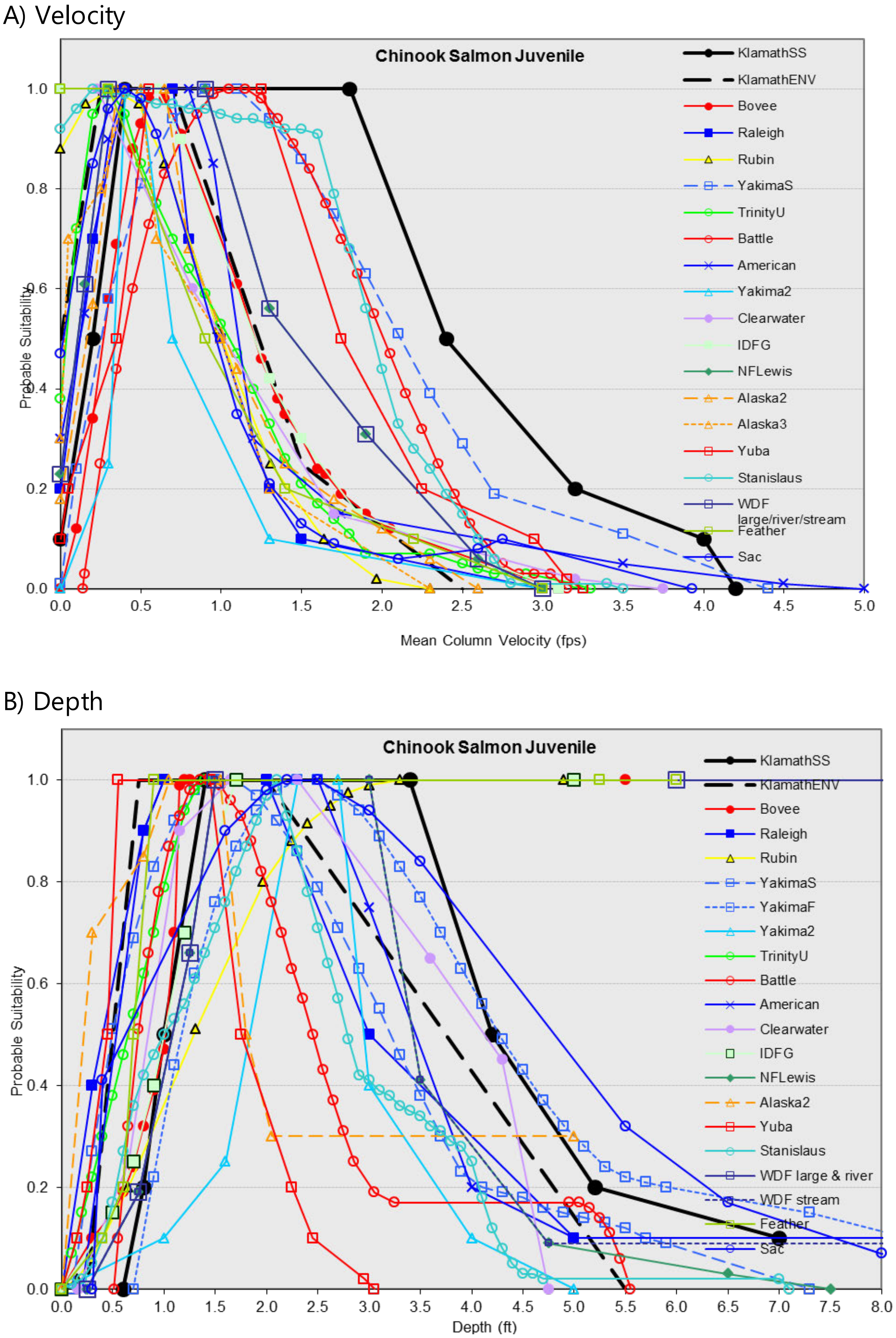



**Figure 9**

**Habitat Suitability Index Values for Velocity and Depth for Juvenile Chinook Salmon on Multiple Rivers**

Note:
Compiled by SJRRP (2012) from multiple published and unpublished empirical (when available) and modeled datasets. The Stanislaus River is indicated by the teal circles.

### 7.2.5.4.2 *Water Depth and Velocity Approach (Juvenile Rearing and Migration)*

Juvenile Chinook salmon habitat suitability models for depth and velocity have been developed previously for the Stanislaus River (Aceituno 1990) and applied to floodplain habitat estimates for the San Joaquin River (SJRRP 2012). These estimates suggest optimal depth values between 0 m and 1.4 m (0 ft and 4.5 ft) in floodplain or off-channel conditions (Aceituno 1990; SJRRP 2012). The same studies assigned optimal velocity values for those habitat types at between 0 m/s and 0.91 m/s (0 ft/s and 3 ft/s; Aceituno 1990). These values are based on the velocity requirement for Chinook salmon. While the needs of *O. mykiss* may be different and may use short inundation off-channel habitats for rearing under certain circumstances, research suggests that their primary rearing habitat is in-channel (Merz et al. 2015). Therefore, the SEP Group has used values supporting Chinook salmon as the basis for floodplain objectives. Depth and velocity objectives have been defined consistently across short and long inundation floodplains, with the additional guidance that shorter inundation floodplains may exhibit higher velocities as a function of gradient and more confined channel geometry. Productivity on longer inundation floodplains, by contrast, may benefit from slower velocities often associated with longer hydraulic residence times.

Water velocity in-channel is generally assumed to be greater than in off-channel habitats. Velocity is flow-dependent and variable within and across years as well as at a sub-habitat scale as a function of habitat structure. Additionally, in-channel habitat may be used simultaneously by multiple species and life history stages. As such, no single velocity or velocity range objective was defined for in-channel habitat. Increased flow variability during the summer has been correlated with higher levels of anadromy in juvenile *O. mykiss* (Pearsons et al. 2008; Kendall et al. 2014), whereas increased residency has been hypothesized (Pearsons et al. 1993; Cramer et al. 2003; McMillan et al. 2007) to be linked with more stable summer high flows and correlated with increased summer flows in females (Berejikian et al. 2013). Flow variability in the Stanislaus River has declined significantly from historic unimpaired conditions under reservoir operations. To support anadromy in juvenile *O. mykiss*, the SEP Group has additionally defined a flow variability objective for in-channel habitat.

### 7.2.5.4.3 *Cover, Structure, and Substrate Rationale (Juvenile Rearing and Migration)*

Cover, structure, and substrate are core components of the physical habitat for juvenile salmonids that can interact with other physical habitat components (e.g., water velocity and depth) and ecosystem dynamics (e.g., primary and secondary productivity, predator-prey interactions) to influence habitat use by juvenile salmonids. Cover and structure, specifically, have been correlated with the density in juvenile salmonids (McMahon and Hartman 1989), and substrate remediation in the form of gravel augmentation has been correlated with increased habitat use by juvenile salmonids in the Merced River (Sellheim et al. 2015).

### 7.2.5.4.4 Cover, Structure, and Substrate Approach (Juvenile Rearing and Migration)

As concepts, cover and structure have significant overlap—encompassing a range of common physical elements and differing primarily based on the function they serve for juvenile salmonids. For example, a root wad might be considered cover when its function is to provide juveniles with refuge from predators or high flows; a root wad might be considered structure when its function is to increase habitat complexity, regulate territory size, or provide a base for invertebrate prey to attach. Similarly, for juvenile fish, substrate of a certain size (e.g., large cobble or boulders) can provide cover and structure.

Many studies have examined a range of physical structures definable as "cover" in terms of the extent to which they support suitable habitat for juvenile salmonids (Raleigh et al. 1986; Hampton 1988; WDFW and WDOE 2004; Sutton et al. 2006). Physical structures constituting cover and suitability scores for common cover types are not addressed consistently across these studies. In 2012, the SJRRP developed a summary of habitat suitability scores for cover from multiple sources for use in modelling suitability of floodplain rearing habitat (Table 46; SJRRP 2012). Average HSI scores from this summary were applied as the basis for floodplain rearing habitat cover objectives.

**Table 46**
**Summary of Habitat Suitability Index Scores for Juvenile Salmon Cover**

| Cover Type | HSI Score for each Cover Type | | | | Average HSI Value |
|---|---|---|---|---|---|
| | Raleigh et al. 1986 | Sutton et al. 2006 | WDFW and WDOE 2004 | Hampton 1988 | |
| No Cover | 0.01 | N/A | 0.1 | 0.1 | 0.07 |
| Woody Debris | 0.9 | 0.6 | N/A | 0.7 | 0.73 |
| Cobble/Boulder | 0.2 | 0.5 | N/A | 0.18 | 0.29 |
| Grass | N/A | 0.5 | 0.48 | N/A | 0.49 |
| Gravel | 0.25 | 0.3 | N/A | N/A | 0.28 |
| Willow | N/A | 0.8 | N/A | N/A | 0.80 |
| Undercut Bank | 1 | 1 | 1 | 1 | 1.00 |
| Aquatic Vegetation | 0.3 | 0.6 | 1 | 0.5 | 0.60 |
| Overhanging Vegetation | 0.38 | 0.8 | 1 | 0.1 | 0.57 |
| Root Wad | N/A | 0.7 | 1 | 0.7 | 0.80 |

Note:
Summary of HSI scores for juvenile salmon from a range of sources developed for application to assessment of floodplain habitat quality by the SJRRP (2012)

Substrate objectives were defined separately for short inundation floodplain, long inundation floodplain, and in-channel habitat types. Substrate objectives are defined broadly to comport with the habitat gradient and target velocity range as well as support vegetative cover establishment and the assumed productivity mechanisms. For in-channel habitats areas, to the extent that spawning and rearing areas overlap spatially, substrate should be defined based on needs for spawning and egg development and emergence. However, substrate objectives for in-channel rearing habitat have additionally been provided here and are applicable to those in-channel areas not targeted for spawning.

#### *7.2.5.4.5 Physical Characteristics of Rearing Habitat Objectives (Juvenile Rearing and Migration)*

Objectives defining the physical characteristics of rearing habitat for Chinook salmon and *O. mykiss* juveniles are provided in Table 45.

### 7.2.5.5 Rearing Habitat Accessibility and Extent: Inundation Timing, Frequency, and Duration (Juvenile Rearing and Migration)

The preceding sections described the water quality and physical elements of high-quality rearing habitats. Some rearing habitats are ephemeral and the temporal overlap between the juvenile rearing period and the existence of the different rearing habitats determines, in part, the benefits attributable to these habitats. In addition, timing and duration of inundation of certain shallow water rearing habitats affect their value to rearing juvenile salmonids. Finally, the area of inundated habitat must be sufficient to achieve Biological Objectives for the focal salmonid populations.

#### *7.2.5.5.1 Habitats, Timing, and Associated Parameters (Juvenile Rearing and Migration)*

Timing of rearing and migration can be presumed to occur year-round when considering the three salmonid species covered in this report, although the timing varies by species and across years. For juvenile fall-run Chinook salmon (fry, parr, and smolt), the rearing and migration period has been defined as extending from the last week of January through the second week of June. For spring-run Chinook salmon, this period extends from the last week of December through the second week of June. For *O. mykiss*, the juvenile rearing period is considered to be year-round. As such, a separate rearing period for yearlings has not been defined. However, a specific period has been identified with different objectives to support smoltification in anadromous life history forms of *O. mykiss*; it extends from December through March.

Rearing and migration Environmental Objectives have been defined for the three primary habitat types as follows.

**Floodplain – Long Inundation**

This habitat type serves the specific functions of rearing habitat for juvenile Chinook salmon and a migration "rest stop" and predator avoidance pathway for juvenile Chinook salmon and *O. mykiss*. It is applicable to the lower section of the river (downstream of Ripon) and is characterized by lower gradients and longer seasonal inundation event durations (10 to 21 days) that allow for autochthonous primary and secondary production and result in high prey densities. This productivity is supported by a substrate with a higher proportion of fines, shallower water depths, and lower velocities. As a result of the low velocities and high prey densities, the supportive temperature range and maximum temperature threshold for this habitat are higher.

**Floodplain – Short Inundation**

This habitat type serves the specific functions of rearing habitat and a migration "rest stop" and predator avoidance pathway for juvenile Chinook salmon and *O. mykiss*. It is applicable to the portions of the river upstream of Ripon and is characterized by higher gradients and shorter seasonal inundation events (1 to 9 days) that support elevated prey densities primarily through allochthonous input of displaced terrestrial invertebrates and, to a lesser extent, benthic invertebrate drift. As a function of the gradient, velocities are generally higher and the substrate is coarser, though depths remain lower than in-channel. The supportive temperature range is similar to that of in-channel habitats.

**In-Channel**

This habitat type serves the specific functions of rearing habitat for juvenile *O. mykiss* and migration pathways for juvenile Chinook salmon and *O. mykiss*. It is applicable to all portions of the river (including side channels and braided channels) and is characterized by perennial flows and a greater range of depths and velocity than off-channel habitats. Prey densities are generally lower than off-channel habitats and velocities are greater, resulting in a lower temperature range and maximum temperature threshold than long-inundation floodplain habitats. Colder temperatures in this habitat also support smoltification during certain times of year, and variability in flow and temperature support anadromy in *O. mykiss* (Pearsons et al. 2008; Soggard et al. 2012; Benjamin et al. 2013; Kendall et al. 2014).

Several of the critical parameters applied to quantify desired conditions are common to multiple habitat types. Sections 7.2.5.5.2 through 7.2.5.5.6 provide a breakdown of desired conditions for each species, organized by parameter, for each applicable habitat type. Tables B-5a through B-5d in Appendix B provide a summary of these Environmental Objectives.

#### *7.2.5.5.2 Inundation Duration and Frequency Rationale (Juvenile Rearing and Migration)*

The flood pulse and seasonal inundation of floodplains drive key hydrologic and geomorphic processes that provide substantial habitat and trophic benefits to river ecosystems and fish (Junk et al. 1989; Junk and Wantzen 2004; Poff et al. 2010). The action of floodplain inundation and the extension of the photic zone it creates have been shown to enhance phytoplankton biomass (Schemel et al. 2004; Sommer et al. 2004; Ahearn et al. 2006), zooplankton growth (Müller-Solger et al. 2002; Grosholz and Gallo 2006), and drift invertebrate biomass (Boulton and Lloyd 1992; Sommer et al. 2001a, 2001b). Greater frequency of inundation has also been linked to higher levels of invertebrate productivity (Grosholz and Gallo 2006). It is therefore not surprising that juvenile Chinook salmon rearing on floodplains and other off-channel habitats tend to be larger and in better physical condition than those that rear in the main channel of rivers (Sommer et al. 2001a, 2001b; Jeffres et al. 2008; Limm and Marchetti 2009; Henery et al. 2010).

In higher gradient off-channel and floodplain habitats, short-duration inundation can displace terrestrial invertebrates from soil and vegetation, and drive terrestrial invertebrate distribution by modifying heterogeneity of organic matter (Langhans 2006). In low-gradient floodplains, longer inundation times and extended solar exposure can stimulate autochthonous primary and secondary production that can drive high prey densities and fish production (Grosholz and Gallo 2006). Research from the Cosumnes River floodplain found that secondary productivity began to increase in as few as 10 days after inundation (Jeffres, unpublished data) and reached high levels at approximately 14 days (Grosholz and Gallo 2006). A similar pattern was observed in the Yolo Bypass floodplain (Katz, unpublished data). Research in the Yolo Bypass further indicates that after approximately 21 days, productivity levels have stabilized or are in decline (Katz, unpublished data). Grosholz and Gallo (2006) recommend a 2- to 3-week flooding duration and frequency to best support native fish.

The timing of inundation—both on its own and through its interaction with duration and frequency—also exerts significant influence over floodplain habitat quality for salmonids. On an annual time scale under unimpaired flow conditions, inundation event frequency is often tied closely with water year type, and many habitats may not inundate during dryer years. For rearing habitat benefits to be realized for a given cohort, inundation must occur in 1 out of every 2 years (assuming a yearling strategy in some percentage of outmigrants). At a daily time scale for short duration inundation events, where displacement of terrestrial invertebrates is a main prey source, the frequency of inundation drives the timing of habitat availability and increased prey density. For longer inundation events, autochthonous production may continue to increase during a single event, primarily as a function of duration (Grosholz and Gallo 2006). Research from the Yolo Bypass and Cosumnes floodplains, however, indicates that drawdown between events can reset the productivity cycle once productivity rates have begun to stabilize or decline (Grosholz and Gallo 2006; Katz, unpublished data).

##### *7.2.5.5.3 Inundation Duration and Frequency Approach (Juvenile Rearing and Migration)*

Inundation objectives presented here apply habitat type-specific inundation event duration and timing as a surrogate for mechanism and extent of food production and availability (assuming other identified parameters and conditions, including temperature, water quantity, and substrate type). Specifically, short-duration inundation events are assumed to have elevated levels of invertebrate drift (benthic and terrestrial) as primary prey source. Long-inundation events are assumed to have autochthonous secondary productivity as a primary prey source, with terrestrial and benthic invertebrate drift as a secondary source. Duration of discrete events is measured based on a period following a minimum drawdown time. Minimum annual frequency has been established based on the potential for floodplain rearing benefits to have been experienced by adults in any given year, assuming a mix of primarily 2- and 3-year-old retuning adults.

#### *7.2.5.5.4 Inundation Duration and Frequency Objectives (Juvenile Rearing and Migration)*

Specific objectives for inundation for juvenile Chinook salmon and *O. mykiss* rearing are provided in Table 47.

**Table 47**
**Environmental Objectives for Inundation for Juvenile Chinook Salmon and *O. mykiss* Rearing**

<table>
<tr><th>Habitat Type</th><th>Temporal Extent</th><th>Parameter</th><th>Range (Metric)</th></tr>
<tr><td rowspan="2">Floodplain – Long Inundation</td><td rowspan="4">Fall-run:<br>Last week of January to second week of June<br><br>Spring-run:<br>Last week of December to second week of June<br><br>O. mykiss:<br>January to December (year-round)</td><td>Duration</td><td>10 to 21 wetted acre days</td></tr>
<tr><td>Frequency</td><td>Minimum of 1 in 3 years recurrence interval;<br>Minimum of 1 week drawdown to distinguish discrete event</td></tr>
<tr><td rowspan="2">Floodplain – Short Inundation</td><td>Duration</td><td>1 to 9 wetted acre days</td></tr>
<tr><td>Frequency</td><td>Minimum of 2 in 3 years recurrence interval during all years (minimum of 1 week drawdown to distinguish discrete event);<br>Minimum of 1 event per year in wet years/years where inundation occurs</td></tr>
</table>

#### *7.2.5.5.5 Habitat Spatial Extent and Distribution Rationale (Juvenile Rearing and Migration)*

In order for Biological Objectives to be achieved, spatial extent of rearing habitat must be sufficient to support the combined habitat needs of all rearing juveniles within the system necessary to achieve Biological Objectives.

Juvenile Chinook salmon either defend or rely on food from an area of territory (Cramer and Ackerman 2009), even when schooling (Neuswanger 2014). Additionally, territory size is thought to limit the density and production of stream-dwelling salmonids (Chapman 1966; Allen 1969; Grant and Kramer 1990). Territory size requirements of individual fish of a given size tend to be constant regardless of the local numbers of fish abundance (Grant and Kramer 1990; Cramer and Ackerman 2009), and in natural systems result in competition for space and displacement of smaller and weaker individuals (Titus 1990; Keeley and Grant 2001; Keeley 2003; Cramer and Ackerman 2009). Smaller and weaker individuals in turn occupy suboptimal territories (Titus 1990; Keeley and Grant 2001) and are likely to experience increased stress, which may reduce growth and fitness, and increased mortality. Providing adequate quantity and quality of territory during rearing and emigration may reduce the negative effects associated with competition for space (SJRRP 2012).

An important component of territory size is the relationship between territory size and fish body size, also known as the "allometry of territory size" (Grant and Kramer 1990). Because salmonids in streams defend territories—from small (post-emergent) juveniles until they either become ocean-ready fish (smolts) or become sexually mature—they must increase the area they defend to meet increasing food and energy (energetic) requirements as they grow (Keeley and Slaney 1996). The result is a dynamic where territory requirements expand through time for growing fish, while fish numbers are diminishing. The required extent and distribution of rearing and migration habitat for juvenile salmonids can therefore be conceptualized as a function of their abundance, size, emigration speed, and survival rate. From this perspective, rearing habitat needs vary based on location and time, where the rearing habitat extent necessary in any one location is equivalent to that which is required by the maximum number of juvenile fish that will occupy that habitat on any day during the rearing and emigration period.

Grant and Kramer (1990) provided a general multi-species (interspecific) regression model for allometric territory size that attempted to account for variability among species. Following the rationale above, allometric territory size relationships may be applied as a predictor of space requirements and maximum densities of juvenile salmonids in streams.

##### *7.2.5.5.6 Habitat Spatial Extent and Distribution Approach (Juvenile Rearing and Migration)*

To establish objectives for spatial extent and distribution of rearing habitat, the Emigrating Salmonid Habitat Estimation (ESHE) model, developed by Cramer Fish Sciences and The Nature Conservancy (SJRRP 2012), was applied. The ESHE model simulates stationary growth (rearing) and downstream movement (emigration) of individual daily groups (cohorts) of juvenile spring-run and fall-run Chinook salmon. The model tracks their numbers (abundance), average speed, size, the amount of territory needed per fish (territory size), and the amount of suitable habitat required to sustain the number of juvenile salmon present within a model reach. Model outputs provide daily estimates of the number of juvenile spring-run and fall-run Chinook salmon present in each model reach and the required area of suitable habitat needed to support them throughout the rearing and emigration period.

The ESHE model applies multiple parameters (and associated functions) in order to calculate juvenile salmon abundance and habitat needs of daily cohorts, including the following:

- **Initial abundance**: the number of juvenile Chinook salmon entering the model based on the target number of reproducing parent fish

- **Initial timing and size**: the number of fish on each day that exit the spawning grounds and the average size of the fish exiting the spawning grounds
- **Migration speed**: the daily downstream movement of juvenile salmon in each reach
- **Survival rate**: the number of fish that avoid death each day in each reach
- **Growth**: the daily growth and resulting size of juvenile salmon in each reach
- **Territory size**: territory size requirements of juvenile salmon in each reach based on their size
- **Required suitable habitat**: the required suitable habitat needed to support the juvenile salmon present in each reach

The values for each of the parameters described above were populated based on a combination of measured and modeled data. Whenever possible and appropriate, preference was given to measured data from the Stanislaus River. A summary of key model inputs is provided in Table 48.

**Table 48**
**Summary of Key Emigrating Salmonid Habitat Estimation Model Inputs along with Sources and Notes**

| Parameter | Value |
|---|---|
| Number of Reproducing Fish | Target: 13,200 (Fall-run); 13,200 (Spring-run)<br>Current: 2,150 (Fall-run) |
| Female Fish Percentage | 60% |
| Number of eggs per fish (fecundity) | 5,813 |
| Egg Survival to Emergence | 0.68 |
| Yearlings Percentage | 15% |
| Entry Numbers and Location | RM 58 – 54 (25.64%)<br>RM 53 – 49 (40.98%)<br>RM 53 – 49 (13.46%)<br>RM 43 – 39 (8.77%)<br>RM 38 – 34 (11.15%) |
| Migration Speed – Pre-smolts | 4.14, 12.62, or 24.91 km/day (2.57, 7.84, or 15.48 miles/day) |
| Migration Speed – Smolts | 7.11, 18.55, or 35.13 km/day (4.42, 11.53, or 21.83 miles/day) |
| Egg to Smolt Survival | 10.18% |
| Egg Survival (Current) | 33% |
| Egg Survival (Target) | 68% |
| Habitat Quality | 100% |

To provide habitat spatial extent and distribution objectives that would account for differences in rearing and migration behavior across wet and dry years and be applicable to cohort abundance consistent with existing and target population sizes, separate ESHE model runs were completed for current and target population levels under slow and fast outmigration scenarios (four total model runs). Results from the model runs are presented in Table 49.

**Table 49**
**Summary of Key ESHE Model Inputs Along with Sources and Notes**

| ESHE Results | | | |
|---|---|---|---|
| **Abundance** | **Migration Type** | **Habitat Area ($m^2$)** | **Habitat Area (Acres[2])** |
| Current | Fast | 25,055 | 6.19 |
| Current | Slow | 278,346 | 68.78 |
| Target | Fast | 330,541 | 81.68 |
| Target | Slow | 2,861,357 | 707.05 |
| **Estimated Inundated Area (Example)** | | | |
| **Habitat Quality** | **Abundance** | **Migration** | **Inundated Area (Acres)** |
| 7% to 30% (SJRRP 2012) | Target | Slow | 2,356.8 – 10,100.7 |

Notes:
– Rearing habitat need outputs from the ESHE model for slow current and target Chinook salmon populations at slow and fast emigration rates.
– Habitat area needs estimates assume 100% suitability.
– The Estimated Inundated Area (Example) applies the measured range of on-the-ground habitat suitability from the San Joaquin River to the highest output (Target/Slow) from the four modeled scenarios as an example of how ESHE-estimated habitat extent objectives translate into habitat extent need on the ground.

It is important to note that model results assume 100% habitat suitability. However, actual habitat suitability within a given area of rearing habitat may be significantly lower. As a component of their floodplain habitat needs analysis, the SJRRP compiled and examined on-the-ground information on habitat condition from the San Joaquin River basin and found that floodplain habitat suitability ranged from 7% to 30% (SJRRP 2012). Relating the estimated habitat area need provided by ESHE to the percentage of habitat suitability on-the-ground yields the required rearing habitat area. An example to this effect is provided in Table 49.

In order to account for differences among years, rearing habitat spatial extent objectives were established based on the range of 100% suitable habitat area needs estimated across the four modeled scenarios. Calculating on-the-ground habitat spatial extent needs for the Stanislaus River will require the application of this range to applicable on-the-ground percent habitat suitability. Habitat distribution objectives were similarly presented as a range, describing the range in percent of the total habitat area necessary in any given reach. Rearing habitat spatial extent and distribution needs were calculated based on targets for spring- and fall-Chinook salmon and are intended to apply primarily to floodplain rearing habitat.

# 8 Stressors

Stressors are conditions (physical, biological, or ecological) within the system that limit or inhibit the attainment, existence, maintenance, or potential for desired conditions, as characterized by the Biological and Environmental Objectives. These limitations may be due to a lack of quality or quantity of desired conditions. For example, the river may have an adequate number of acres of rearing habitat, but a large proportion may not be suitable. Conversely, the available habitat in a river may be all suitable, but there may not be enough acres to support the population goals. Either of these situations would limit the attainment of Biological Goals and thus stressors. Identification of stressors is critical to highlight components of desired conditions that are not being achieved and identify the specific obstacles (i.e., stressor[s]) inhibiting desired conditions.

As a complement to the identification of stressors, ranking stressors accomplishes the following:

- Enables the development of specific actions to achieve desired conditions by resolving stressors
- Facilitates the prioritization and sequencing of those actions to maximize benefits by addressing the most significant stressors first

In cases where other prioritization considerations (e.g., financial and political) prevent stressors from being addressed in order of importance, stressor ranking also helps to correctly set expectations about the extent of progress towards desired conditions that a given action will achieve and/or the suite and scale of actions necessary to achieve or make progress towards desired conditions.

## 8.1 Stressor Identification and Ranking Approach

The process for identifying and ranking stressors involves the following four key steps:

1. Identification of the range of stressors affecting each life history stage

    - For each life history stage, stresses that limit the success of that life history stage were identified (e.g., lack of suitable holding habitat for migrating adult salmonids). Stressors, or drivers of stresses, were framed in terms of parameters specified in Environmental Objectives (e.g., temperature and DO). Stressors not specifically addressed in the objectives that could impact Biological or Environmental Objectives were also included (e.g., predation). In some cases, stressors may be interrelated both for a given life history stage (i.e., two lower magnitude stressors cumulatively result in a third higher magnitude stressor) or across life history stages (i.e., a stress to one life history stage results in a different stress to one or more subsequent life history stages).

2. Assignment of stressors for each life history stage as relevant to current and future scenarios

- Stressors were considered relevant to 1) current population and conditions; 2) target population and conditions; or 3) both.
    - In the first case, the stressor affects the species or ecosystem under current conditions and/or at the current species population levels.
    - In the second case, the stressor, although not currently impacting populations or ecosystem conditions, is predicted to become impactful once populations approach recovery; when ecosystem conditions progress towards desired conditions; or as a function of some other trend, transition, or tipping point occurring in the future.
    - In the third case, a stressor is currently having an impact on the species, and it is expected that the magnitude or nature (e.g., scale and predictability) of that impact will change as populations increase, progress towards Environmental Objectives is made, or some other future condition occurs.

3. Scoring of coarse scale stressors and component fine scale stressors by life history stage for current conditions and the target of future conditions, as applicable

    - Stressors are assigned a score of 1 to 4 points (1 being lowest [i.e., minimal impact or certainty] and 4 being highest [i.e., greater impact or certainty]) in two categories: magnitude and certainty. Magnitude scores are based on the scale and severity of the impact to populations from the stress. Certainty scores are based on the understanding of a stressor's related impact as a function of the available information base as well as the predictability of that impact. In combination, magnitude and certainty scores generate an overall score, guide stressor ranking, and provide an indication about the appropriate stressor response. Although stressors are scored separately for each life history stage, score definitions for magnitude and certainty are common to all life history stages, allowing for ranking of stressors across life history stages. The highest score for any stressor is then assigned to the life history stage stress; a life history stage stress cannot be scored lower than any of the stressors. Additional details about the stressor scoring process are provided in Section 8.1.3.

4. Stressor ranking and prioritization across life history stages

    - Once scored, stressors for individual life history stages are combined for each of the three species (fall-run Chinook salmon, spring-run Chinook salmon, and *O. mykiss*). Stressors are then sorted and ranked based on their magnitude and certainty scores. Stressors are also assigned a stressor response type based on scoring. In addition to the severity of the stress, a high magnitude score indicates the potential need for a major action, depending on certainty. A low magnitude score, depending on certainty, suggests a need for either monitoring to ensure the magnitude does not increase, or research to confirm the low magnitude score and potentially inform adaptive management. Because stressor ranking is intended to guide and prioritize the development of actions to advance objectives and achieve desired conditions, stressors with high magnitude and high certainty are considered the highest priority.

### 8.1.1 Stressor Identification

The SEP Group identified stressors by examining the Environmental Objectives for each life history stage and discerning the following:

- Which Environmental Objectives are not being achieved under current conditions
- Any aspects of Biological Objectives that are not being achieved under current conditions and would not be addressed by meeting the Environmental Objectives
- Any specific factors that are currently inhibiting achievement of Environmental Objectives and Biological Objectives

In many cases, a stressor is directly related to an Environmental Objective. For example, the lack of suitable habitat for spring-run Chinook salmon holding is a stressor that is directly related to the Environmental Objective for spring-run adult holding habitat. However, in other cases, a stressor is a category that may encompass multiple Environmental Objectives. For example, the lack of suitable migratory conditions for fall-run Chinook salmon is a stressor for the juvenile rearing and migration life history stage that addresses multiple Environmental Objectives and biological processes, including water quality, flow, habitat, and predation. In general, the SEP Group used expert opinion to develop stressors that prevented attainment of Environmental Objectives and Biological Objectives in the Stanislaus River. The collective knowledge and experience of the SEP Group were used to develop a comprehensive list of stressors. The process of stressor scoring and ranking was informed and supported by the quality and quantity of existing information (data and literature).

### 8.1.2 Assignment of Stressors to Current and Future Conditions

The SEP Group assigned stressors according to the potential to achieve Biological Objectives under two scenarios:

- Scenario 1: Current conditions
- Scenario 2: 20 years in the future and assuming the attainment of the Biological Objectives (i.e., fish populations approaching goals for the Stanislaus River) and increased air temperatures

The assumption of a restored population under Scenario 2 implied that habitat requirements would be greater than under current conditions and sufficient to support population goals for the Stanislaus River. The assumption of increased air temperatures under Scenario 2 implied that temperature would be more of a stressor in the future when compared with current conditions.

## 8.1.3 *Stressor Scoring*

### 8.1.3.1 Scoring Framework Adapted from Delta Regional Ecosystem Restoration Implementation Plan

The Delta Regional Ecosystem Restoration Implementation Plan (DRERIP), the first of four regional plans intended to implement the CALFED Ecosystem Restoration Program, developed specific guidance for the evaluation of actions and stressors to assess performance and guide adaptive management.[11] DRERIP includes a scoring framework for ranking the effect of different actions to achieve an objective. The framework applies magnitude and certainty scores as a basis for a balanced ranking sensitive to spatial and temporal scale. The stressor ranking the SEP Group used applies an adapted version of the DRERIP framework to accommodate the application of the framework to the ranking of stressors limiting desired conditions as opposed to actions to achieve them.

### 8.1.3.2 Key Concepts and Terminology

#### *8.1.3.2.1 Magnitude*

Magnitude assesses the size or level of the impact from a stressor. Magnitude can be assigned using consideration of population or habitat effects. Higher scores require consideration of the scale or extent.

#### *8.1.3.2.2 Certainty*

Certainty describes the scientific basis for scoring the scale and magnitude of a particular stressor. Certainty considers both the predictability and understanding of linkages in the driver-linkage-outcome pathway from the stressor to the impact.

#### *8.1.3.2.3 Other Key Component of Scoring*

The terms importance, predictability, and understanding are used in the magnitude and certainty scoring definitions to characterize conceptual model linkages between a driver (i.e., stressor) and an outcome (i.e., stress/impact).

**Importance**

Importance, as used in this section, is the degree to which a stressor-impact linkage controls an outcome relative to other drivers and linkages affecting that same outcome. The stressor analysis was designed to encompass all known potential drivers, linkages, and outcomes, but this concept recognizes that some stressors are more important than others in determining how the system works.

[11] Available from: https://www.wildlife.ca.gov/Regions/3/erpdeltaplan/science_process

**Predictability**

Predictability, as used in this report, is the degree to which the performance or the nature of the outcome can be predicted from the stressor. Predictability seeks to capture the variability in the driver-outcome relationship. It can encompass temporal or spatial variability in conditions of a stressor, variability in the processes that link the driver stressor to the impact, or variability in the level of understanding about the cause-effect relationship. Any of these forms of variability can lead to difficulty in predicting change in an outcome based on changes in a stressor.

**Understanding**

Understanding, as used in this report, is a description of the known, established, and/or generally agreed upon scientific understanding of the cause-effect relationship between a single stressor and a single outcome (i.e., stress). Understanding may be limited due to the following: a lack of knowledge and information; disagreements in the interpretation of existing data and information; the basis for assessing the understanding of a linkage or outcome is based on studies done elsewhere and/or on different organisms; or conflicting results have been reported. Understanding should reflect the degree to which the stressor analysis and scoring does, in fact, represent conditions in the system.

### 8.1.3.3 Specific Scoring Criteria

#### *8.1.3.3.1 Criteria for Scoring Magnitude*

There are four levels of criteria for scoring magnitude. A rating of 4 requires large-scale action. A rating of 1 is interpreted having negligible effect on magnitude.

**4-High**

A rating of 4 means that a sustained major population-level effect (e.g., natural productivity, abundance, spatial distribution, and/or genetic and life history diversity) or a landscape-scale habitat effect (including habitat quality, spatial configuration and/or dynamics) is expected. This requires a large-scale action.

**3-Medium**

A rating of 3 means an expected sustained minor population effect or an effect on a large area (regional) or multiple patches.

**2-Low**

A rating of 2 means an expected sustained effect that is limited to small fraction of a population, addresses productivity and diversity in a minor way, or has limited spatial (local) or temporal habitat effects.

**1-Minimal**

Little effect is expected.

#### *8.1.3.3.2 Criteria for Scoring Certainty: Understanding and Predictability*

Scoring for certainty hinges on the level of understanding, predictability, and to a lesser extent importance. Certainty is based on the understanding score, which is modified (shifted up or down) by the associated predictability that accompanies the understanding, as shown in Figure 10.

**4-High:**

- Understanding is "high," **and**
- Nature of outcome (i.e., stress) is either: a) predictable (i.e., largely unconstrained by variability in ecosystem dynamics, other external factors, or b) is expected to confer effects under conditions or times of greatest importance (i.e., control over the outcome relative to other drivers and linkages affecting that same outcome).

**3-Medium:**

- Understanding is "high" (see scoring for 4) but nature of outcome is somewhat unpredictable, **or**
- Understanding is "medium" and nature of outcome (i.e., stress) is predictable (i.e., largely unconstrained by variability in ecosystem dynamics or other external factors).

**2-Low:**

- Understanding is "medium" but nature of outcome is somewhat unpredictable, **or**
- Understanding is "low" and nature of outcome (i.e., stress) is predictable (i.e., largely unconstrained by variability in ecosystem dynamics or other external factors).

**1-Minimal:**

- Understanding is lacking, **or**
- Understanding is "low" and nature of outcome (i.e., stress) is unpredictable (i.e., greatly dependent on highly variable ecosystem processes or other external factors).

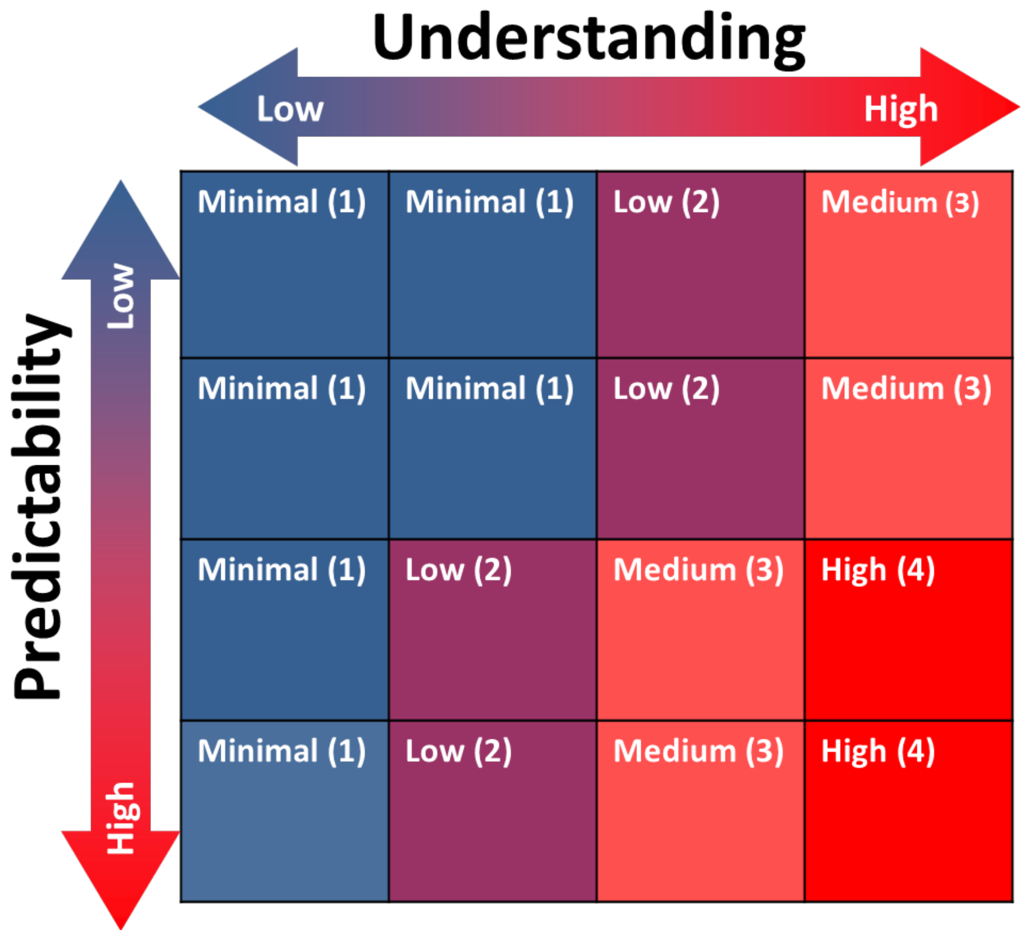



**Figure 10**
**Matrix Depicting Certainty Scoring Based on a Combination of Understanding and Predictability**

Note:
Understanding and predictability have specific definitions that determine the resulting score on the certainty matrix. See Section 8.1.3.2.3 for definitions.

#### *8.1.3.3.3 Scoring Understanding (as a Component of Certainty Scoring)*

Understanding is "**high**" based on near-term and long-term conditions as follows:

- Near-term conditions:
  - A "high" certainty is warranted in the near term when either of the following occurs:
    - Recent (i.e., within the last 10 years) and robust (e.g., multiple years spanning wet and dry conditions) agency data on the system for the stressor/variable of interest

    - More than one peer-reviewed paper of conditions on the system from within the last 20 years generally supporting the score
- Long-term conditions:
  - In general, future conditions are expected to be less certain than the near-term condition (because data or published papers are not yet available). A "high" certainty in the long term is warranted when either of the following occurs:
    - There is an established (high understanding per above) trend suggesting that near-term conditions are highly likely to maintain the certainty over the next 20 years or more.
    - There is a well-understood relationship between increased abundance of salmonids (the operating assumption of the long-term condition) and the certainty of the stressor.

Understanding is "**medium**" based on the following near-term and long-term conditions:

- Near-term conditions:
  - A "medium" certainty in the near-term is warranted when either of the following occurs:
    - There are agency data on the system for the stressor/variable of interest, but the data are not as recent and/or not as abundant/robust as described for the high score.
    - One peer-reviewed paper from the scientific literature and/or grey literature reports on the system from multiple disparate sources (i.e., different projects, not periodic interim reports from the same project) from within the last 20 years generally support the score.
- Long-term conditions:
  - A "medium" certainty in the long term is warranted when either of the following occurs:
    - There is some evidence suggesting that the near-term conditions are highly likely to continue or to increase the certainty of the score over the next 20 or more years.
    - There is evidence to suggest a relationship between increased abundance of salmonids in the system (the operating assumption of the long-term condition) and the certainty of the stressor.

Understanding is "**low**" based on the following near-term and long-term conditions:

- Near-term conditions:

  - No recent or robust data are available, and score is supported by one scientific grey literature report on the system from within the last 20 years.
- Long-term conditions:
  - There is little or no evidence suggesting that the near-term conditions are predictive of conditions 20 or more years into the future, and little evidence suggesting that increases in salmonid abundance will make the stressor score more certain in the future.

Understanding is "**minimal**" based on the following conditions:

- No record of robust data, and no available literature in the system or scientific grey literature report on the system older than 20 years

#### 8.1.3.4 Scoring Stress Based on Contributing Stressors

Once all the fine scale component stressors were scored, each coarse scale life history stage stress was given the highest score for any fine scale stressor. A life history stage stress cannot be scored lower than any of the component stressors.

### *8.1.4 Stressor Ranking and Prioritization*

Stressor prioritization is a function of the combination of scores for magnitude and certainty. Scores in these categories not only combine to produce the overall stressor ranking, but also provide insight into the appropriate stressor response as follows:

- High magnitude → Action
- Low magnitude → No action
- High certainty → Monitoring
- Low certainty → Research

In combination, magnitude and certainty scores reveal even greater detail about appropriate stressor response and prioritization as follows:

- High magnitude + High certainty → High priority action response
- High magnitude + Low certainty → High priority research response
- Low magnitude + High certainty → Low priority monitoring response
- Low magnitude + Low certainty → Low priority research response

Additionally, upper mid-range certainty scores, although still strong enough to warrant action (as opposed to research), indicate the likely need for adaptive management of the action and/or subsequent associated actions in order to achieve the desired stressor reduction. Similarly, low mid-range certainty scores indicate a high research priority with a focus on clarifying the design of specific action(s) to respond to and resolve the stressor. Figure 11 presents the full range of stressor responses associated with different magnitude and certainty score combinations.

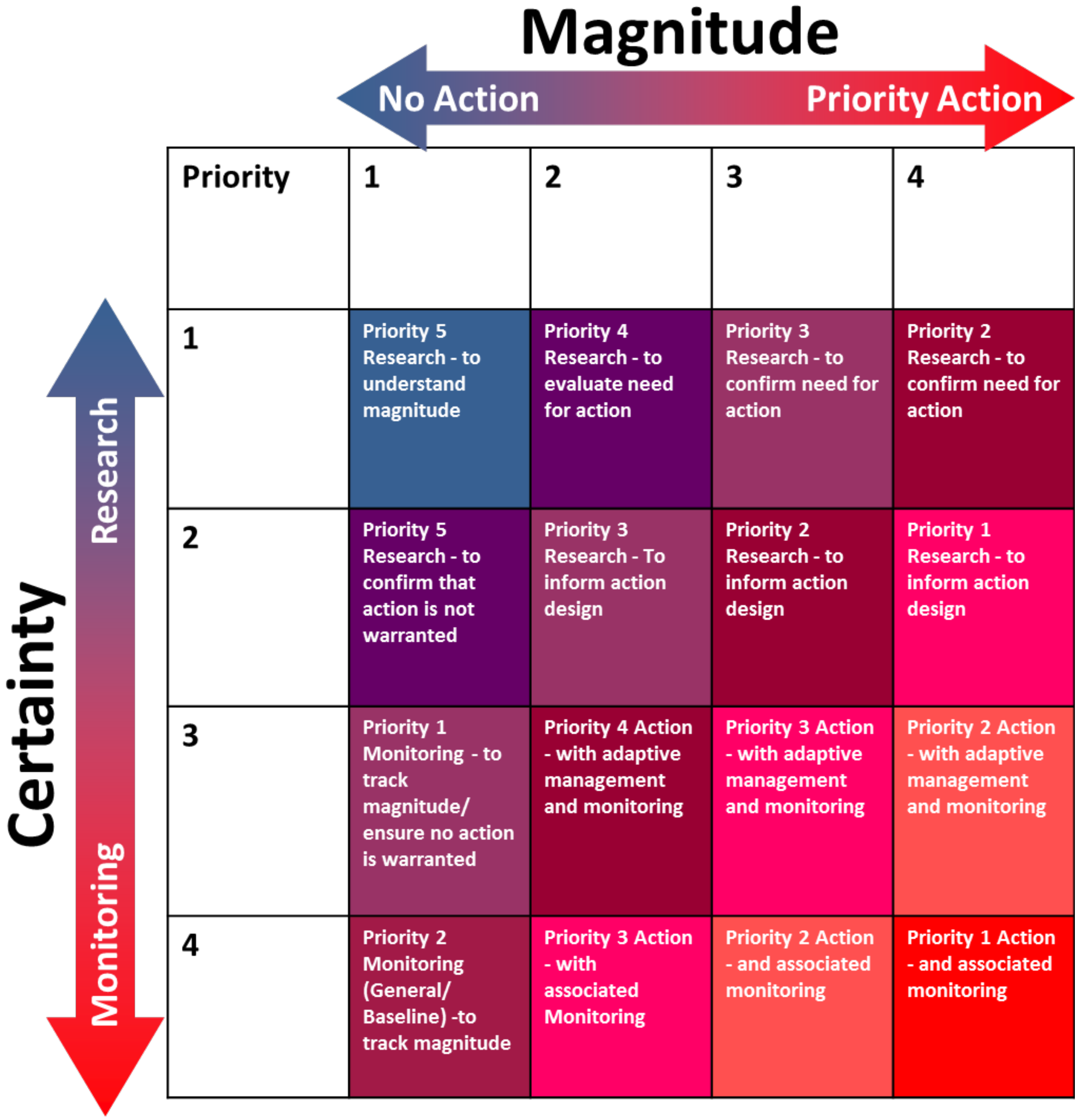



**Figure 11**

**Stressor Response Priorities Based on Combined Magnitude (Horizontal) and Certainty (Vertical) Scores**

Note:
Magnitude and certainty have specific definitions that determine the resulting score on the Priority matrix. See Section 8.1.3.2 for definitions.

To develop the overall stressor response prioritization for each species, stressor magnitude and certainty scores for all life history stages were combined. Stressor response priorities were then assigned to the coarse scale multi-variate stressors and the fine scale individual variable driven stressors. They were then grouped based on those applicable to near-term conditions (i.e., current and recovering populations) and long-term conditions (i.e., target populations). The results of this synthesis are summarized in Section 8.7.

## 8.2 Stressors on Adult Migration

Adult migration through freshwater represents one of the last stages in the Chinook salmon life cycle and a key (and most often terminal) stage in the steelhead life cycle. Individuals that reach this stage have avoided mortality in earlier life history stages and therefore have very high value from a life history perspective.

The SEP Group evaluated two categories of stress in the near term and long term for adult salmonids migrating into the San Joaquin and Stanislaus rivers, including the following:

- Failure to reach the natal stream due to straying or direct mortality
- Indirect lethal and sub-lethal impacts to migrating salmon (those that affect their subsequent holding or spawning success)

In addition, for fall-run Chinook salmon, the stress arising from late access to the spawning grounds was evaluated. Measuring any of these effects presents challenges: delays and direct mortality of migrating adults may go unnoticed if it occurs downstream of the first monitoring station in freshwater, and detecting reduced gamete viability generally requires directed studies of egg development success (e.g., in a hatchery).

Water temperature, DO, in-river predation/poaching, physical and biological passage barriers, toxic chemicals, and attraction flows are among the factors (stressors) that contribute to stress on the target populations during their adult migrations (Section 8.2.2). Near-term stresses reflect those that would impede attainment of Environmental or Biological Objectives under current conditions, including densities of target populations that may occur on the path to attainment of near-term objectives. Evaluation of stress in the long term assumed that adult salmon densities would increase substantially and that regional warming trends occur as anticipated (Dettinger et al. 2004; Cayan et al. 2008).

Complete blockage of salmonid migration due to impassable barriers (i.e., dams) is a stress that occurs during adult migration. Note that the population impact associated with this stress was assessed in the life history stages following adult migration as a function of the amount and quality of holding, spawning/egg development, and juvenile rearing habitats below the dams. In other words, the effect of impassable barriers is captured by the stress associated with inadequate habitat available in subsequent life history stages. As long as the extent of quality habitats for any freshwater life history stage is limited below the dam and additional acreage of those high-quality habitats are available above impassable dams, the dams will represent a stressor that impairs the ability of salmonid populations on the Stanislaus River to attain the Biological Objectives described in this report. Whether the stress created by inadequate habitat availability in any life history stage is best alleviated by allowing for adult migration beyond the dams or by creating new habitat below the dam is a question that will be evaluated by comparing different conservation proposals (i.e., it is beyond the scope of this report).

### *8.2.1 Current Migration Timing Pattern*

Scoring of stress is based on the potential exposure to stressors along the full migration pathway in the San Joaquin and Stanislaus rivers and across the range of each population's adult migration timing window (Figure 8). For comparison, current temporal distribution of fall-run Chinook salmon adult migration into the Stanislaus River was estimated from passage data collected at the counting weir located near the City of Riverbank (approximately RM 31.5). Some adult migration occurs through most of the target migration window for fall-run Chinook salmon in all years (Table 50); migration typically begins in late September, and the run is largely completed by late December. Typically, 50% of the annual escapement of fall-run Chinook salmon has occurred by the end of October, although in some years this milestone is not attained until early November. The distribution of returning adults appears to coincide with fall pulse flows (engineered releases from reservoirs) that are intended to stimulate upstream migration (Figure 12).

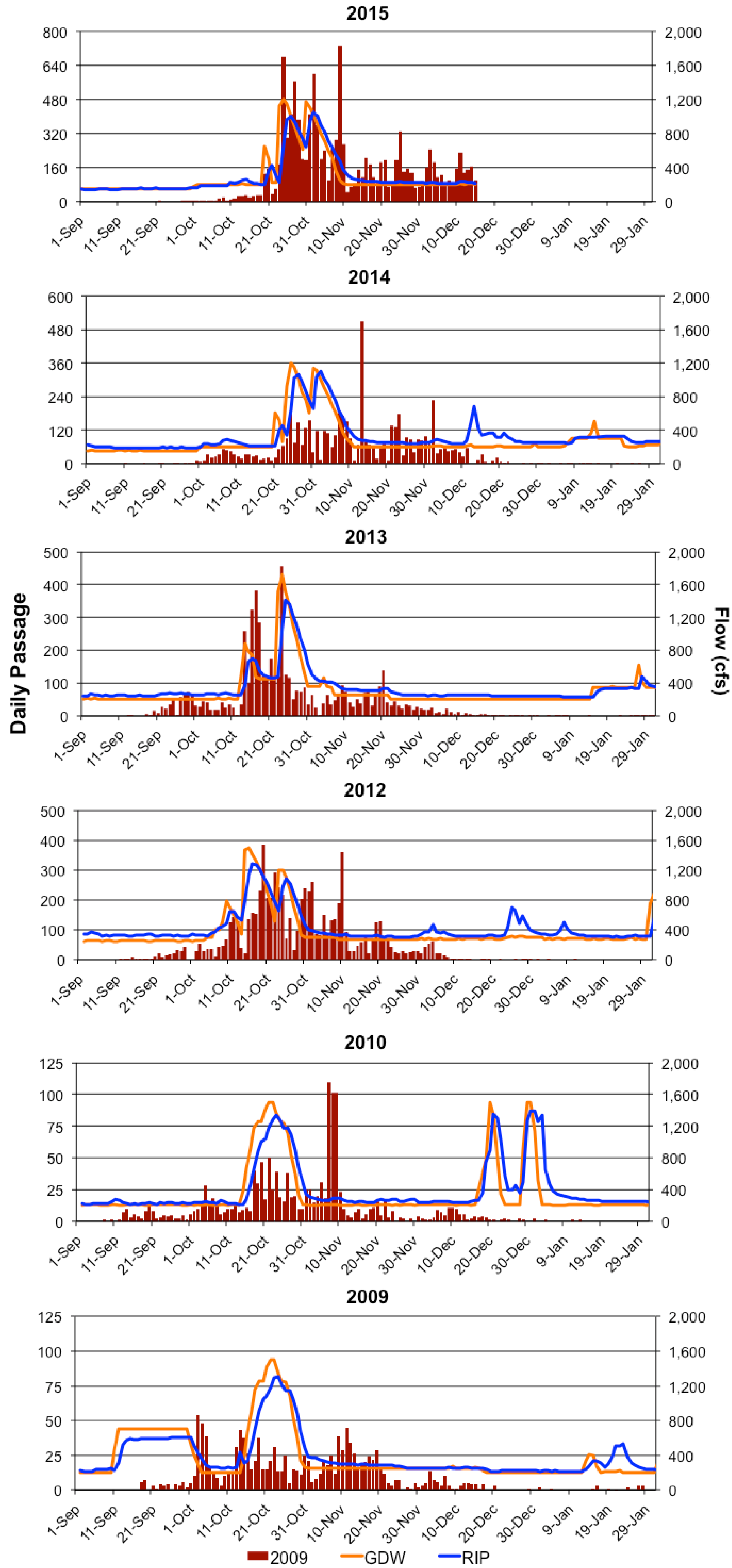



**Figure 12**
**Daily Adult Fall-run Chinook Salmon Passage**

Notes:
Daily adult fall-run Chinook salmon passage (red bars; left axis) measured at the Stanislaus River weir with respect to river flow measured at Goodwin Dam (GDW; orange line; right axis) and Ripon (RIP; blue line, right axis). Years 2009 through 2015 are shown, except for 2011 because high river flows made weir counts unreliable in that year.
Source: FISHBIO, unpublished data. Provided by J.D. Wikert, USFWS, December 2015.

Spring-run Chinook salmon and steelhead migrations in the Stanislaus River are not well monitored at this time, so the SEP Group's knowledge of adult movements in these two populations is based on ad hoc observations.

**Table 50**
**Cumulative Timing of Adult Fall-run Chinook Salmon Migration Past the Stanislaus River Weir, 2003 – 2014**

| | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sep 29 –Oct 5 | | | | | | 10% | 10% | 10% | Weir Data Unreliable | | 10% | |
| Oct 6 – 12 | 10%, 25% | 10% | | 10% | 10% | 25% | | | | 10% | | |
| Oct 13 – 19 | | | 10% | | | | 25% | 25% | | 25% | 25% | 10% |
| Oct 20 – 26 | | 25% | 25% | | 25% | 50% | | | | | 50% | |
| Oct 27 – Nov 2 | 50% | 50% | | 25% | 50% | | 50% | 50% | | 50% | | 25% |
| Nov 3 – 9 | | | 50% | 50% | | 75% | | 75% | | 75% | 75% | |
| Nov 10 – 16 | 75% | 75% | 75% | 75% | 75% | | 75% | | | 90% | | 50% |
| Nov 17 – 23 | | 90% | | | | | 90% | 90% | | | 90% | 75% |
| Nov 24 – 30 | 90% | | 90% | 90% | 90% | 90% | | | | | | |
| Dec 1 – 7 | | | | | | | | | | | | 90% |

Notes:
Numbers and shading represent percentiles of total returns for each year. Escapement timing in 2011 is not shown because flows during that year made weir counts unreliable for much of the migration season.
Source: FISHBIO, unpublished data. Provided by J.D. Wikert, USFWS, December 2015

### *8.2.2 Stress: Failure to Reach Holding or Spawning Habitat in the Natal Stream (Stanislaus) due to Direct Action of Stressors (e.g., Mortality, Straying, and Extreme Delays) (Adult Migration)*

Direct mortality and straying rates for Stanislaus-natal fish are currently unknown because adult salmon presence is not monitored regularly in the Delta, San Joaquin River, or lower Stanislaus River. However, straying of San Joaquin River Chinook salmon is believed to be high, especially when elevated Delta export and reduced San Joaquin River inflow levels alter hydrodynamic patterns in a way that affects homing ability (Marston et al. 2012). Current environmental conditions in the lower San Joaquin (below the Stanislaus confluence) and lower Stanislaus rivers are expected to have a direct, negative influence on successful migration into the Stanislaus in a way that would inhibit Stanislaus River productivity.[12]

Various factors, acting alone and in combination, may result in the failure of adult salmon to reach the Stanislaus River; data associated with these factors differ in quantity and quality. Hourly measures of temperature and DO are available from year-round long-term monitoring at several locations in the migratory corridor of Chinook salmon and steelhead returning to the Stanislaus River. Toxin concentrations also factor into this stress, but available data quality and quantity, as well as the spatial and temporal distribution of data, vary over a range of compounds. In-river fishing mortalities (legal and illegal) are not well monitored, so certainty regarding their effect is minimal. Improved monitoring of certain environmental conditions as well as study of the timing of salmonid migration into the San Joaquin River basin and Stanislaus watershed will be needed to fully understand the population-level effects of this stress.

#### 8.2.2.1 Fall-run Chinook Salmon

Failure of Stanislaus-bound fall-run Chinook salmon to reach the Stanislaus River in the near term as a direct result of poor environmental conditions was scored as a “medium” magnitude stress (Table 51) with a minimal degree of certainty. Certainty could be improved with additional monitoring of migrating adult salmon lower in the watershed (e.g., near where the San Joaquin River enters the Delta and/or the confluence of the Stanislaus River and San Joaquin River).

Without corrective action, failure of Stanislaus-bound fall-run Chinook salmon to reach spawning grounds as a direct response to poor environmental conditions will remain a “medium” magnitude stress (Table 51) over the long term. Without additional monitoring, certainty of this stress will remain minimal in the long term.

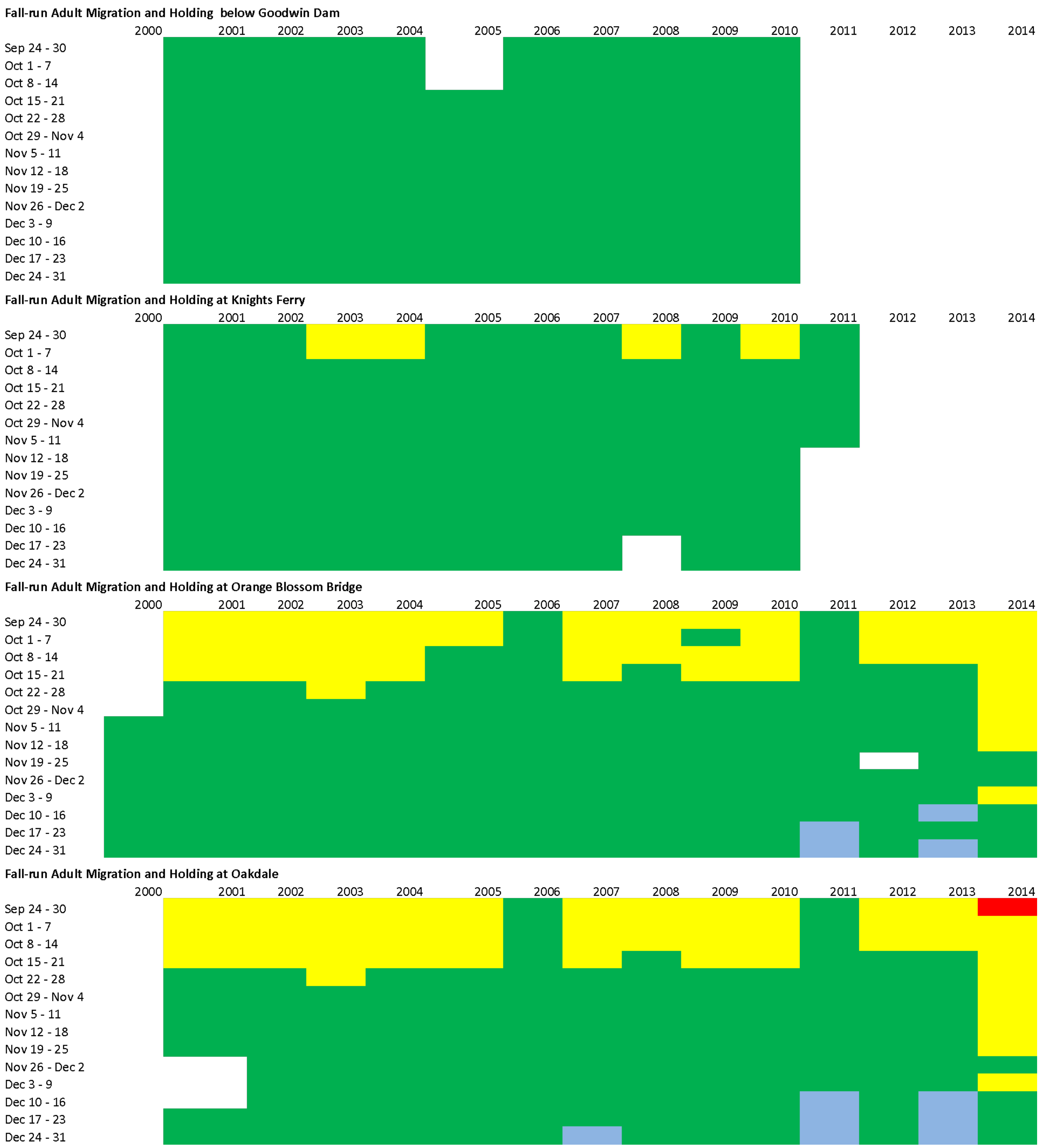
[12] The SEP Group currently has no Biological Objective pertaining to adults failing to reach the Stanislaus River or straying into the Stanislaus from other natal watersheds (however, see Biological Objective regarding genetic effects of hatchery strays). Without additional monitoring for adult salmon entering the lower San Joaquin River, such an objective would not be measurable. Management of the Stanislaus River is only partially responsible for conditions in the lower San Joaquin River. Additional objectives for migration success and associated Environmental Objectives will be incorporated into the SEP’s report on objectives and stressors for the San Joaquin Basin as a whole. Stresses impacting adult migration into the Stanislaus from the San Joaquin are documented here because they may affect Biological Objectives for other life history stages and as a placeholder for issues that must be addressed in a basin-wide assessment of stressors.

**Table 51**
**Adult Migration (Fall-run Chinook Salmon) Stressor Scores**

| | NT | | LT | | | | Stressors | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Temperature | | DO | | Toxins | | Fishing and Poaching | | Passable Physical Barriers (including low water levels and SAV) | | Attraction Flows | |
| Stress | M | C | M | C | Where | When | NT | LT | NT | LT | NT | LT | NT | LT | NT | LT | NT | LT |
| Failure to Reach Holding or Spawning Habitat in the Natal Stream (Stanislaus) due to Direct Action of Stressors (e.g., mortality, straying, and extreme delays) | 3 | 1 | 3 | 1 | Ripon and downstream to Stockton DWSC | Late Sept through early Oct | M: 2 C: 1 | M: 2 C: 1 | M: 2 C: 1 | M: 2 C: 1 | M: 1 C: 1 | M: 1 C: 1 | M: 1 C: 1 | M: 1 C: 1 | | | M: 3 C: 1 | M: 3 C: 1 |
| Indirect Mortality (e.g., disease outbreaks) and Sub-lethal Negative Effects | 3 | 3 | 4 | 3 | Primarily Stockton DWSC to Ripon (temperatures remain high up to Orange Blossom Bridge in some years) | Late Sept through mid-Oct to mid-Nov, depending on location | M: 3 C: 3 | M: 4 C: 3 | M: 3 C: 2 | M: 4 C: 2 | M: 3 C: 2 | M: 3 C: 2 | | | M: 2 C: 1 | M: 2 C: 1 | M: 3 C: 2 | M: 3 C: 2 |
| Limited Early Access to River (relative to migration window) due to Impassable or Unsuitable Conditions | 3 | 2 | 3 | 2 | Primarily Stockton DWSC to Ripon (temperatures remain high up to Orange Blossom Bridge in some years) | Late Sept through early Oct | M: 3 C: 2 | M: 3 C: 2 | M: 3 C: 2 | M: 3 C:2 | M: 2 C: 1 | M: 2 C: 1 | | | | | M: 3 C: 2 | M: 3 C: 2 |

Notes:
– Stress and stressors (i.e., contributing factors to a particular stress) for fall-run adult migration in the Stanislaus River for the near term (current conditions) and long term (assuming restored abundance goals and higher air temperatures). Scores for each stress were evaluated and assigned based on the scores for contributing stressors.
– M: Magnitude assesses the size or level of the impact from a stressor. Magnitude can be assigned using consideration of population or habitat effects, and higher scores require consideration of the scale or extent.
– C: Certainty describes the scientific basis for scoring the scale and magnitude of a particular stressor. Certainty considers both the predictability and understanding of linkages in the driver-linkage-outcome pathway from the stressor to the impact.
– Blank space denotes that stressor that is listed for the cell was not scored for the associated row because it is not believed to contribute to the stress identified in that row.
SAV: submerged aquatic vegetation
Scoring:
4: High
3: Medium
2: Low
1: Minimal
LT: long term
NT: near term

Comparing the desired adult migration window for Stanislaus River fall-run Chinook salmon run (late September through December) with the timing of temperature and DO conditions downstream of the weir, there is evidence that adult fall-run Chinook salmon migration to the Stanislaus River could be delayed or blocked completely during key time periods in the migration window, either in the lower San Joaquin River mainstem or the lower Stanislaus River, in most years (Figure 13).



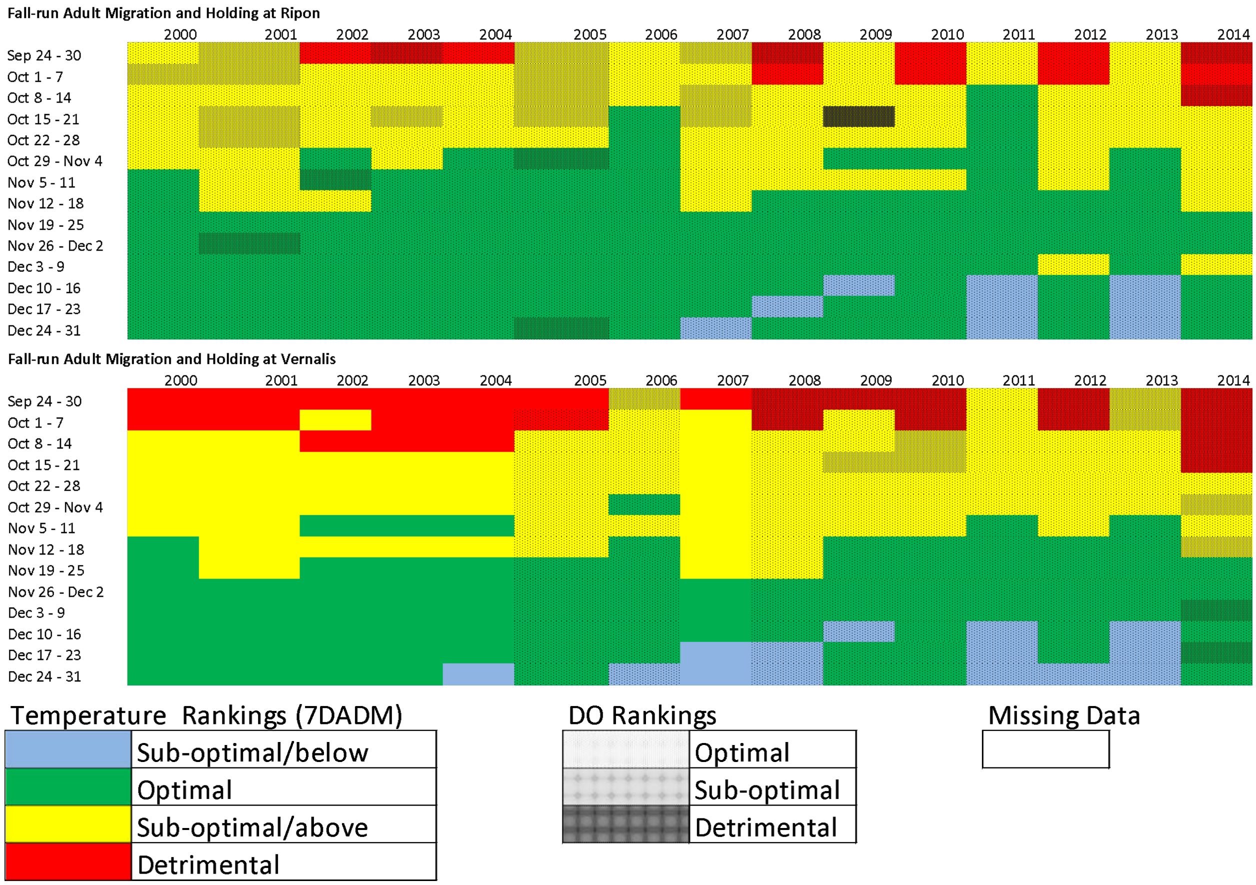



**Figure 13**
**Fall-run Chinook Salmon Adult Migration and Holding**

Notes:
Temperature and DO rankings are based on observed data during periods of adult migration and holding. Time periods with rankings of stressful or detrimental provide evidence for the potential for barriers to migration and/or reduced egg viability. Rankings reflect the Environmental Objectives for temperature and DO (Section 7). Data are from the California Data Exchange Center (CDEC) for each location.

High temperatures and low DO likely block salmon migration at levels that are recorded in most years in the lower San Joaquin and lower Stanislaus rivers (see Environmental Objectives for Adult Migration, Section 7.2.1) during the first few weeks of the fall-run Chinook salmon migration (late September and early October). Furthermore, fall-run Chinook salmon migration into the Stanislaus River corresponds with the onset of scheduled pulse flows (Figure 12), and these pulses typically occur in the second or third week of October, several weeks after the fall-run migration is expected to begin. Prior to the onset of flows that may cue fall-run Chinook migration, any adult fish waiting to begin migration in the Delta or lower San Joaquin River would be exposed to poor water quality conditions that may be associated with mortality or straying. Scored collectively, these factors probably have a sustained minor population-level effect (or “medium” magnitude) on adult salmon attempting to reach the Stanislaus River. The certainty of this stress is minimal because there is

”medium” to “high” understanding of the relationship across multiple factors (DO and temperature) on this stress, but the predictability is “low.” Some individuals can and do complete their migration despite very poor conditions in the migratory corridor, and the timing of adult migration is related to the timing of return from the ocean, which is uncertain and not well monitored. Negative consequences of low DO and high temperatures may be reinforced by the direct effect of toxins on migration success. Generally, toxin concentrations are not high enough to cause complete migration failure for prolonged periods (Hoogeweg et al. 2011); however, the interaction of multiple toxins with high temperatures and low DO levels leads to minimal certainty of the magnitude score (i.e., the magnitude of the effect of toxins on migration success may be higher than expected).

#### 8.2.2.2 Spring-run Chinook Salmon

Failure of Stanislaus-bound spring-run Chinook salmon to reach the Stanislaus River in the near term was scored as a “medium” magnitude stress with a minimal degree of certainty in the near term (Table 52). As described for fall-run Chinook salmon, certainty regarding this stress is “minimal” because the magnitude is related to the temporal distribution of salmon returns from the ocean (i.e., the stock of adult migrants available to begin river migration at any point in time), a factor that is not well monitored.

Without corrective action, failure of Stanislaus-bound spring-run Chinook salmon to reach the Stanislaus River is expected to be a high magnitude stress over the long term (Table 52). Temperatures are expected to increase in the future and will exacerbate low DO conditions in the lower San Joaquin River and Delta. These conditions will increase the stress caused by lack of attraction pulse flows later in the migration window or pulses of limited size and duration. The projected deterioration of migration conditions, combined with an increase in density (and temporal distribution) of migrating spring-run adults, will increase the certainty of this stress to a low level in the long term. Magnitude will still depend on temporal distribution of returning migrants, but, unless corrected, the period of inhospitable migration conditions is expected to become so large that the certainty of the impact is increased. As with fall-run Chinook salmon, increased monitoring of spring-run adult migrants upstream and in the lower part of the watershed would increase the certainty of this stress.

**Table 52**
**Adult Migration (Spring-run Chinook Salmon) Stressor Scores**

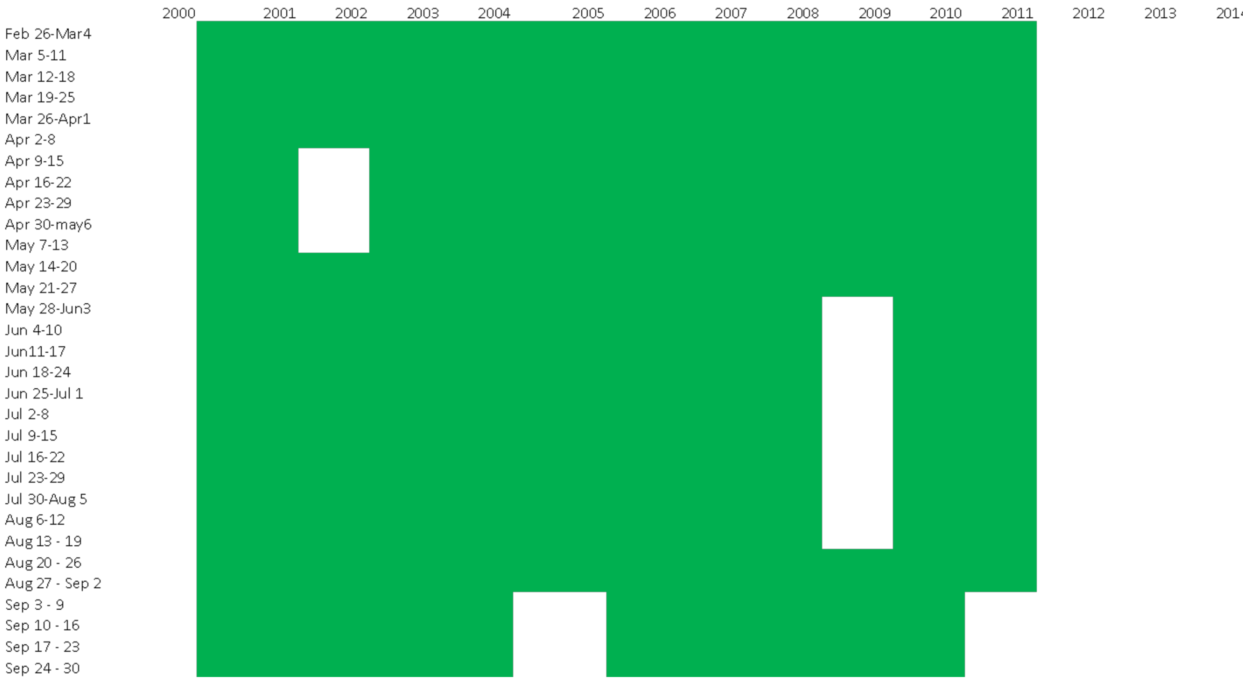
| Stress | NT | | LT | | Where | When | Stressors | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Temperature | | DO | | Toxins | | Fishing and Poaching | | Passable Physical Barriers (incl. low water levels and SAV) | | Attraction Flows | |
| Stress | M | C | M | C | Where | When | NT | LT | NT | LT | NT | LT | NT | LT | NT | LT | NT | LT |
| Failure to Reach Holding or Spawning Habitat in the Natal Stream (Stanislaus) due to Direct Action of Stressors (e.g., mortality, straying, and extreme delays) | 2 | 1 | 3 | 2 | Ripon and downstream to Stockton DWSC | Late September through early October | M: 2 C: 1 | M: 3 C: 2 | M: 2 C: 1 | M: 3 C: 2 | M: 1 C: 1 | M: 1 C: 1 | M: 1 C: 1 | M: 1 C: 1 | | | M: 2 C: 1 | M: 3 C: 2 |
| Indirect Mortality (e.g., disease outbreaks) and Sub-lethal Negative Effects | 3 | 2 | 4 | 2 | Primarily Stockton DWSC to Ripon (temperatures remain high up to Orange Blossom Bridge in some years) | Most of March through June in most years | M: 3 C: 2 | M: 4 C: 2 | M: 3 C: 2 | M: 3 C:2 | M: 2 C: 1 | M: 2 C: 1 | | | M: 2 C: 1 | M: 2 C: 1 | M: 3 C: 2 | M: 4 C: 2 |

Notes:
– Stress and stressors (i.e., contributing factors to a particular stress) for spring-run adult migration in the Stanislaus River for the near term (current conditions) and long term (assuming restored abundance goals and higher air temperatures). Scores for each stress were evaluated and assigned based on the scores for contributing stressors.
M: Magnitude assesses the size or level of the impact from a stressor. Magnitude can be assigned using consideration of population or habitat effects, and higher scores require consideration of the scale or extent.
– C: Certainty describes the scientific basis for scoring the scale and magnitude of a particular stressor. Certainty considers both the predictability and understanding of linkages in the driver-linkage-outcome pathway from the stressor to the impact.
– Blank space denotes that stressor that is listed for the cell was not scored for the associated row because it is not believed to contribute to the stress identified in that row.
Scoring:
4: High
3: Medium
2: Low
1: Minimal
LT: long term
NT: near term

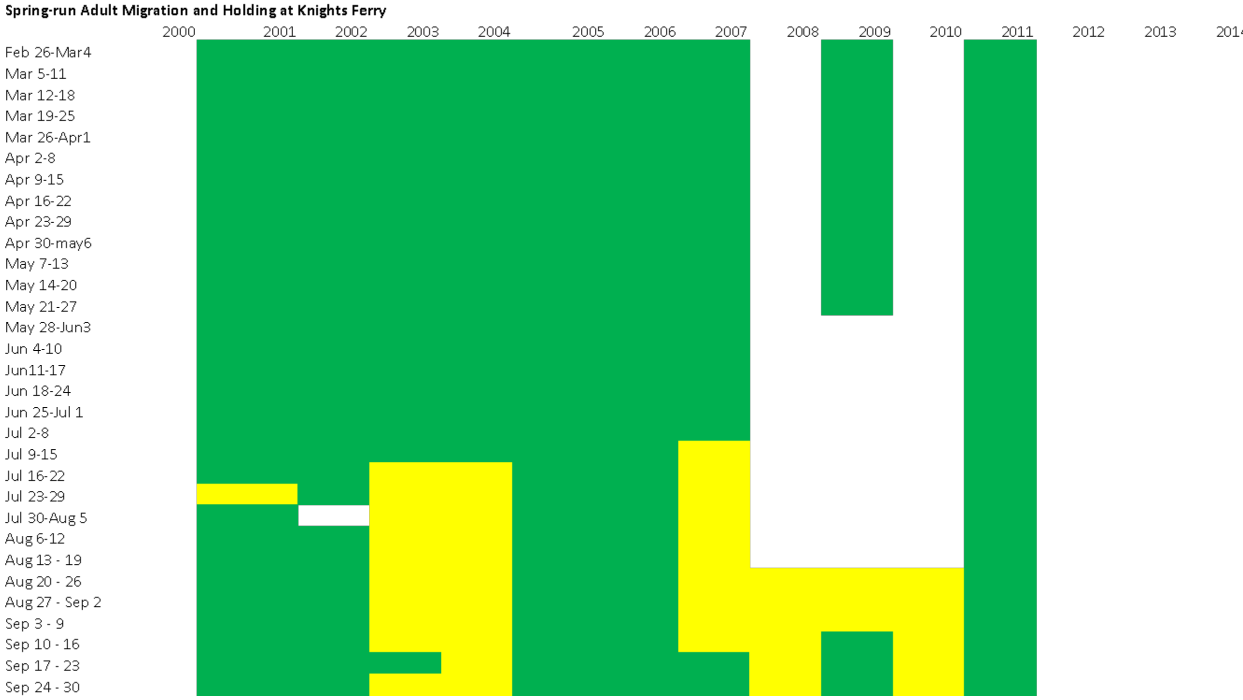
Unlike the fall-run Chinook salmon, migration conditions become progressively worse during the spring-run Chinook salmon migration period—spring-run that delay migration are unlikely to find suitable conditions later in the migration season. Adult spring-run Chinook salmon exposed to a combination of high temperatures, low DO, and extremely low river flows are likely to experience significant delays that cause them to stray to other watersheds where better conditions prevail or die as they wait for suitable migration conditions to occur. The combination of factors that produce straying and/or mortality during migration are likely to affect a fraction of adult migrants in a recovering spring-run population in the near term. Based on the timing of temperature and DO conditions during the spring (Figure 14), it is likely that as the spring-run population grows in the near term, many adult spring-run Chinook salmon will experience conditions that can block their migration toward holding grounds in the Stanislaus River during part of their migration season.

Temperatures that can block migration occur at Ripon and Vernalis after May in most years and earlier than May under drought conditions. Those DO conditions known to block Chinook salmon migrations (see Environmental Objectives for Adult Migration, Section 7.2.1) also occur frequently in the Stockton DWSC from June through the summer and at Vernalis starting in July. Finally, pulse flows that might attract adult spring-run Chinook salmon occur in late April and May as part of water quality standards designed to improve survival of emigrating juvenile Chinook salmon; however, before and after these scheduled pulses occur, required base flows in the lower San Joaquin and Stanislaus rivers may be inadequate to promote adult migration. Straying or mortality resulting from temperature-related or DO-related migration blockages (or the interaction of these factors with contaminant concentrations) may be expected for the latter half of the migration period, but the certainty of this effect is minimal because of uncertainty regarding the timing pattern of spring-run entering the San Joaquin River basin.

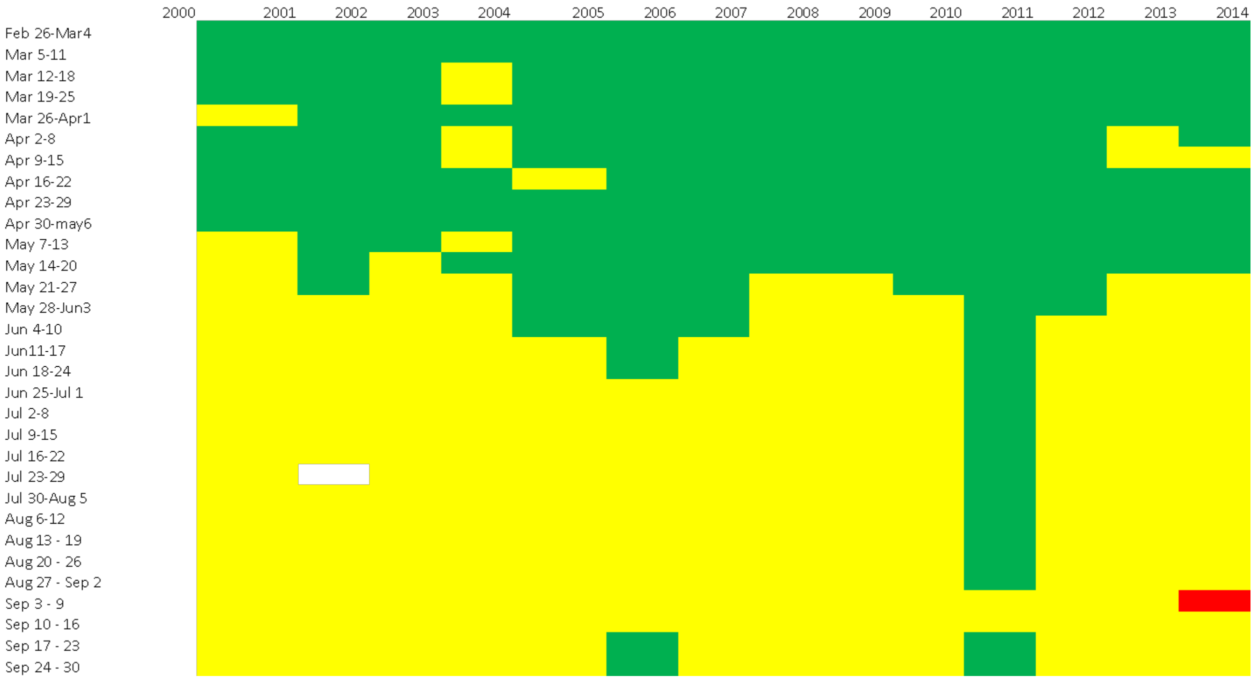
**Spring-run Adult Migration and Holding below Goodwin Dam**



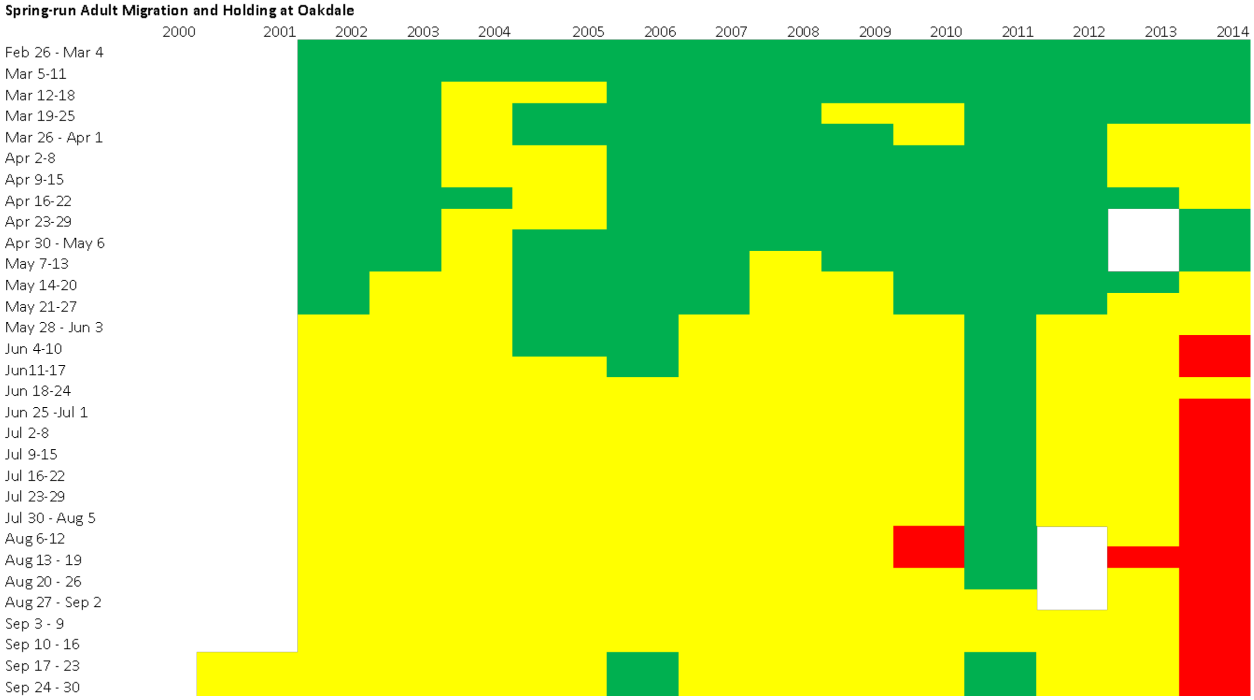

**Spring-run Adult Migration and Holding at Knights Ferry**



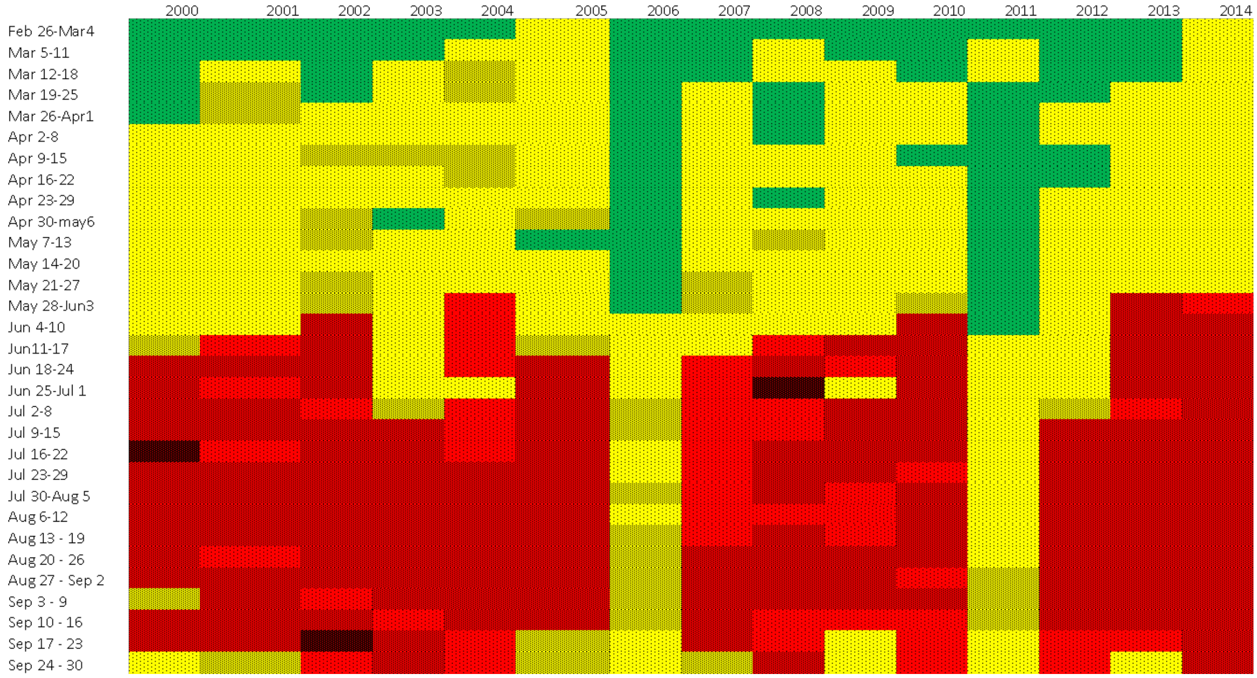
**Spring-run Adult Migration and Holding at Orange Blossom Bridge**



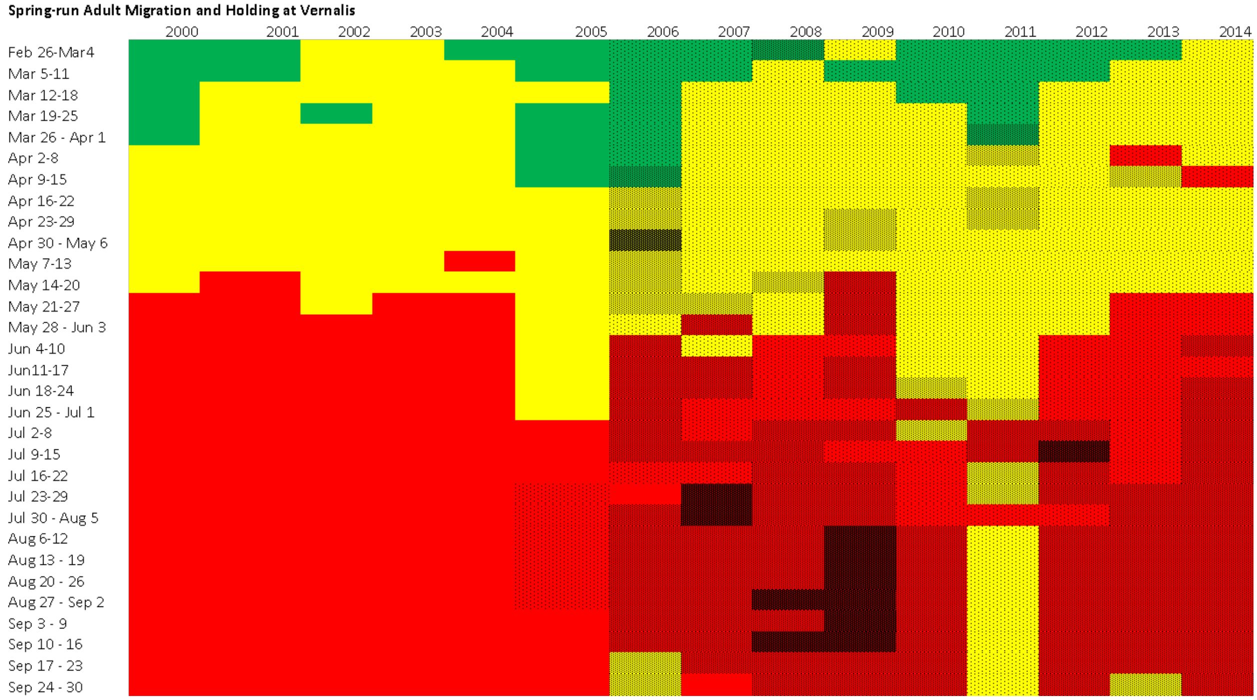

**Spring-run Adult Migration and Holding at Oakdale**



Spring-run Adult Migration and Holding at Ripon




Spring-run Adult Migration and Holding at Vernalis



Temperature Rankings (7DADM)

| | |
|---|---|
| | Sub-optimal/below |
| | Optimal |
| | Sub-optimal/above |
| | Detrimental |

DO Rankings

| | |
|---|---|
| | Optimal |
| | Sub-optimal |
| | Detrimental |

Missing Data

**Figure 14**
**Spring-run Chinook Salmon Adult Migration and Holding**

Notes:
Temperature and DO rankings are based on observed data during periods of adult migration and holding. Time periods with rankings of stressful or detrimental provide evidence for the potential for barriers to migration and/or reduced egg viability. Rankings reflect the Environmental Objectives for temperature and DO (Section 7). Data are from the CDEC for each location.

Temperature increases expected in the long term will likely increase the magnitude of direct effects on spring-run migration as a larger fraction of the population experiences inhospitable migration conditions. High temperatures in the long term will also tend to reduce DO levels experienced by adult Chinook salmon migrating into the lower San Joaquin and Stanislaus rivers, especially because current regulations allow for lower DO levels in the Stockton DWSC during the spring than during the fall-run Chinook salmon migration season (CVRWQCB 2018). Furthermore, pulse flows intended to help transport juvenile Chinook salmon are currently scheduled from mid-April to mid-May, but the timing of these pulse flows may strand a significant fraction of up-migrating adult spring-run Chinook salmon (i.e., those that return later in the season) in the Delta and lower San Joaquin River. As a result, direct impacts to spring-run Chinook salmon migration success in the long term are expected to increase to a sustained major population-level effect. The certainty of this effect in the long term increases to "low" because the duration of conditions that block upstream migration is expected to cover a larger portion of the migration window. Again, certainty could be improved with additional monitoring of spring-run Chinook salmon adult migrants.

#### 8.2.2.3 Steelhead

Stressful conditions that would cause failure of steelhead migration to spawning grounds on the Stanislaus River are expected to generate low level stress with a minimal degree of certainty in the near term (Table 53). Stressful conditions that could result in migration failure occur early and late in the migration season in most years. Certainty of direct effects on migration success is "minimal" for the same reasons as those described for Chinook salmon; also, migration timing of steelhead may be more plastic than it is for Chinook salmon (i.e., some steelhead that experience poor migration conditions may be able to wait for improved migration conditions to arise).

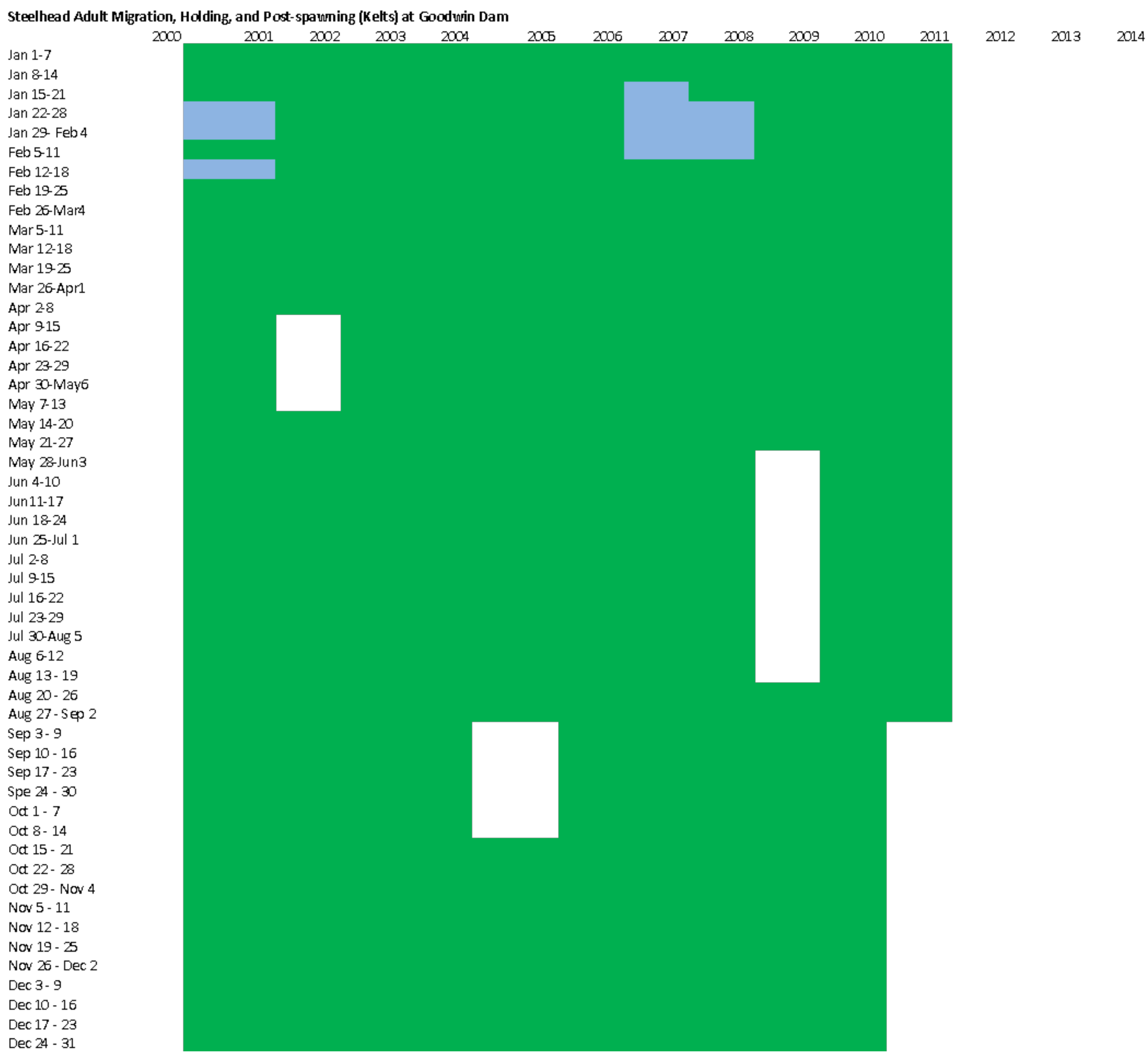
Without corrective action, factors that would drive blockage of migrating steelhead are likely to remain a "low" magnitude stress (Table 53) in the long term. Without additional monitoring, certainty will remain minimal, meaning the magnitude of the stress could be higher or lower than estimated here.

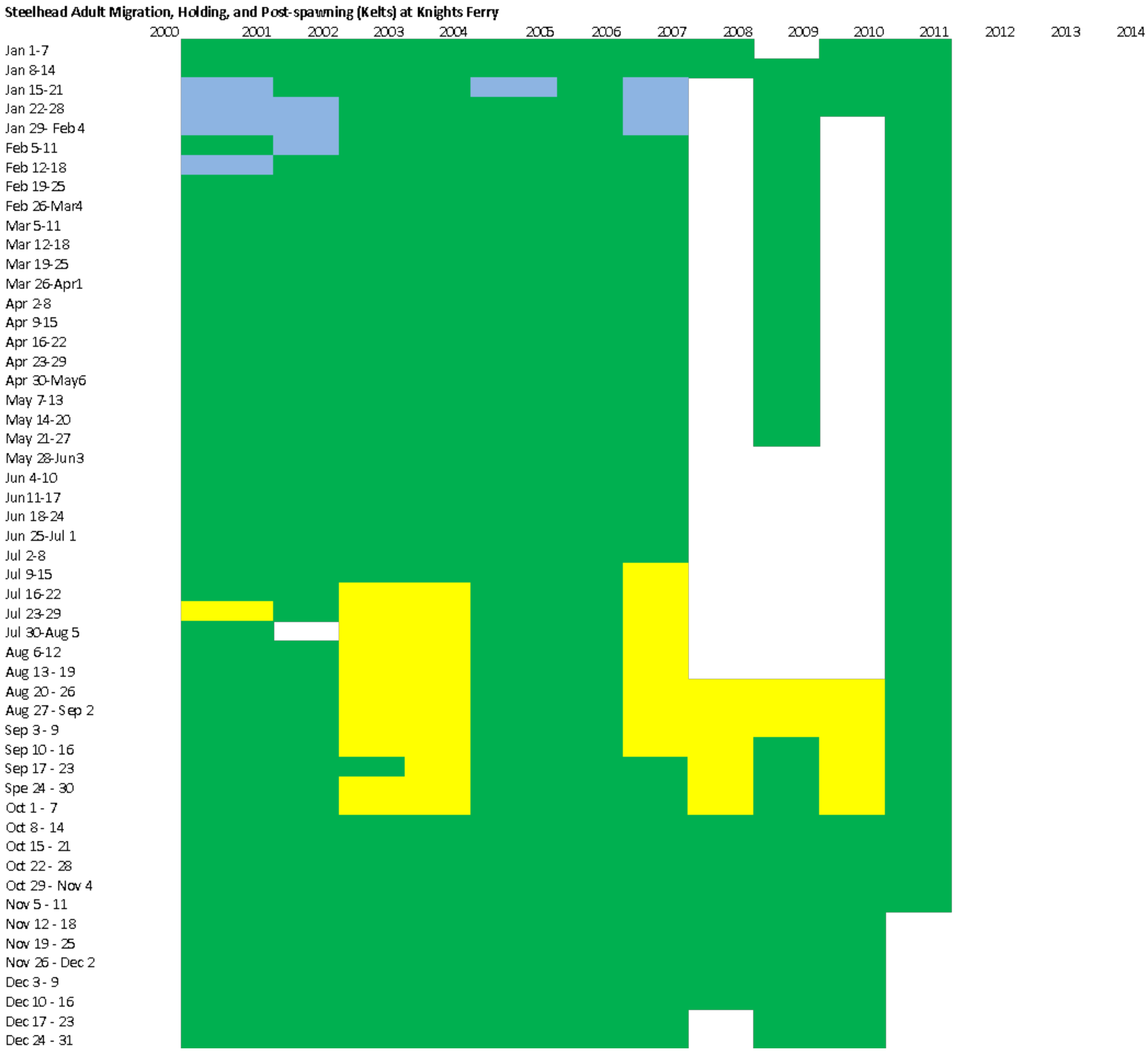
**Table 53**
**Adult Migration (Steelhead) Stressor Scores**

| Stress | Near Term | | Long Term | | Where | When | Stressors | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Temperature | | DO | | Toxins | | Fishing and Poaching | | Passable Physical Barriers (including low water levels and SAV) | | Attraction Flows | |
| | M | C | M | C | | | NT | LT | NT | LT | NT | LT | NT | LT | NT | LT | NT | LT |
| Failure to Reach Holding or Spawning Habitat in the Natal Stream (Stanislaus) due to Direct Action of Stressors (e.g., mortality, straying, and extreme delays) | 2 | 1 | 2 | 1 | Primarily Stockton to Ripon; toxins may be a problem up to Orange Blossom Bridge | September through mid-October | M: 2 C: 1 | M: 2 C: 1 | M: 2 C: 1 | M: 2 C: 1 | M: 1 C: 1 | M: 1 C: 1 | M: 1 C: 1 | M: 1 C: 1 | | | M: 2 C: 1 | M: 2 C: 1 |
| Indirect Mortality (e.g., disease outbreaks) and Sub-lethal Negative Effects | 3 | 1 | 3 | 1 | Primarily Stockton DWSC to Ripon (temperatures remain high up to Orange Blossom Bridge in some years) | September through mid-October (temperature and DO) and March through April (temperature and toxins) | M: 3 C: 1 | M: 3 C: 1 | M: 2 C: 1 | M: 2 C: 1 | M: 3 C: 1 | M: 3 C: 1 | | | M: 1 C: 3 | M: 1 C: 3 | M: 3 C: 1 | M: 3 C: 1 |

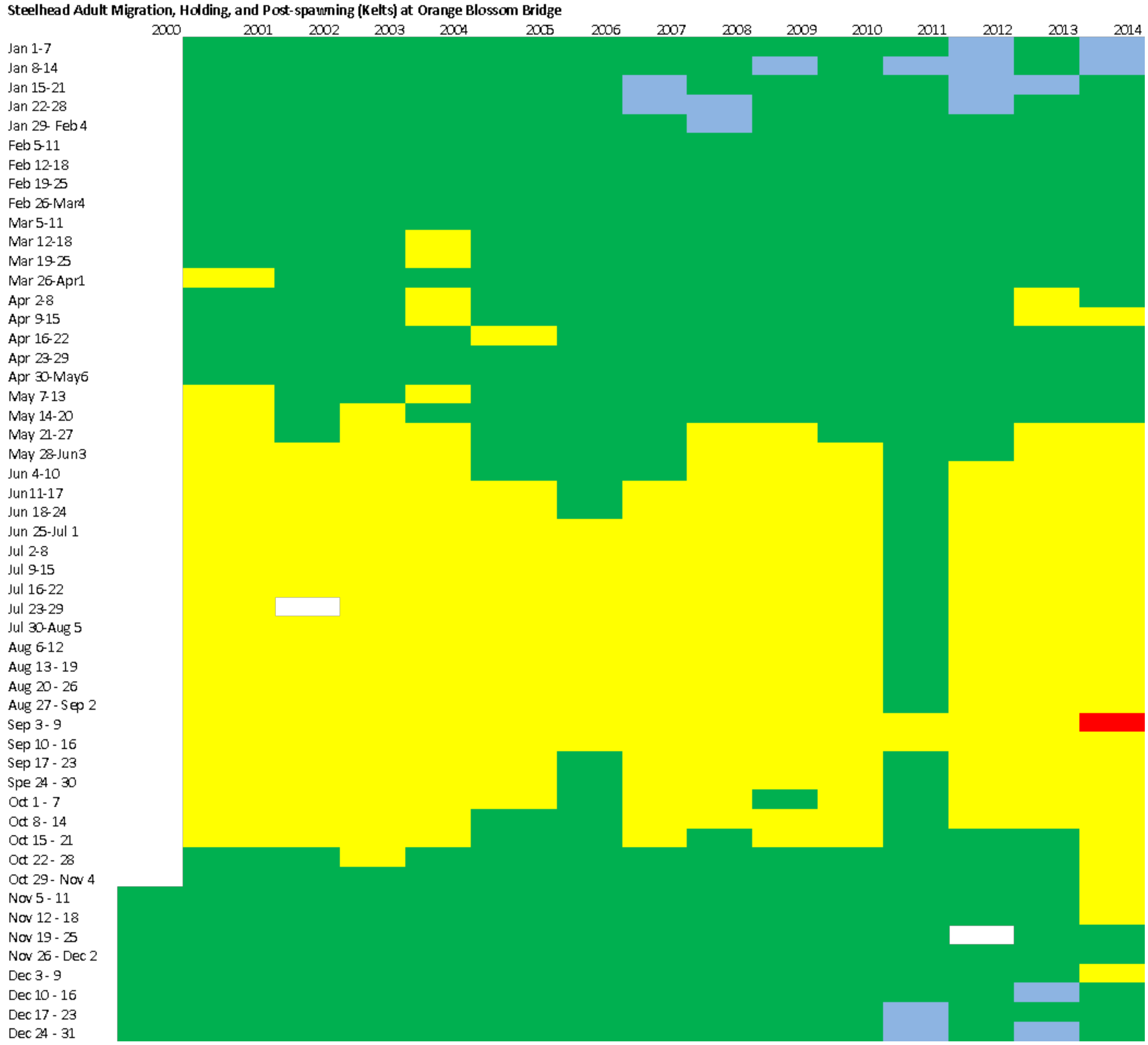
Notes:
– Stress and stressors (i.e., contributing factors to a particular stress) for steelhead adult migration in the Stanislaus River for the near term (current conditions) and long term (assuming restored abundance goals and higher air temperatures). Scores for each stress were evaluated and assigned based on the scores for contributing stressors.
– M: Magnitude assesses the size or level of the impact from a stressor. Magnitude can be assigned using consideration of population or habitat effects, and higher scores require consideration of the scale or extent.
– C: Certainty describes the scientific basis for scoring the scale and magnitude of a particular stressor. Certainty considers both the predictability and understanding of linkages in the driver-linkage-outcome pathway from the stressor to the impact.
– Blank space denotes that stressor that is listed for the cell was not scored for the associated row because it is not believed to contribute to the stress identified in that row.
Scoring:
4: High
3: Medium
2: Low
1: Minimal
LT: long term
NT: near term

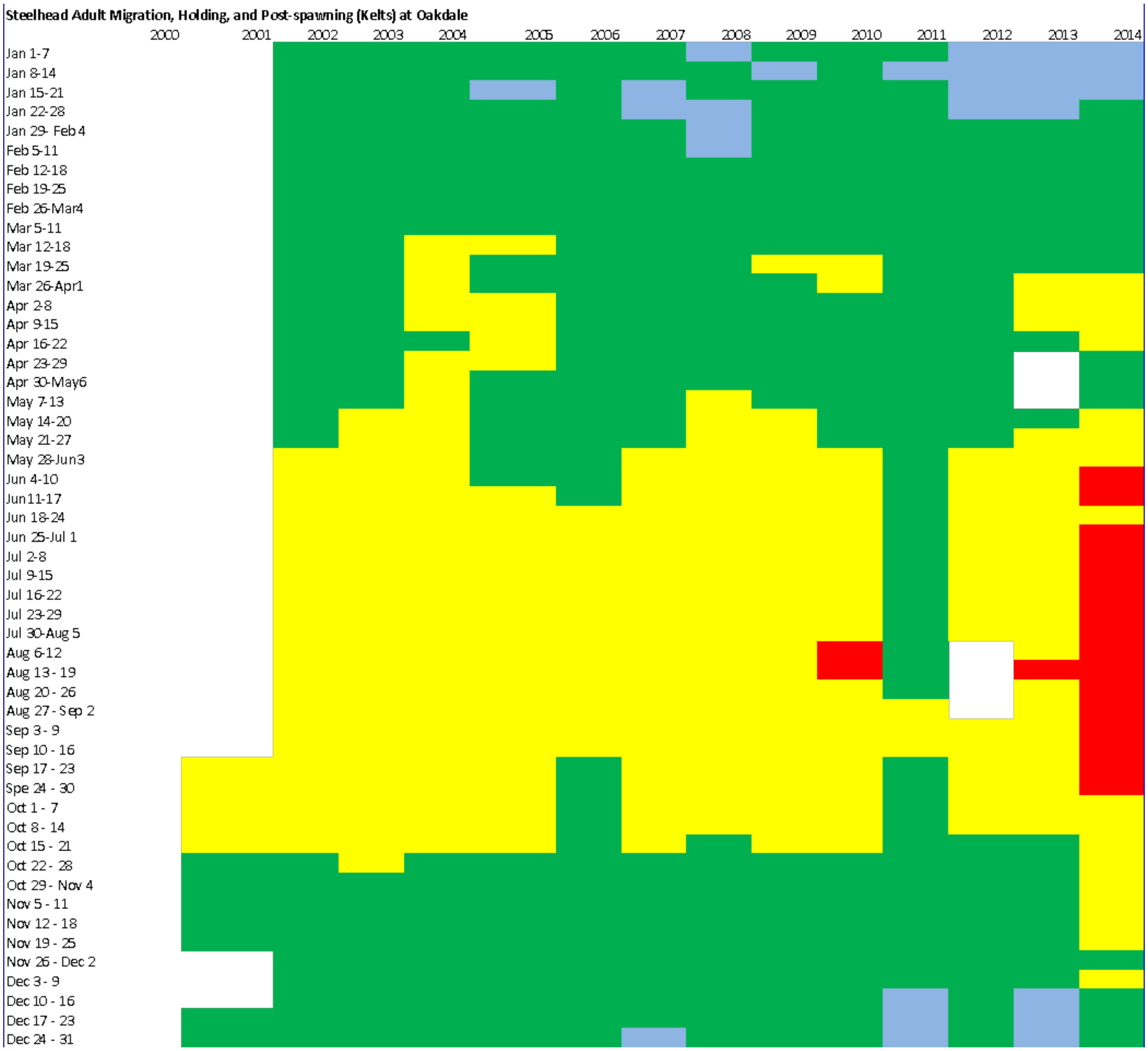
The steelhead adult migration period is longer than that for spring-run or fall-run Chinook salmon (Figure 8). Temperatures that would block migrating adult steelhead occur during the early part of this migration window at Vernalis and occasionally at Ripon (Figure 15). Steelhead may occasionally be blocked by low DO at Vernalis and the Stockton DWSC early in the migration season. Toxins do not reach concentrations that would be expected to completely block steelhead migrations for a protracted period (Hoogeweg et al. 2011 and Appendix B). However, concentrations may be lethal or cause complete migration blockage sporadically from March through May in the lower San Joaquin and infrequently in the lower Stanislaus River (between Ripon and Orange Blossom Bridge) during April and May. The frequency of such events and uncertainty regarding the temporal distribution of adult steelhead migrations and interaction of toxins with high temperature and/or low DO conditions leads to “minimal” certainty regarding the effect of toxins on this stress.

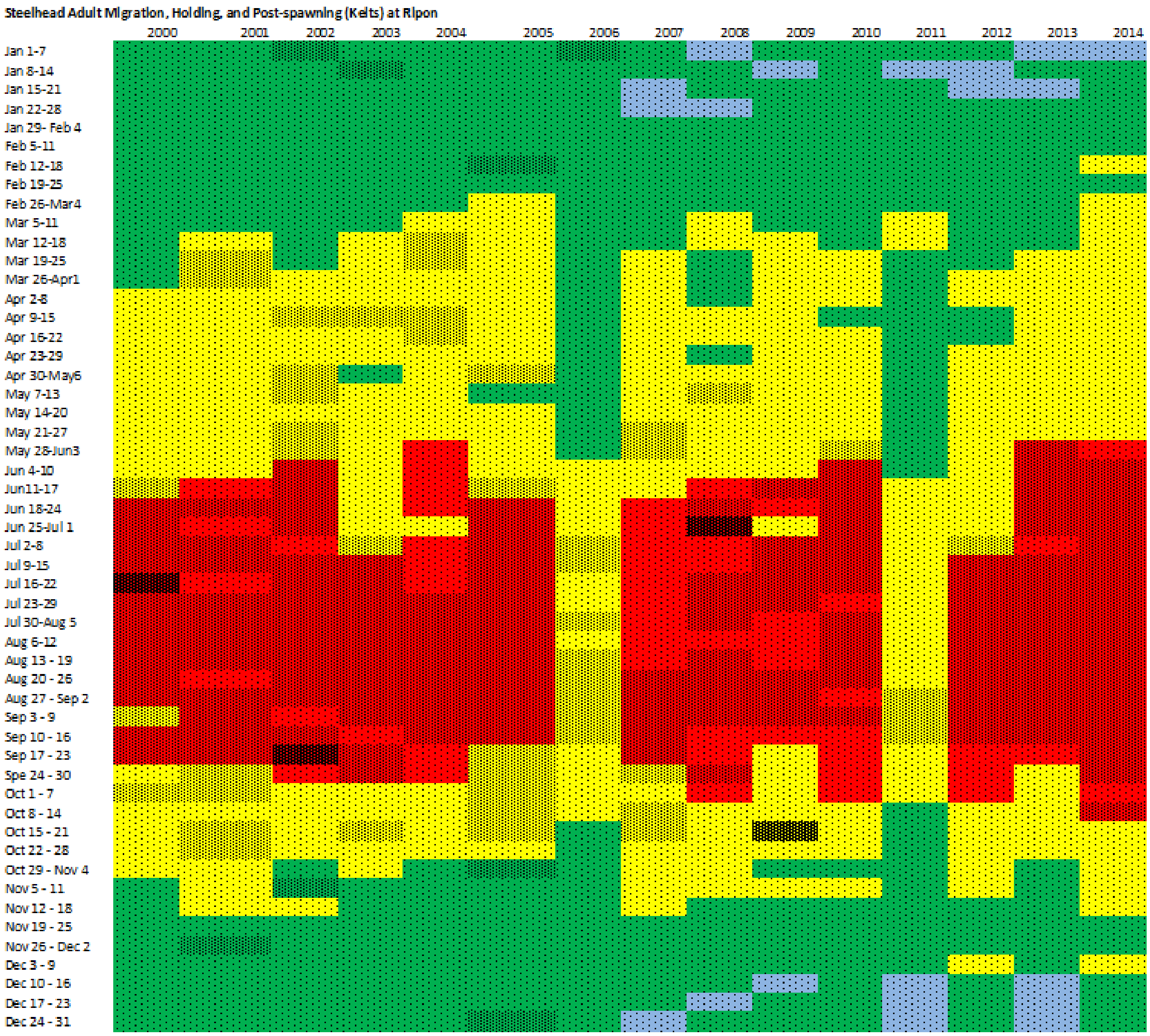



Steelhead Adult Migration, Holding, and Post-spawning (Kelts) at Knights Ferry
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
Jan 1-7
Jan 8-14
Jan 15-21
Jan 22-28
Jan 29- Feb 4
Feb 5-11
Feb 12-18
Feb 19-25
Feb 26-Mar4
Mar 5-11
Mar 12-18
Mar 19-25
Mar 26-Apr1
Apr 2-8
Apr 9-15
Apr 16-22
Apr 23-29
Apr 30-May6
May 7-13
May 14-20
May 21-27
May 28-Jun3
Jun 4-10
Jun 11-17
Jun 18-24
Jun 25-Jul 1
Jul 2-8
Jul 9-15
Jul 16-22
Jul 23-29
Jul 30-Aug 5
Aug 6-12
Aug 13 - 19
Aug 20 - 26
Aug 27 - Sep 2
Sep 3 - 9
Sep 10 - 16
Sep 17 - 23
Spe 24 - 30
Oct 1 - 7
Oct 8 - 14
Oct 15 - 21
Oct 22 - 28
Oct 29 - Nov 4
Nov 5 - 11
Nov 12 - 18
Nov 19 - 25
Nov 26 - Dec 2
Dec 3 - 9
Dec 10 - 16
Dec 17 - 23
Dec 24 - 31

**Steelhead Adult Migration, Holding, and Post-spawning (Kelts) at Orange Blossom Bridge**




Steelhead Adult Migration, Holding, and Post-spawning (Kelts) at Oakdale
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
Jan 1-7
Jan 8-14
Jan 15-21
Jan 22-28
Jan 29- Feb 4
Feb 5-11
Feb 12-18
Feb 19-25
Feb 26-Mar4
Mar 5-11
Mar 12-18
Mar 19-25
Mar 26-Apr1
Apr 2-8
Apr 9-15
Apr 16-22
Apr 23-29
Apr 30-May6
May 7-13
May 14-20
May 21-27
May 28-Jun3
Jun 4-10
Jun 11-17
Jun 18-24
Jun 25-Jul 1
Jul 2-8
Jul 9-15
Jul 16-22
Jul 23-29
Jul 30-Aug 5
Aug 6-12
Aug 13 - 19
Aug 20 - 26
Aug 27 - Sep 2
Sep 3 - 9
Sep 10 - 16
Sep 17 - 23
Spe 24 - 30
Oct 1 - 7
Oct 8 - 14
Oct 15 - 21
Oct 22 - 28
Oct 29 - Nov 4
Nov 5 - 11
Nov 12 - 18
Nov 19 - 25
Nov 26 - Dec 2
Dec 3 - 9
Dec 10 - 16
Dec 17 - 23
Dec 24 - 31


Steelhead Adult Migration, Holding, and Post-spawning (Kelts) at Ripon
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
Jan 1-7
Jan 8-14
Jan 15-21
Jan 22-28
Jan 29- Feb 4
Feb 5-11
Feb 12-18
Feb 19-25
Feb 26-Mar4
Mar 5-11
Mar 12-18
Mar 19-25
Mar 26-Apr1
Apr 2-8
Apr 9-15
Apr 16-22
Apr 23-29
Apr 30-May6
May 7-13
May 14-20
May 21-27
May 28-Jun3
Jun 4-10
Jun11-17
Jun 18-24
Jun 25-Jul 1
Jul 2-8
Jul 9-15
Jul 16-22
Jul 23-29
Jul 30-Aug 5
Aug 6-12
Aug 13 - 19
Aug 20 - 26
Aug 27 - Sep 2
Sep 3 - 9
Sep 10 - 16
Sep 17 - 23
Spe 24 - 30
Oct 1 - 7
Oct 8 - 14
Oct 15 - 21
Oct 22 - 28
Oct 29 - Nov 4
Nov 5 - 11
Nov 12 - 18
Nov 19 - 25
Nov 26 - Dec 2
Dec 3 - 9
Dec 10 - 16
Dec 17 - 23
Dec 24 - 31

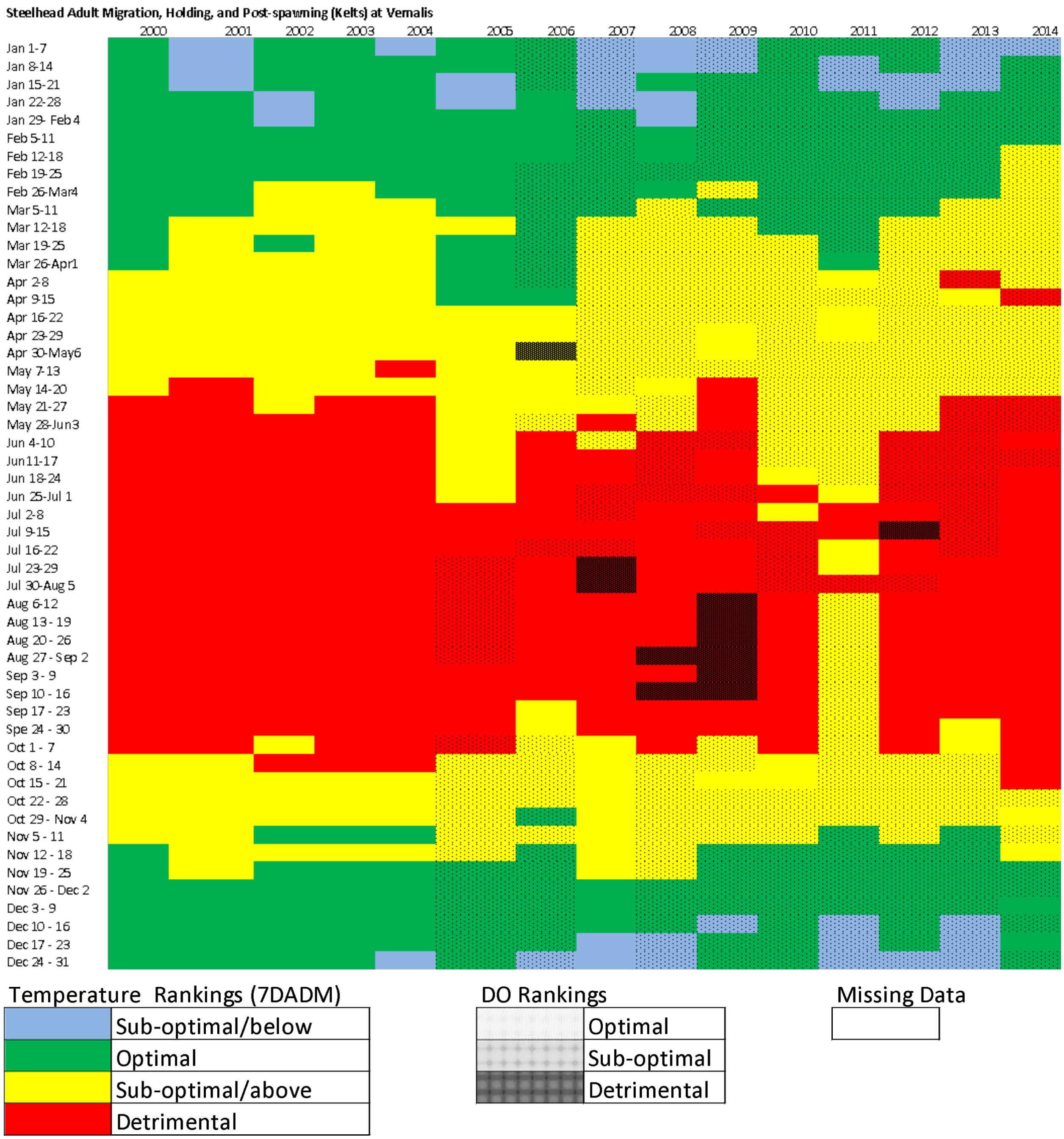



**Figure 15**

**Steelhead Adult Migration, Holding, and Post-Spawning (Kelts)**

Notes:

Temperature and DO rankings are based on observed data during periods of adult migration and holding. Time periods with rankings of stressful or detrimental provide evidence for the potential for barriers to migration and/or reduced egg viability. Rankings reflect the Environmental Objectives for temperature and DO (Section 7). Data are from the CDEC for each location.

### *8.2.3 Stress: Indirect Mortality (e.g., Disease Outbreaks) and Sub-Lethal Negative Effects (Adult Migration)*

Salmon and steelhead may suffer indirect lethal or sub-lethal negative effects following exposure to stressful or detrimental environmental conditions during migration. These effects include death due to disease or lack of energy reserves, either as fish migrate or in subsequent life history stages (indirect mortality), and reduced fertility (negative sub-lethal effects). Disease outbreaks are very rare in the Stanislaus River currently (Wikert 2014, pers. comm.), but may not be detected if they occur below the salmon counting weir on the Stanislaus River. In addition, disease outbreaks and agonistic interactions with other salmon are more likely when the density of migrating adults is high; high densities among adult migrants have not occurred frequently in the recent past, but would be expected to occur more frequently under restoration in the near term and especially in the long term. Reduction in gamete viability (if any) is unmeasured currently; however, productivity of returning spawners as measured by fry production at Oakdale is very low in many years (Appendix A), suggesting that adult fecundity or egg viability may be compromised during adult migration.

#### 8.2.3.1 Fall-run Chinook Salmon

Reduced spawning success of fall-run Chinook salmon as an indirect lethal or sub-lethal result of poor environmental conditions during adult migration was scored as a "medium" magnitude stress with a "medium" degree of certainty in the near term (Table 51). Magnitude is "medium" because multiple factors contribute to this stress, each stressor is expected to exacerbate the others (i.e., synergies exist among high temperature, low DO, and high contaminant loads), and most of the migration season is characterized by stressful or detrimental conditions for these variables. Certainty of sub-lethal effects is "medium" because the degree and duration of adverse conditions to which fish are exposed are well understood and the effect of that exposure (e.g., quantification of the response to stressful conditions) is moderately well-documented (see Environmental Objectives for Adult Migration, Section 7.2.1) and predictable.

Without corrective action, reduced success of Stanislaus-bound fall-run Chinook salmon as an indirect or sub-lethal result of poor environmental conditions during adult migration is expected to become a high magnitude stress over the long term because temperatures and density of migrating salmon are expected to increase, and both would contribute to an increased magnitude of stress (Table 51). Certainty of this stress will remain "medium" in the long term. Certainty is not expected to decline because temperature increases in the San Joaquin watershed, and increasing density of fishes will tend to exacerbate stress that already exists.

Cumulatively, numerous conditions experienced by a large fraction of migrating adult fall-run Chinook salmon are consistent with those known to result in indirect mortality and/or sub-lethal effects such as reduced fecundity. Thus, a sustained minor population-level impact to productivity is expected with “medium” certainty. Fall-run Chinook salmon migrating towards or through the Stanislaus River currently experience multiple stressful or detrimental conditions during most of their migration period (Table 51). Arrival of adults in the Stanislaus River closely corresponds to the schedule of fall pulse flows (Figure 12), and these flows currently occur in the second or third week of October. Adults that arrive in the Delta or lower San Joaquin River prior to the onset of pulse flows are exposed to inhospitable conditions. Stressful DO conditions persist in the Stockton DWSC through mid-October in most years into early October at Vernalis and as far upstream as Ripon (Figure 13). In addition, at least half of the migrating population is currently exposed to stressful temperatures in almost every year at Vernalis and in most years at Ripon (Figures 12 and 13). Stressful temperatures persist into mid-October in most years as far upstream as Orange Blossom Bridge. Exposure to toxins during the upstream migration may also cause migration delays, energetic expense, and exacerbate susceptibility to pathogens and poor water quality conditions. Passable barriers, including low water levels and dense pockets of submerged aquatic vegetation, may increase the drain on energy reserves required to complete migration—both are responses to highly variable ecosystem processes or other external factors, so the certainty of their impacts is minimal. Increased study of the viability of eggs produced by female Chinook salmon that migrate into the Stanislaus River is called for in the SEP Biological Objectives pertaining to egg viability (Section 6.2.5.4.2).

In the future, water temperatures during the fall migration season are expected to increase in response to regional warming patterns. This will increase the magnitude of the temperature and DO stressors and their synergistic effect on the toxin stressor. If these conditions occur in the long term, and pulse flows are not scheduled in a way that leads to earlier migration through the lower San Joaquin River corridor, then the magnitude of this stress is expected to become high (i.e., a sustained major population-level effect). Certainty will remain “medium.” Improved monitoring of the temporal pattern of adult salmon migration and study of indirect mortality and sub-lethal negative effects would increase the certainty surrounding this stress and could change the magnitude score.

#### 8.2.3.2 Spring-run Chinook Salmon

Reduced spawning success of spring-run Chinook salmon as an indirect lethal result of poor environmental conditions during adult migration was scored as a “medium” magnitude stress with a “low” degree of certainty in the near term (Table 52). Unlike the fall-run Chinook salmon, the sub-lethal negative effects of damage to developing gametes was not included in the stress experienced by up-migrating spring-run Chinook salmon adults because these fish are expected to develop gametes during their holding period, not during adult migration. Reduced energetic reserves needed to produce gametes (during the holding period) is a sub-lethal negative effect on spring-run Chinook salmon. Certainty is low because although there is high understanding of the extent of adverse conditions, predictability of the effect of those conditions is low for the most important indirect lethal outcomes (disease outbreaks) for spring-run resulting from this stress. Disease outbreaks are affected by the density of migrating fish, which may vary within and among years. Similarly, the negative sub-lethal effect of stress on the energy reserves holding salmon need in order to produce gametes is uncertain because it relies, in part, on the duration of the holding period and the energetic status of fish returning from the ocean.

Without corrective action, indirect mortality and/or reduced fecundity of Stanislaus-bound spring-run Chinook as a result of poor environmental conditions during adult migration will become a high magnitude stress over the long term (Table 52). Two of the main environmental conditions that cause the stress (temperature and density of returning migrants) are expected to increase in the future; this increases the potential frequency and extent of disease outbreaks and/or reduced fecundity due to energetic stress on this run. Certainty of this stress will remain low in the long term for the same reasons it is low in the near term.

Adult spring-run salmon migrating during the late winter and spring are exposed to multiple stressors, each of which exacerbates the others (i.e., synergies exist among high temperature, low DO, and high contaminant loads), and most of the migration season is characterized by stressful or detrimental conditions for these variables. Taken together, multiple stressors during the spring-run migration period are likely to have minor population-level effects in the short term and sustained minor and/or periodic major population effects in the long term. Both indirect lethal and sub-lethal effects will be responsive to variability in ecosystem conditions, particularly the density, timing, and condition of spring-run adults returning from the ocean. Stressful DO conditions prevail in the Stockton DWSC through most of the migration window, although supportive DO conditions occur most of the time at Vernalis and upstream. Temperatures are stressful or detrimental through most of the migration window in most years as far upstream as Ripon (Figure 14). Furthermore, spring-run Chinook migrants are exposed to multiple contaminant stressors in the lower San Joaquin River up to Ripon on the Stanislaus River. USGS monitoring of the San Joaquin River at Vernalis detected a minimum of six (and up to 14) pesticides in each sample (Orlando et al. 2014). Monitoring data coincide with model results, indicating high frequency of benchmark exceedances that could lead to indirect mortality during migration or in later life history stages.

In the long term, increasing density of adult spring-run migrants combined with expected increases in water temperature (and corresponding declines in DO and the effect of toxins) lead to an increase in the potential magnitude of sub-lethal and indirect lethal effects during adult migration (or during holding as a result of conditions experienced while migrating); the current timing of spring-pulse flows will not alleviate these impacts on adult migrants that arrive early (March) or later in the migration window (late May through June). Long-term certainty of such impacts is “low.” In both the near term and the long term, increased monitoring and studies of migrating and holding adult spring-run Chinook salmon would increase certainty regarding this stress.

#### 8.2.3.3 Steelhead

Reduced spawning success of steelhead as an indirect or sub-lethal result of poor environmental conditions during adult migration was scored as a "medium" magnitude stress with minimal certainty in the near term (Table 53). Magnitude is "medium" because, although only a small fraction of the migration season is characterized by stressful or detrimental conditions for temperature and DO, contaminant loads may be harmful early and late in the migration season. Certainty is minimal because the temporal distribution of adult steelhead migrations (and its overlap with impaired migration conditions) is not well documented.

Unless corrective actions are taken, the indirect effects of poor environmental conditions on migrating steelhead adults will remain "medium" in the long term. Certainty will remain minimal (Table 53).

Periodically high temperatures, low DO levels, and episodic high toxic loads downstream of the Stanislaus-San Joaquin confluence during the early fall steelhead migration period (late September) and downstream of Ripon during the spring migration period indicate that a "medium" magnitude negative effect on steelhead productivity may result from poor environmental conditions during upstream migration. The current timing and frequency of managed pulse flows to attract adult steelhead to the Stanislaus River do not cover most of the steelhead migration season; low flows that persist in the absence of short-term, scheduled pulse flows are not adequate to ensure optimal migration of adult steelhead to their holding and spawning habitats. The certainty surrounding this stress is minimal because the SEP Group's understanding of the precise response of migrating steelhead to poor environmental conditions is limited, the temporal distribution of adult migrants is virtually unknown, and some of the negative outcomes are sensitive to environmental conditions such as the density of migrating adults. Migrating steelhead adults would experience poor DO conditions in many years through the first several weeks of their migration season as far upstream as Ripon. Temperatures are generally stressful through mid-November and March through April at Vernalis and through mid-October at Ripon. Toxic contaminants are elevated during September and March through May downstream of Ripon and in March through May in the lower San Joaquin downstream of its confluence with the Stanislaus River (Hoogeweg et al. 2011; Appendix C); migrants may also be exposed to a high frequency of pesticide exposures, which may significantly impair successful migration. Steelhead are unlikely to be impaired to a great extent by low water levels or dense patches of invasive vegetation. Increased study of migrating steelhead in the Stanislaus River—including their temporal and spatial distribution in the river, survival prior to spawning, and the viability of their eggs—would increase the certainty surrounding the magnitude of this stress.

### *8.2.4 Stress: Limited Early Access to River (Relative to Migration Window) due to Impassable or Unsuitable Conditions (Adult Migration)*

Biological Objectives include time windows in which target populations are expected to be able to complete each of their freshwater life history stages. These time windows represent the potential for salmonids to express the diverse life history strategies that:

- Enhance population stability in the face of adverse conditions (in freshwater or marine environments)
- Promote population resilience when suitable environmental conditions return

Failure to provide environmental conditions that allow for expression of the full range of life history diversity in each life history stage may also have the effect of limiting the portfolio of life history strategies that emerge in subsequent life history stages. For example, constraints on the adult migration window can exacerbate limited diversity in the timing of spawning and egg development and, in turn, the size and temporal distribution of outmigrating juvenile salmonids. Recent research demonstrates a limited portfolio of life histories among fall-run Chinook salmon emigrating from the Stanislaus River, including relatively low proportions of smolt-sized migrants (Zeug et al. 2014; Sturrock et al. 2015). Limited access of fall-run Chinook salmon to their Stanislaus River spawning grounds affects the expression of different adult life history strategies and the potential timing, diversity, and success of subsequent life history stages. This stress is scored only for fall-run Chinook salmon. Delayed migration among spring-run Chinook salmon has little effect on subsequent spawning timing because there is a holding period between migration and spawning. Delayed migration is most likely to result in mortality or straying because migration conditions become worse as the spring-run adult season progresses, and is thus captured under the heading “failure to reach holding or spawning habitat in the natal stream due to direct action of stressors” (Section 8.2.2.2). Delayed migration is not considered as a stress for steelhead.

#### 8.2.4.1 Fall-run Chinook Salmon

In the near term, asymmetrical access to the spawning grounds for adult fall-run Chinook salmon as a result of delayed migration is a “medium” magnitude stress. Certainty surrounding this effect is “low” (Table 51).

Without corrective action, in the long term, late access to the spawning grounds will remain a “medium” magnitude stress, and certainty will remain “low” because better documentation is needed for the relationship between delayed migration and loss of diversity in adult migration phenotypes (i.e., selection) and effects in subsequent life history stages (Table 51).

Delayed migration of fall-run Chinook salmon can be attributed to high temperatures and low DO levels in their migration corridor (Figure 13), particularly in the lower San Joaquin River. In addition, the timing of fall attraction flows leads to a peak migration that occurs in mid to late October (Figure 12). Salmon that arrive prior to the pulse flow are likely to experience deleterious conditions and expend additional energy reaching the spawning grounds; thus, these fish are most likely to experience reduced fecundity or pre-spawning mortality. Truncation of the migration period for fall-run Chinook salmon is likely to select against early migrating phenotypes; this can reduce population diversity, resilience, and viability even if there is no genetic basis for the phenotypes. In addition, late migration may result in a truncated spawning period and subsequent constriction of diversity in subsequent life history strategies (e.g., timing of emigration and size of juveniles). All of these potential effects suggest the need for additional research on the population-level effects of, and potential to alleviate, persistent delays in migration of adult fall-run Chinook salmon.

### *8.2.5 Contributing Management Factors*

The environmental factors that drive the failure to reach holding or spawning habitats are coupled and work synergistically. For example, temperature affects both DO concentration and fish demand for DO, and it modulates the impact of certain contaminants on migrating adult salmon. Similarly, residence time, nutrient concentration, and temperature all impact the degree of nutrient-related stressors (e.g., macrophyte density or low DO) in the river. Finally, flow rates also play a role in regulating water temperature, residence time, and contaminant/nutrient concentrations in the river.

Reservoir operations, including releases and coldwater pool management, exert significant influence over these stressors. Reservoir coldwater pool levels and release rates determine, in part, temperatures along the river corridor from late spring through early fall. The timing and duration of attraction flows determine the extent to which adult salmonids are exposed to inhospitable water quality conditions in the lower San Joaquin River and Delta. In all but the wettest years (when uncontrolled runoff and flood prevention procedures lead to higher flows), reservoir releases determine the timing, duration, and magnitude of attraction flows for migrating adult salmonids in both fall and spring. Spring pulse flows in the Stanislaus and San Joaquin rivers are required by the WQC Plan (D-1641) in order to move juvenile Chinook salmon downstream—these flows may also provide migration cues to upmigrating adult spring-run Chinook salmon. However, the pulse flows are only scheduled to occur between late April and early May; adult fish migrating later in the migration period will generally experience base flows that are a tiny fraction of the San Joaquin River basin's unimpaired runoff (TBI 2014, unpublished data). It should also be noted that pulse flow and base flow standards are frequently weakened during consecutive dry or critically dry years (e.g., 2015 and 2016) below the reduced levels required in years with dry or critically dry hydrology. Such reductions affect both outmigrant juvenile fall-run and spring-run Chinook salmon and adult spring-run Chinook salmon attempting to migrate into the San Joaquin and Stanislaus rivers. Flow modifications in the lower San Joaquin River and Stanislaus River are necessary to achieve adequate migration opportunities distributed throughout the fall-run migration time window.

Non-flow management practices may exacerbate or alleviate stressors on adult migration. For example, the destruction of riparian habitat along the Stanislaus River has likely reduced the amount of shade in the river corridor; this can increase temperatures and primary productivity in the river. Groundwater depletions have likely reduced the hyporheic inputs that probably buffered the Stanislaus River against warm temperatures in late spring, summer, and early fall. Groundwater recharge programs may help to reestablish this benefit and reduce water temperatures in the river during critical months. Urban and agricultural developments in the watershed have increased contaminant loads to the river; adjustments to land use practices or the development of contaminant control programs may reduce contaminant loads and the stress they generate for migrating adult salmonids. Finally, the design and operation of the Stockton DWSC coupled with low flow and excessive BOD have exacerbated the low DO conditions and resulting migration stressors in the Delta (Gowdy and Grober 2005).

## 8.3 Stressors on Adult Holding

Adult holding occurs in the salmonid life cycle after immigration into freshwater, but before spawning. Fall-run Chinook salmon adults spend a relatively short period of time holding; the duration of their holding period is usually dependent on the availability of water temperatures suitable for spawning, passage delays from physical barriers, and the presence of suitable mates. Spring-run Chinook adults hold over the summer months, generally without eating, awaiting water temperatures appropriate for spawning. *O. mykiss* adults may “hold” in the river throughout the year; however, unlike salmon, they are usually foraging and growing or recovering from spawning. Both spring-run Chinook and *O. mykiss* lack access to the high elevation habitats these populations used historically because passage to these habitats is now blocked by dams. Stressors on adult holding may result in direct mortality or injury, disease, and/or increased energy expenditure that can reduce fecundity. The degree of stress to the population associated with complete lack of access to high elevation habitat must be assessed in the context of the amount and quality of holding habitat still accessible.

The SEP Group evaluated two categories of stress in the near term and long term for adult salmonids holding into the Stanislaus River: lack of suitable holding habitat and loss of fecundity.

Stressors on the adult holding life history stage (Tables 54 through 56) include the following:

- Water temperature
- Loss of inputs to coarse sediment that drive macroinvertebrate production
- Low DO
- Unsuitable water velocity and depth
- Lack of cover
- Insufficient prey density

- High predator density
- Presence of contaminants
- Disease
- Poaching

Measuring any of these effects presents challenges. Direct mortality of holding adults may go unnoticed, especially as holding usually occurs in deeper pools, and detecting reduced gamete viability generally requires directed studies of egg development success such as in a hatchery (Section 6.2.5.4.2).

Near-term stresses reflect those that would impede attainment of Environmental or Biological Objectives under current conditions. Evaluation of these stresses in the long term incorporated analysis of current conditions and assumed that adult salmon densities would increase substantially and that global and regional warming trends occur as anticipated (Dettinger et al. 2004; Cayan et al. 2008).

## *8.3.1 Current Holding Timing Patterns*

Scoring of stress is based on the potential exposure to stressors across the full range of each population's adult holding timing window (see Figure 8). Current temporal distribution of fall-run Chinook salmon adult holding in the Stanislaus River occurs throughout the adult migration and spawning periods from late September through December. Spring-run Chinook salmon holding is assumed to begin soon after migration begins (March) and end with spawning (late August through October in other Central Valley populations; Williams 2006). *O. mykiss* holding is assumed to occur year-round as both resident and anadromous forms occur within the watershed (Zimmerman et al. 2008). Zimmerman et al. (2008) also found resident rainbow trout with steelhead mothers.

## *8.3.2 Stress: Lack of Suitable Holding Habitat (Adult Holding)*

Historically, spring-run Chinook salmon and *O. mykiss* would have utilized sections of the river that are now blocked by dams. The valley floor remains accessible to all runs of Chinook salmon and *O. mykiss*. Reservoir operations and land use changes have modified the instream water temperatures in the remaining accessible habitat.

### 8.3.2.1 Fall-run Chinook Salmon

In the near term, lack of suitable holding habitat for fall-run Chinook salmon in the Stanislaus River was scored as a "low" magnitude stress (Table 54) with a "medium" degree of certainty.

Without corrective action, the lack of suitable holding habitat for fall-run Chinook salmon will increase to a "medium" magnitude stress (Table 54) over the long term, and certainty will remain "medium."

**Table 54**
**Holding Stressors for Fall-run Chinook Salmon**

| Stress | Near Term | | Long Term | | Where | When | Stressors | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Temperature | | DO | | Velocity | | Depth | | Cover | | Predator Density | | Contaminants | | Coarse Sediment Input | | Disease | | Poaching | |
| | M | C | M | C | | | Near Term | Long Term | Near Term | Long Term | Near Term | Long Term | Near Term | Long Term | Near Term | Long Term | Near Term | Long Term | Near Term | Long Term | Near Term | Long Term | Near Term | Long Term | Near Term | Long Term |
| Lack of suitable holding habitat | 2 | 3 | 3 | 3 | Whole river | September through October | M: 2<br>C: 3 | M: 3<br>C: 3 | M: 1<br>C: 2 | M: 1<br>C: 2 | M: 1<br>C: 2 | M: 1<br>C: 2 | M: 1<br>C: 2 | M: 1<br>C: 2 | M: 2<br>C: 2 | M: 2<br>C: 2 | M: 2<br>C: 2 | M: 2<br>C: 2 | M: 2<br>C: 2 | M: 2<br>C: 2 | M: 1<br>C: 3 | M: 1<br>C: 3 | M: 2<br>C: 2 | M: 3<br>C: 2 | M: 1<br>C: 2 | M: 2<br>C: 2 |
| Loss of fecundity | 2 | 2 | 3 | 2 | Whole river | January through June | M: 2<br>C: 2 | M: 3<br>C: 2 | M: 1<br>C: 2 | M: 1<br>C: 2 | M: 1<br>C: 2 | M: 1<br>C: 2 | M: 1<br>C: 2 | M: 1<br>C: 2 | | | | | M: 2<br>C: 2 | M: 2<br>C: 2 | | | | | | |

Notes:
– Stress and stressors (i.e., contributing factors to a particular stress) for fall-run adult holding in the Stanislaus River for the near term (current conditions) and long term (assuming restored abundance goals and higher air temperatures). Scores for each stress were evaluated and assigned based on the scores for contributing stressors.
– M: Magnitude assesses the size or level of the impact from a stressor. Magnitude can be assigned using consideration of population or habitat effects, and higher scores require consideration of the scale or extent.
– C: Certainty describes the scientific basis for scoring the scale and magnitude of a particular stressor. Certainty considers both the predictability and understanding of linkages in the driver-linkage-outcome pathway from the stressor to the impact.
– Blank space denotes that stressor that is listed for the cell was not scored for the associated row because it is not believed to contribute to the stress identified in that row.
Scoring:
4: High
3: Medium
2: Low
1: Minimal

The stressor that scored the highest for suitable holding habitat for adult fall-run Chinook salmon is water temperature. Temperatures are stressful for holding at and downstream of Orange Blossom Bridge from the start of the fall-run Chinook salmon migration and holding period through mid-October in most years (Figure 13). Temperatures are commonly in the supportive range for holding upstream of Knights Ferry, but stressful temperatures have occurred even at this location (e.g., during September and early October 2015; Wikert 2014, pers. comm.). Fall-run are expected to experience stressful to detrimental contaminant conditions when holding between Orange Blossom Bridge and Riverbank and minor stressful conditions when holding upstream of Orange Blossom Bridge. However, due to their short duration of holding and small proportion of population exposure, the magnitude of impact due to contaminants is expected to be "low."

Other stressors ranked "low" or "minimal," with the exception of disease, which is expected to increase in the long term to "medium" magnitude (Table 54) based on climate change models predicting warmer temperatures and a higher concentration of adults after achieving population targets.

#### 8.3.2.2 Spring-run Chinook Salmon

In the near term, lack of suitable holding habitat for spring-run Chinook salmon in the Stanislaus River was scored as a "medium" magnitude stress with a "high" degree of certainty (Table 55).

Without corrective action, lack of suitable holding habitat for spring-run Chinook salmon will increase to a "high" magnitude stress (Table 55) over the long term, and certainty will remain "high."

**Table 55**

**Holding Stressors for Spring-run Chinook Salmon**

| | NT | | LT | | Stressors | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Temperature | | DO | | Velocity | | Depth | | Cover | | Predator Density | | Contaminants | | Coarse Sediment Input | | Disease | | Poaching | |
| **Stress** | **M** | **C** | **M** | **C** | **NT** | **LT** | **NT** | **LT** | **NT** | **LT** | **NT** | **LT** | **NT** | **LT** | **NT** | **LT** | **NT** | **LT** | **NT** | **LT** | **NT** | **LT** | **NT** | **LT** |
| Lack of suitable holding habitat | 3 | 4 | 4 | 4 | M: 3<br>C: 4 | M: 4<br>C: 4 | M: 1<br>C: 2 | M: 2<br>C: 2 | M: 1<br>C: 2 | M: 1<br>C: 2 | M: 1<br>C: 2 | M: 1<br>C: 2 | M: 2<br>C: 2 | M: 2<br>C: 2 | M: 2<br>C: 2 | M: 3<br>C: 2 | M: 2<br>C: 2 | M: 2<br>C: 2 | M: 1<br>C: 3 | M: 1<br>C: 3 | M: 2<br>C: 2 | M: 3<br>C: 2 | M: 1<br>C: 2 | M: 2<br>C: 2 |
| Loss of fecundity | 3 | 2 | 3 | 2 | M: 2<br>C: 2 | M: 3<br>C: 2 | M: 1<br>C: 2 | M: 1<br>C: 2 | M: 1<br>C: 2 | M: 1<br>C: 2 | M: 1<br>C: 2 | M: 1<br>C: 2 | | | | | M: 3<br>C: 2 | M: 3<br>C: 2 | | | | | | |

Notes:
– Location: upstream of Ripon
– When: March through September
– Stress and stressors (i.e., contributing factors to a particular stress) for spring-run adult holding in the Stanislaus River for the near term (current conditions) and long term (assuming restored abundance goals and higher air temperatures). Scores for each stress were evaluated and assigned based on the scores for contributing stressors.
– M: Magnitude assesses the size or level of the impact from a stressor. Magnitude can be assigned using consideration of population or habitat effects, and higher scores require consideration of the scale or extent.
– C: Certainty describes the scientific basis for scoring the scale and magnitude of a particular stressor. Certainty considers both the predictability and understanding of linkages in the driver-linkage-outcome pathway from the stressor to the impact.
– Blank space denotes that stressor that is listed for the cell was not scored for the associated row because it is not believed to contribute to the stress identified in that row.
Scoring:
4: High
3: Medium
2: Low
1: Minimal
LT: long term
NT: near term

Temperature is the main driver of this stress for spring-run Chinook salmon; holding habitat with suitable temperatures is currently constrained to the reach just downstream of Goodwin Dam in most years. Temperatures are stressful for holding at and downstream of Orange Blossom Bridge from mid-May through the end of the spring-run Chinook salmon holding period (September) in every year (Figure 14). Stressful temperatures also occur frequently from July through September upstream at Knights Ferry, particularly during drought years (e.g., 2013 through 2015; Wikert 2014, pers. comm.). Unless corrective measures are taken, stressful and detrimental temperatures may occur during the holding season throughout currently available habitat under prolonged drought sequences. Even though it is expected to be periodic, such impacts would present a severe constraint on attainment of objectives for the spring-run population in the long term. Spring-run are expected to experience stressful contaminant conditions when holding from Orange Blossom Bridge to Knights Ferry; due to their long duration of exposure, it is expected that contaminants may contribute to spring-run mortality. Upstream of Knights Ferry, contaminants are not expected to be an issue for holding spring-run.

#### 8.3.2.3 O. mykiss

In the near term, lack of suitable holding habitat for *O. mykiss* was scored as a "medium" magnitude stress with a "high" degree of certainty (Table 56).

Without corrective action, lack of suitable *O. mykiss* holding will become a "high" magnitude stress (Table 56) over the long term, and certainty will remain "high."

**Table 56**
**Holding Stressors for *O. mykiss***

| Stress | NT | | LT | | Where | When | Stressors | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Temperature | | DO | | Velocity | | Depth | | Cover | | Prey Density | | Predator Density | | Contaminants | | Coarse Sediment Input | | Disease | |
| | M | C | M | C | | | NT | LT | NT | LT | NT | LT | NT | LT | NT | LT | NT | LT | NT | LT | NT | LT | NT | LT | NT | LT |
| Lack of suitable holding habitat | 3 | 4 | 4 | 4 | Whole River | January through December | M: 3 C: 4 | M: 4 C: 4 | M: 1 C: 2 | M: 1 C: 2 | M: 1 C: 2 | M: 1 C: 2 | M: 1 C: 2 | M: 1 C: 2 | M: 2 C: 2 | M: 2 C: 2 | M: 2 C: 2 | M: 2 C: 2 | M: 2 C: 2 | M: 2 C: 2 | M: 3 C: 2 | M: 3 C: 2 | M: 3 C: 3 | M: 3 C: 3 | M: 2 C: 2 | M: 2 C: 2 |

Notes:
– Stress and stressors (i.e., contributing factors to a particular stress) for *O. mykiss* adult holding in the Stanislaus River for the near term (current conditions) and long term (assuming restored abundance goals and higher air temperatures). Scores for each stress were evaluated and assigned based on the scores for contributing stressors.
– M: Magnitude assesses the size or level of the impact from a stressor. Magnitude can be assigned using consideration of population or habitat effects, and higher scores require consideration of the scale or extent.
– C: Certainty describes the scientific basis for scoring the scale and magnitude of a particular stressor. Certainty considers both the predictability and understanding of linkages in the driver-linkage-outcome pathway from the stressor to the impact.
– Blank space denotes that stressor that is listed for the cell was not scored for the associated row because it is not believed to contribute to the stress identified in that row.
Scoring:
4: High
3: Medium
2: Low
1: Minimal
LT: long term
NT: near term

Temperature and loss of coarse sediment input are the main drivers of this high-magnitude stress for *O. mykiss*. Temperatures were largely stressful in nearly every year from June through September at Orange Blossom Bridge and stressful during some weeks between July and September during most years at Knights Ferry (Figure 15). Without corrective action, lethal water temperatures that accompany extended droughts and low reservoir storage could potentially extirpate the entire population of steelhead and resident rainbow trout. This is of particular concern in the long term.

Since adult *O. mykiss* feed in freshwater (especially recovering kelts), functioning alluvial coarse sediment is necessary to provide macroinvertebrate habitat to sustain the food chain, especially in the 4 miles of the canyon reach just below Goodwin Dam. With little to no off-channel habitat available for fish or for food production, food must come from in-channel sources or move downstream from the reservoir above. *O. mykiss* holding conditions are expected to get worse in the long term based on the assumption of higher water temperatures and increased numbers of *O. mykiss* competing for available spots, but this stress is rated as maximum magnitude, including in the near term. As such, the scoring system used here does not capture the deterioration of conditions in the future, in the absence of conservation actions. Contaminants will likely contribute to some mortality of *O. mykiss* as well as reduce the availability of food.

### *8.3.3 Stress: Loss of Fecundity (Adult Holding)*

Exposure to stressful or detrimental environmental conditions while holding may result in lower egg viability, pre-spawn mortality, or partial-spawn mortality (some, eggs remain in the female after death). Reduction in gamete viability (if any) is unmeasured currently; however, productivity of returning spawners as measured by fry production at Oakdale is very low (Appendix A), suggesting that adult fecundity or egg viability may be compromised during adult migration or holding.

#### 8.3.3.1 Fall-run Chinook Salmon

In the near term, reduced fecundity for fall-run Chinook salmon that experience poor environmental conditions during holding was scored as a “low” magnitude stress with a “medium” degree of certainty (Table 54).

Without corrective action, reduced fecundity will increase to a “medium” magnitude stress over the long term for fall-run, and certainty will remain “medium” (Table 54).

The SEP Group expects that this stress currently has a sustained effect limited to a small fraction of the fall-run Chinook salmon population as these fish exhibit minimal holding behavior. Holding among fall-run is thought to happen mostly while adults are either waiting for temperatures in the spawning reach to cool sufficiently or seeking a suitable spawning partner. The short duration of holding for fall-run will limit the impacts from exposures to contaminants. In the long term, higher temperatures predicted by climate models are likely to increase the magnitude of this stress.

#### 8.3.3.2 Spring-run Chinook Salmon

In the near term, reduced fecundity for spring-run Chinook salmon as a result of conditions during the holding period is expected to be a "low" magnitude stress, but certainty is "low" as well (Table 55).

Without corrective action, reduced fecundity for spring-run Chinook salmon will increase to a "medium" magnitude stress over the long term, and certainty will remain "low" (Table 55).

Spring-run Chinook salmon adults hold in river from March through September, generally in deeper pool areas. Currently, these are distributed throughout the river either in deep mine pits or in Goodwin Canyon. Temperatures are usually supportive in the upstream areas when reservoir storage is sufficient to retain cold water through the summer (e.g., temperatures below Goodwin Dam; Figure 14). However, during prolonged drought, the temperature of water released from Goodwin Dam can exceed stressful levels for extended periods (e.g., more than 16°C [60.8°F] at approximately RM 57.5 on July 8 and 23, 2015; Wikert 2014, pers. comm.) and this would be expected to result in reduced fecundity for holding spring-run Chinook salmon.

#### 8.3.3.3 O. mykiss

*O. mykiss* are not expected to experience a reduction in fecundity as a result of conditions during the holding period from any of the existing or future stressors analyzed in this report.

### *8.3.4 Contributing Management Factors*

Dams block access to historic high-elevation holding habitats, particularly for spring-run Chinook salmon and *O. mykiss*. The holding behavior for fish in these populations is restricted to warmer, lower elevation tailwaters below Goodwin Dam. Availability of holding habitat is expected to deteriorate in the long term.

Reservoir operation is a major driver of the environmental factors that control the impact of stressors on adult salmonids during their pre-spawn holding period, and that may lead to post-migration mortality or suboptimal gamete production among adult salmonids. For example, flow rates and coldwater pool management regulate water temperature and residence time in the river. In addition, the volume of water released from the reservoir will affect dilution of contaminant discharges to the river. The environmental factors that drive the failure to attain holding habitat Environmental Objectives, post-migration mortality, or negative sub-lethal effects are often coupled and work synergistically (e.g., temperature affects both DO concentration and fish demand for DO). Furthermore, residence time, nutrient concentration, and temperature all impact the degree of nutrient-related stressors (e.g., macrophyte density or low DO) in the river.

Other non-flow management practices may exacerbate or alleviate stressors on adult holding. For example, the destruction of riparian habitat along the Stanislaus River has likely reduced the amount of shade in the river corridor; this can increase temperatures and primary productivity in the river. Groundwater depletion has likely terminated the hyporheic inputs that possibly buffered the Stanislaus River against warm temperatures in late spring, summer, and early fall. Groundwater recharge programs may help to reestablish this benefit and reduce water temperatures in the river during critical months. Creation of gravel bars and alluvial in-channel islands offer the opportunity to create thermal complexity and provide coldwater refuges during peak temperature times (Ock and Kondolf 2012).

Urban and agricultural developments in the watershed have increased contaminant loads to the Stanislaus River. Adjustments to land use practices or the development of contaminant control programs may reduce contaminant loads and the stress they generate for migrating adult salmonids.

## 8.4 Stressors on Spawning

Spawning is a short life history stage, lasting hours for Chinook salmon (Berejikian et al. 2000) and an average of 3 days for *O. mykiss* (Briggs 1953; Shapovalov and Taft 1954; Hannon 2003). Despite its brevity, spawning is an important transitional link from one generation of salmonids to the next. Physiological conditions in fish trigger the onset of spawning at specific times of the year for different species. Spawning salmonids require adequate space, correctly sized gravel, appropriate river depth and velocities, nearby cover (especially for *O. mykiss*), and clean water (e.g., devoid of disruptive contaminants) to spawn successfully. In addition, avoiding interbreeding is also an important component of spawning success that supports the Biological Objectives.

Stresses are potential negative outcomes that prevent attainment of Environmental and Biological Objectives. The following three stresses were evaluated for spawning salmonids in the Stanislaus River:

- Inadequate availability of high-quality spawning habitat segregated from other runs
- Interbreeding or introgression
- Compression of the spawning window due to delayed spawning

Stressors are variables that contribute to stress, alone or in combination. River temperatures, DO, velocity, depth, cover, contaminants, predation, poaching, amount of available spawning habitat segregated from that used by other populations (necessary to prevent interbreeding or redd superimposition by one population that reduces productivity of another population), disease, and impacts from hatchery operations were individually considered to assess their relative contribution to population stresses during the spawning life history stage.

Near-term stresses reflect those that would impede attainment of Environmental or Biological Objectives currently. Evaluation of these stresses in the long term incorporated analysis of current conditions and assumed that adult salmon densities would increase substantially and that global and regional warming trends occur as anticipated (Dettinger et al. 2004; Cayan et al. 2008).

## *8.4.1 Current Spawning Timing*

Scoring of stress and contributing stressors was based on the potential exposure to conditions across the full range of each population's spawning timing window as compared to the expected timing window and spatial extent of spawning in the Stanislaus River (Figure 8). Spring-run Chinook salmon and Central Valley *O. mykiss* spawning are not well monitored at this time, so the current timing of spawning for these two populations is based on the timing for runs observed in other Central Valley watersheds. Spring-run spawning timing was considered to be late August through March (Figure 8). Spawning timing for *O. mykiss* was considered to be between December and April (McEwan 2001; Williams 2006; Figure 8).

## *8.4.2 Current Spawning Extent*

Current spawning area is limited to the area above RM 34 (6 miles downstream of the Oakdale RST), although the majority of redds (mean 90%; Giudice 2014) are observed upstream of the Oakdale RST. Spawning is observed throughout the river upstream of Oakdale to the base of Goodwin Dam.

## *8.4.3 Stress: Inadequate Availability of High-Quality Habitat (Spawning)*

Attainment of goals and objectives for Chinook salmon and *O. mykiss* will require sufficient high-quality habitat, as described in the SEP Group's Environmental Objectives for spawning (Section 7.2.3). High-quality habitat includes adequate amounts of spawning gravel (correctly sized sediments) that is inundated to adequate river depth, at adequate velocity, and by water of adequate quality. To attain SEP Biological Objectives for productivity of each population, high-quality spawning habitat for each population must also be spatially or temporally segregated from other runs or species. Spatial or temporal segregation is intended to prevent redd superimposition, which destroys some or all of the developing eggs or alevins, and genetic introgression between runs (i.e., spring-run and fall-run) or between hatchery and naturally produced individuals, which is hypothesized to reduce diversity and/or fitness. However, interactions between runs and between hatchery and naturally produced fish are discussed in Section 8.4.4.

### 8.4.3.1 Fall-run Chinook Salmon

Inadequate availability of high-quality spawning habitat for fall-run in the near term was rated a "low" magnitude stress with expected minor effect on the population. Certainty of this stress was "medium" (Table 57).

Over the long term, this stress will increase to "high" magnitude. The certainty will remain "medium" (Table 57).

**Table 57**

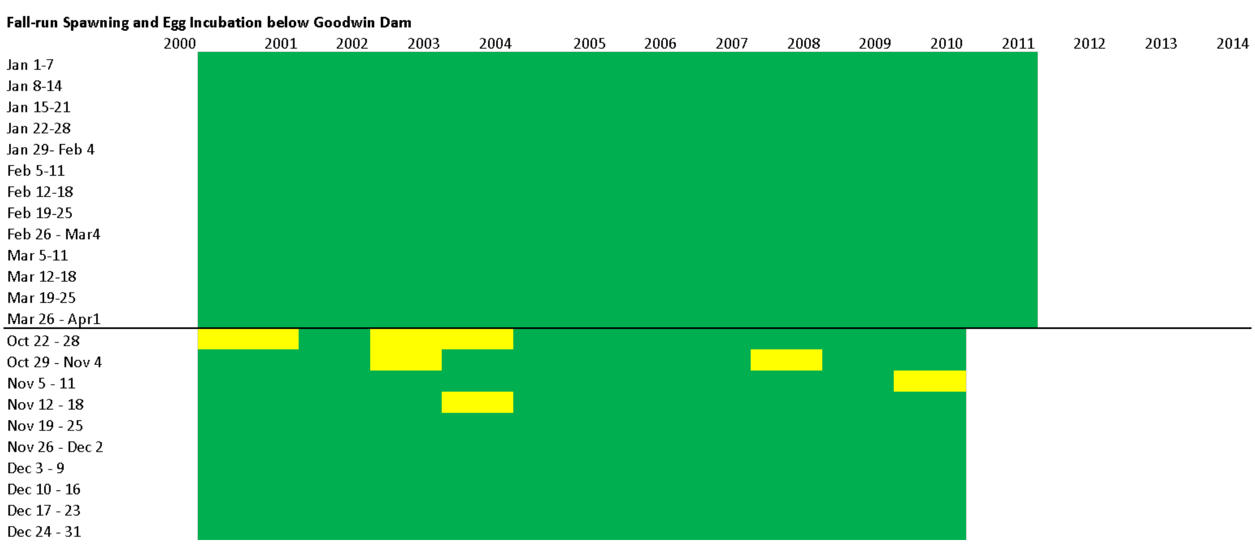
**Spawning Stressors for Fall-run Chinook Salmon in Spawning Reach, October through December**

| | | | | | Stressors | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Fall-run Stressor in Spawning Reach, October-December | NT | | LT | | Temperature | | DO | | Velocity | | Depth | | Coarse Sediment Input | | Cover | | Predator density | | Contaminants | | Habitat Distribution | | Disease | | Poaching | | Hatchery Operations | | Run Segregation | |
| | M | C | M | C | NT | LT | NT | LT | NT | LT | NT | LT | NT | LT | NT | LT | NT | LT | NT | LT | NT | LT | NT | LT | NT | LT | NT | LT | NT | LT |
| Inadequate availability of high-quality habitat | 2 | 3 | 4 | 3 | M: 2 C: 3 | M: 4 C: 3 | M: 1 C: 2 | M: 2 C: 1 | M: 1 C: 2 | M: 1 C: 2 | M: 3 C: 3 | M: 3 C: 3 | M: 2 C: 2 | M: 3 C: 2 | M: 1 C: 2 | M: 1 C: 2 | M: 1 C: 1 | M: 1 C: 1 | M: 2 C: 2 | M: 3 C: 2 | M: 1 C: 4 | M: 3 C: 3 | M: 1 C: 2 | M: 2 C: 2 | M: 1 C: 2 | M: 2 C: 2 | | | | |
| Interactions with hatchery fish and other runs | 4 | 4 | 4 | 3 | | | | | | | | | | | | | | | | | | | | | | | M: 4 C: 4 | M: 4 C: 3 | M: 1 C: 4 | M: 4 C: 3 |
| Compression of the spawning window due to delayed spawning | 2 | 2 | 4 | 2 | M: 3 C: 2 | M: 4 C: 2 | M: 1 C: 2 | M: 2 C: 1 | | | | | | | | | | | | | | | | | | | | | | |

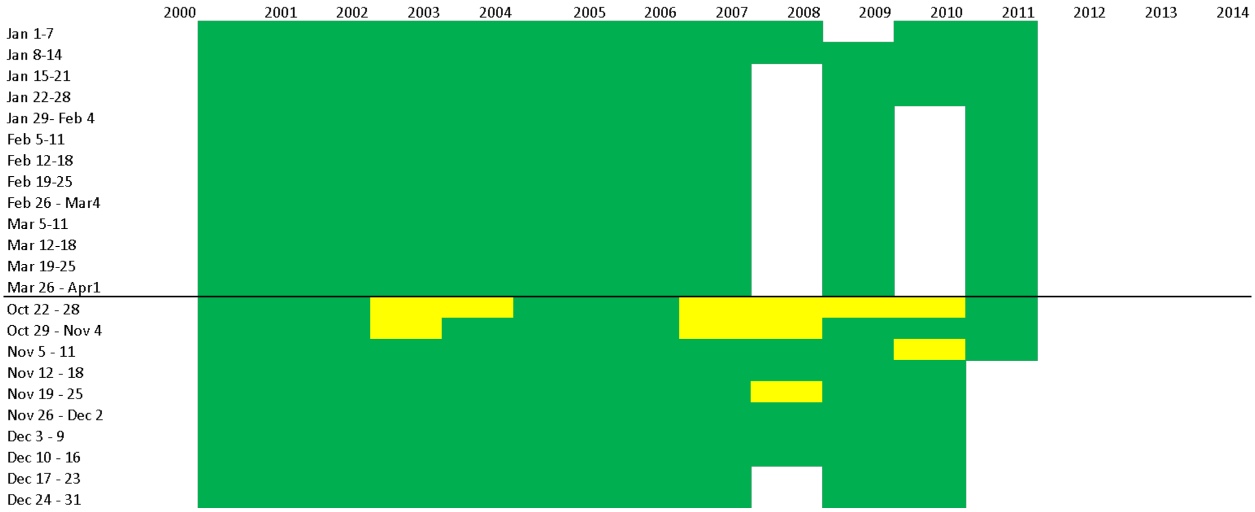
Notes:
– Stress and stressors (i.e., contributing factors to a particular stress) for fall-run spawning in the Stanislaus River for the near term (current conditions) and long term (assuming restored abundance goals and higher air temperatures). Scores for each stress were evaluated and assigned based on the scores for contributing stressors.
– M: Magnitude assesses the size or level of the impact from a stressor. Magnitude can be assigned using consideration of population or habitat effects, and higher scores require consideration of the scale or extent.
– C: Certainty describes the scientific basis for scoring the scale and magnitude of a particular stressor. Certainty considers both the predictability and understanding of linkages in the driver-linkage-outcome pathway from the stressor to the impact.
– Blank space denotes that stressor that is listed for the cell was not scored for the associated row because it is not believed to contribute to the stress identified in that row.
Scoring:
4: High
3: Medium
2: Low
1: Minimal
LT: long term
NT: near term

Currently, the amount of spawning habitat in the Stanislaus River is sufficient for returning fall-run spawners (but see Section 8.4.4). Magnitude for this stress was considered “low” in the near term largely due to adequate availability of spawning habitat with appropriate depth, velocity, substrate, and temperature criteria during the core-spawning period. Other habitat components, such as DO, water velocity, water depth, cover, disease, contaminants, predator density, poaching, and habitat distribution (the distribution of spawning habitats throughout the river), were all rated as “minimal” or “low” magnitude stressors. Competition for spawning habitat space and negative effects from redd superimposition are not expected to be stressors because an estimated 25 to 27 acres of spawning habitat in wet and dry years, respectively, are available on the Stanislaus River (Peterson et al. 2014). This is more than the estimated 14.7 acres needed to support “wild” adult spawners and reach target juvenile numbers (Appendix B, Table B-3).

Certainty for the stress associated with the amount of available habitat was considered to be “medium.” Understanding is “high” with regard to temperatures during the spawning season and spawning habitat availability on the Stanislaus River (Figure 16; Peterson et al. 2014). However, information on DO, contaminants, and predation and poaching in the spawning reach of the river was based largely on professional judgement rather than Stanislaus River-specific studies. There is insufficient information regarding large classes of contaminants and potential impacts in the upstream reaches. The only data for DO are from a gage located at Ripon, which is far from the current spawning area. Spawning surveys conducted by CDFW suggest little evidence of pre-spawn mortalities and egg retention in females in the spawning reach (Giudice 2014); however, there is little information on the viability of spawned eggs. Additionally, although the temperature data for current conditions came from long-term data from California Data Exchange Center (CDEC) gages (at Goodwin Dam, Knights Ferry, and Orange Blossom Bridge), there are no studies indicating whether poor temperature conditions are contributing to spawning delays.

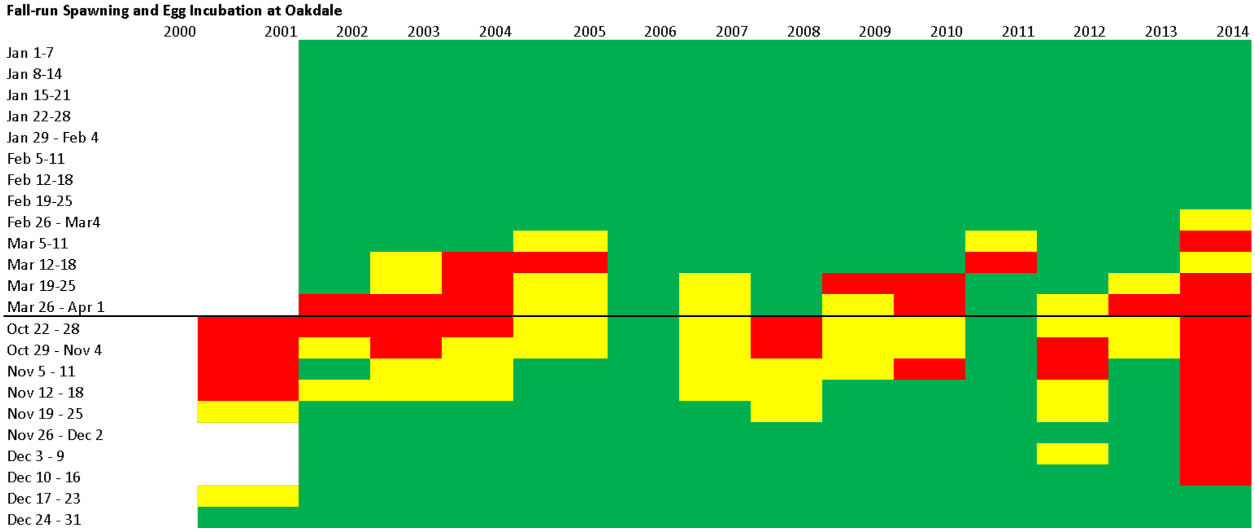


**Fall-run Spawning and Egg Incubation at Knights Ferry**




**Fall-run Spawning and Egg Incubation at Orange Blossom Bridge**


**Fall-run Spawning and Egg Incubation at Oakdale**



| Temperature Rankings (7DADM) | |
|---|---|
| | Sub-optimal/below |
| | Optimal |
| | Sub-optimal/above |
| | Detrimental |

| DO Rankings | |
|---|---|
| | Optimal |
| | Sub-optimal |
| | Detrimental |

Missing Data

**Figure 16**

**Fall-run Chinook Salmon Spawning and Egg Development**

Notes:
Temperature and DO rankings based on observed data during periods of spawning. Time periods with rankings of stressful or detrimental provide evidence for the potential for delayed spawning, increased pre-spawn mortality, and/or reduced egg viability. Rankings reflect the Environmental Objectives for temperature and DO (Section 7). Data are from CDEC for each location.

In the long term, the lack of high-quality habitat will increase to a "high" magnitude stress (major population-level effect) due to several factors. Increases in the expected number of returning spawners will require additional habitat area. Climate change scenarios project more rain, less snow, and warmer water temperatures in the future, which will exacerbate current stressful temperature conditions for spawners (Dettinger et al. 2004; Cayan et al. 2008). Negative effects from DO may increase in magnitude in the long term with the expected increase in stressful temperatures. Finally, as is typical in rivers blocked by dams, the Stanislaus River lacks the ability to replenish gravel and sustain habitat through natural geomorphic processes. In the long term, there will not be enough habitat for adult spawners unless substantial efforts are made to restore this habitat.

The certainty for this stress in the long term remains "medium." There is substantial evidence for the following: the need for additional spawning habitat space as spawning populations increase; predicted increases in temperature over time; and the presence of dams leading to eventual decreased availability of spawning gravels and increased bed armoring. It can be reasonably assumed that, without corrective action, warmer temperature conditions predicted by climate models will contribute to spawning delays and/or failure to spawn.

### 8.4.3.2 Spring-run Chinook Salmon

Inadequate availability of high-quality spawning habitat for spring-run in the near term was rated a "medium" magnitude stress with an expected minor effect on the population; certainty of this stress was "medium" (Table 58).

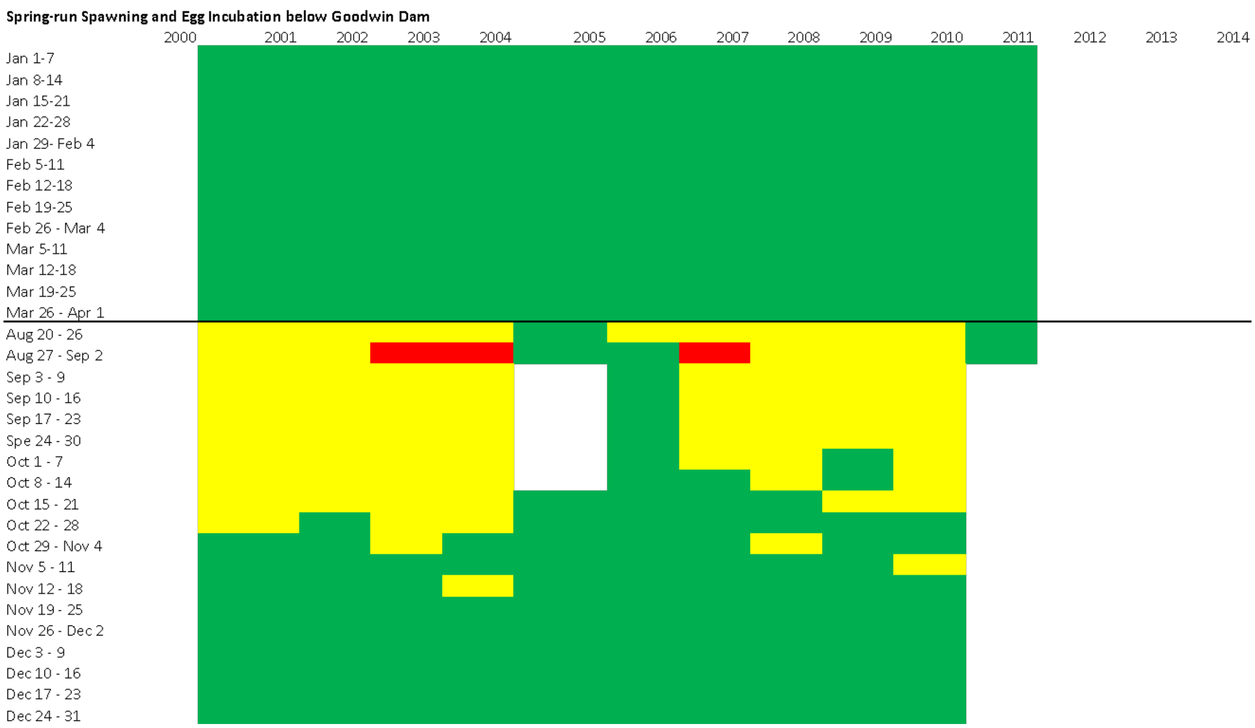
Over the long term, this stress will increase to "high" in magnitude. The certainty will remain "medium" (Table 58).

**Table 58**
**Spawning Stressors for Spring-run Chinook Salmon**

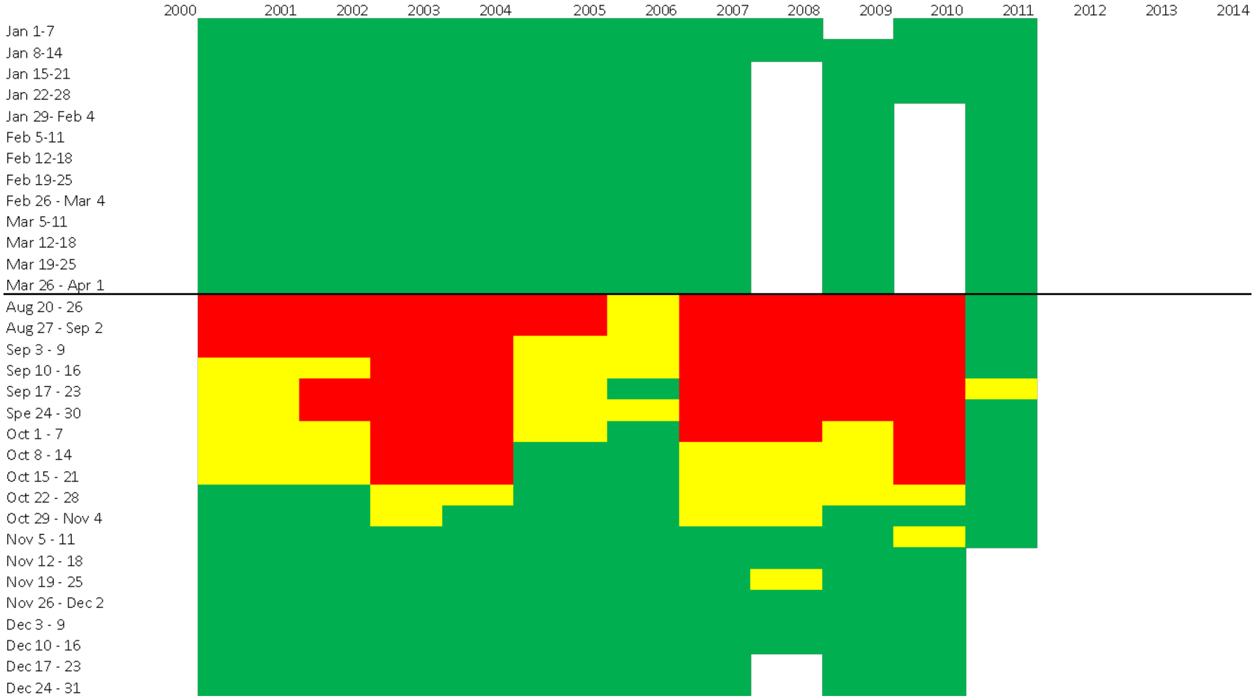
| | | | | | Stressors | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Spring-run Stressor, Spawning Reach, late August-October | NT | | LT | | Temperature | | DO | | Velocity | | Depth | | Coarse Sediment Input | | Cover | | Predator density | | Contaminants | | Habitat Distribution | | Disease | | Poaching | | Hatchery Operations | | Run Segregation | |
| | M | C | M | C | NT | LT | NT | LT | NT | LT | NT | LT | NT | LT | NT | LT | NT | LT | NT | LT | NT | LT | NT | LT | NT | LT | NT | LT | NT | LT |
| Inadequate availability of high-quality habitat | 3 | 3 | 4 | 3 | M: 3 C: 3 | M: 4 C: 3 | M: 1 C: 2 | M: 2 C: 1 | M: 1 C: 2 | M: 1 C: 2 | M: 1 C: 2 | M: 1 C: 2 | M: 1 C: 3 | M: 3 C: 3 | M: 1 C: 2 | M: 1 C: 2 | M: 1 C: 2 | M: 1 C: 2 | M: 2 C: 2 | M: 3 C: 2 | M: 3 C: 3 | M: 4 C: 3 | M: 1 C: 2 | M: 2 C: 2 | M: 1 C: 2 | M: 1 C: 2 | | | | |
| Interactions with hatchery fish and other runs | 4 | 4 | 4 | 3 | | | | | | | | | | | | | | | | | | | | | | | M: 2 C: 3 | M: 4 C: 3 | M: 4 C: 4 | M: 4 C: 3 |
| Compression of the spawning window due to delayed spawning | 3 | 2 | 4 | 2 | M: 3 C: 3 | M: 4 C: 2 | M: 2 C: 1 | M: 2 C: 1 | | | | | | | | | | | | | | | | | | | | | | |

Notes:
– Stress and stressors (i.e., contributing factors to a particular stress) for spring-run spawning in the Stanislaus River for the near term (current conditions) and long term (assuming restored abundance goals and higher air temperatures). Scores for each stress were evaluated and assigned based on the scores for contributing stressors.
– Location: Spawning Reach; When: late August through October
– M: Magnitude assesses the size or level of the impact from a stressor. Magnitude can be assigned using consideration of population or habitat effects, and higher scores require consideration of the scale or extent.
– C: Certainty describes the scientific basis for scoring the scale and magnitude of a particular stressor. Certainty considers both the predictability and understanding of linkages in the driver-linkage-outcome pathway from the stressor to the impact.
– Blank space denotes that stressor that is listed for the cell was not scored for the associated row because it is not believed to contribute to the stress identified in that row.
Scoring:
4: High
3: Medium
2: Low
1: Minimal
LT: long term
NT: near term

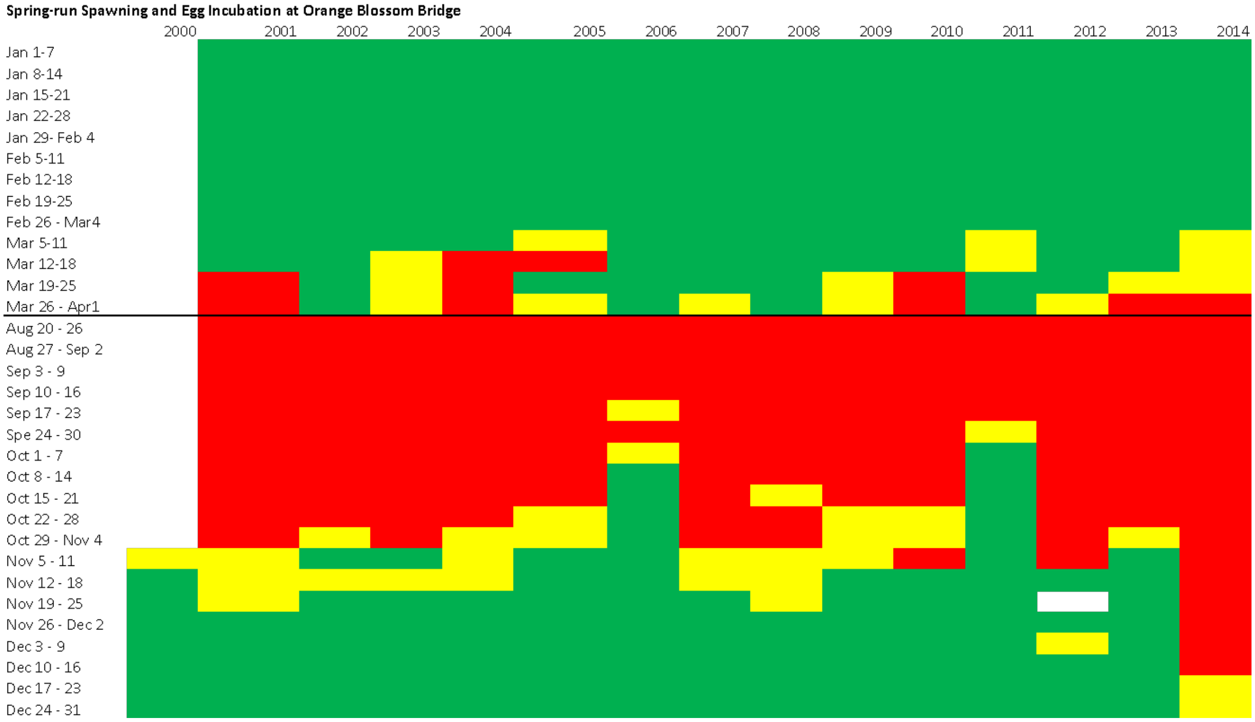
Magnitude for the inadequate availability of high-quality habitat stress was considered “medium” in the near term as a result of habitat component stressors such as temperature and extent of appropriately sized gravel. Temperatures are potentially detrimental or stressful throughout the spawning reach from Orange Blossom Bridge to Goodwin Dam during late August to early November (Figure 17). Similar to fall-run, spring-run would require 14.7 acres of high-quality spawning habitat to support returning adult spawners and juvenile productivity objectives that are required to achieve restoration goals. Although sufficient spawning habitat exists to support current numbers of spawning spring-run, spawning habitat is not segregated from fall-run. Lack of spatial and temporal segregation between fall-run and spring-run will likely result in redd superimposition for spring-run. Together, the many stressors combine to make the inadequate availability of habitat a “medium” magnitude stress.



**Spring-run Spawning and Egg Incubation at Knights Ferry**




**Spring-run Spawning and Egg Incubation at Orange Blossom Bridge**



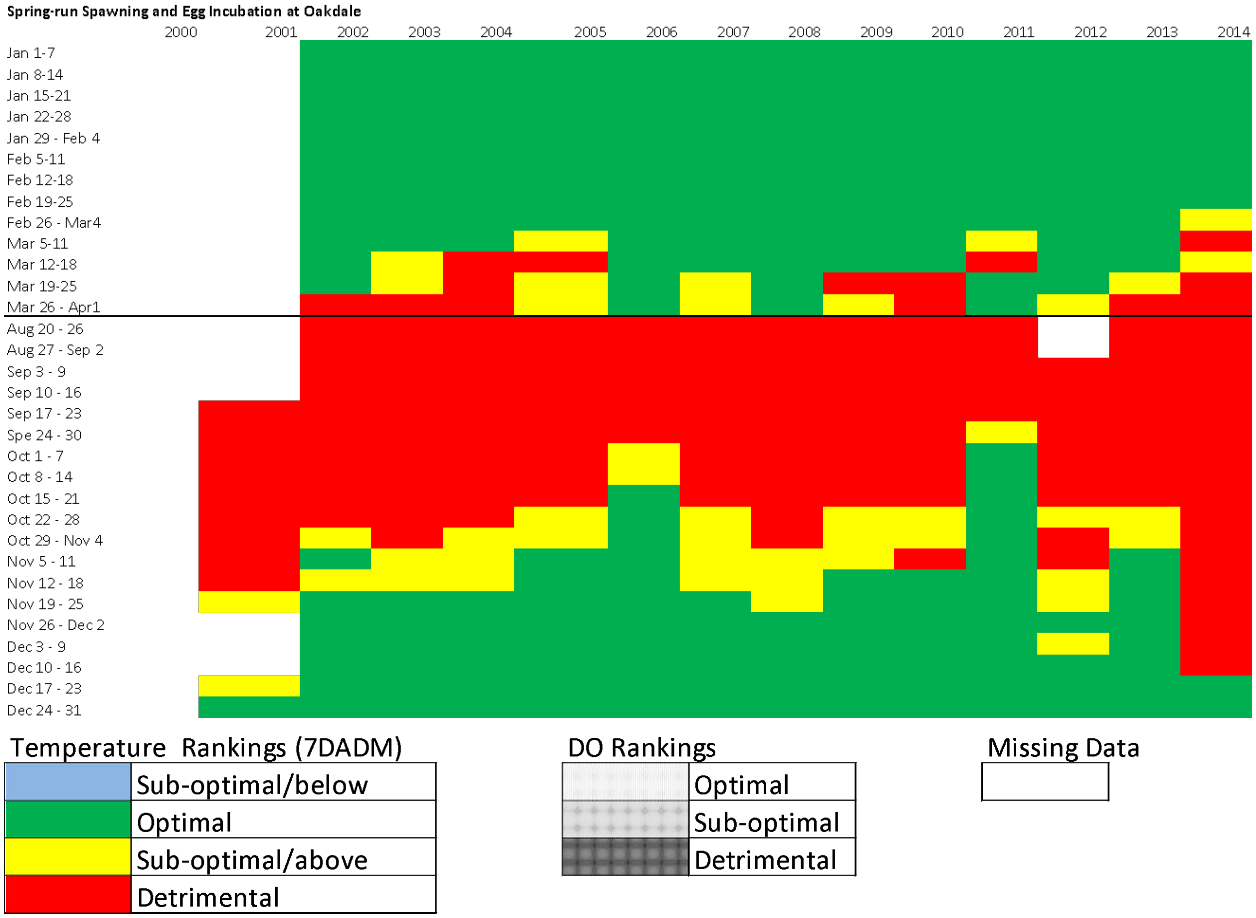



**Figure 17**
**Spring-run Chinook Salmon Spawning and Egg Development**

Notes:
Temperature and DO rankings based on observed data during periods of spawning. Time periods with rankings of stressful or detrimental provide evidence for the potential for delayed spawning, increased pre-spawn mortality, and/or reduced egg viability. Rankings reflect the Environmental Objectives for temperature and DO (Section 7). Data are from CDEC for each location.

Certainty for the aggregate stress, amount of available habitat, was considered to be "medium." Similar to fall-run Chinook salmon, understanding is "medium" with regard to temperatures during the spawning season and spawning habitat availability on the Stanislaus River (Figure 17; Peterson et al. 2014). However, information on DO, contaminants, and predation and poaching in the Stanislaus River was based largely on professional judgement rather than Stanislaus River-specific studies. Insufficient information exists regarding large classes of contaminants, and potential impacts in the upstream reaches are unknown. The only data for DO are from a gage located at Ripon, far from the current spawning area. Additionally, although the temperature data for current conditions came from long-term CDEC gages, there is no information as to whether poor temperature conditions are contributing to spawning delays.

Without corrective measures, the lack of high-quality habitat will increase to a "high" magnitude stress (major population-level effect) in the long term due several factors. Similar to fall-run Chinook salmon, climate change scenarios predicting warmer water temperatures in the future will exacerbate current stressful temperature conditions for spawners (Dettinger et al. 2004; Cayan et al. 2008). Negative effects from DO may also increase in magnitude in the long term as temperatures rise. Increased numbers of fall-run Chinook salmon will continue to impact spring-run redds due to redd superimposition. Finally, over the long term, there will not be enough habitat to accommodate increased numbers of adult spawners due to the increased expected number of spawners and the gradual loss of spawning gravel downstream of the dam.

The certainty for this stress in the long term remains "medium." There is substantial evidence for increased temperatures in the future and for the lack of suitable physical habitat spawning as the number of spawners increase and the dam continues to block replenishment of spawning gravels.

### 8.4.3.3 O. mykiss

Inadequate availability of high-quality spawning habitat for *O. mykiss* in the near term was rated a "low" magnitude stress with an expected minor effect on the population; certainty of this stress was "low" (Table 59).

Over the long term, this stress will increase to "medium" in magnitude. The certainty will remain "low" (Table 59).

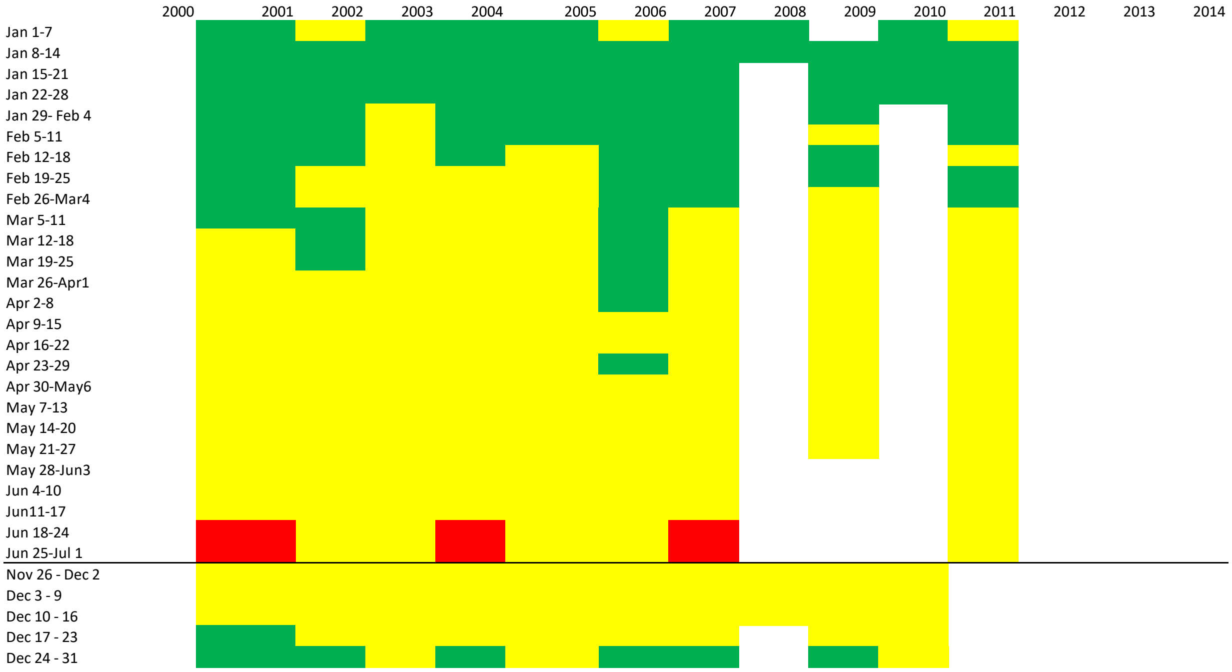
**Table 59**
**Spawning Stressors for *O. mykiss***

| | | | | | Spawning | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ***O. mykiss* Stressor, Spawning Reach, December – April** | **NT** | | **LT** | | **Temperature** | | **DO** | | **Velocity** | | **Depth** | | **Coarse Sediment Input** | | **Cover** | | **Predator density** | | **Contaminants** | | **Habitat Distribution** | | **Disease** | | **Poaching** | | **Hatchery Operations** | |
| | **M** | **C** | **M** | **C** | **NT** | **LT** | **NT** | **LT** | **NT** | **LT** | **NT** | **LT** | **NT** | **LT** | **NT** | **LT** | **NT** | **LT** | **NT** | **LT** | **NT** | **LT** | **NT** | **LT** | **NT** | **LT** | **NT** | **LT** |
| Inadequate availability of high-quality habitat | 2 | 2 | 3 | 2 | M: 2<br>C: 2 | M: 3<br>C: 2 | M: 1<br>C: 3 | M: 2<br>C: 3 | M: 1<br>C: 2 | M: 1<br>C: 2 | M: 1<br>C: 2 | M: 1<br>C: 2 | M: 2<br>C: 2 | M: 2<br>C: 2 | M: 1<br>C: 2 | M: 1<br>C: 2 | M: 2<br>C: 2 | M: 2<br>C: 2 | M: 2<br>C: 2 | M: 3<br>C: 2 | M: 1<br>C: 1 | M: 3<br>C: 2 | M: 1<br>C: 2 | M: 2<br>C: 2 | M: 1<br>C: 2 | M: 1<br>C: 2 | | |
| Interactions with hatchery fish and other runs | 3 | 2 | 3 | 2 | | | | | | | | | | | | | | | | | | | | | | | M: 4<br>C: 4 | M: 4<br>C: 3 |
| Compression of the spawning window due to delayed spawning | 2 | 1 | 3 | 1 | M: 2<br>C: 1 | M: 3<br>C: 1 | M: 2<br>C: 1 | M: 2<br>C: 1 | | | | | | | | | | | | | | | | | | | | |

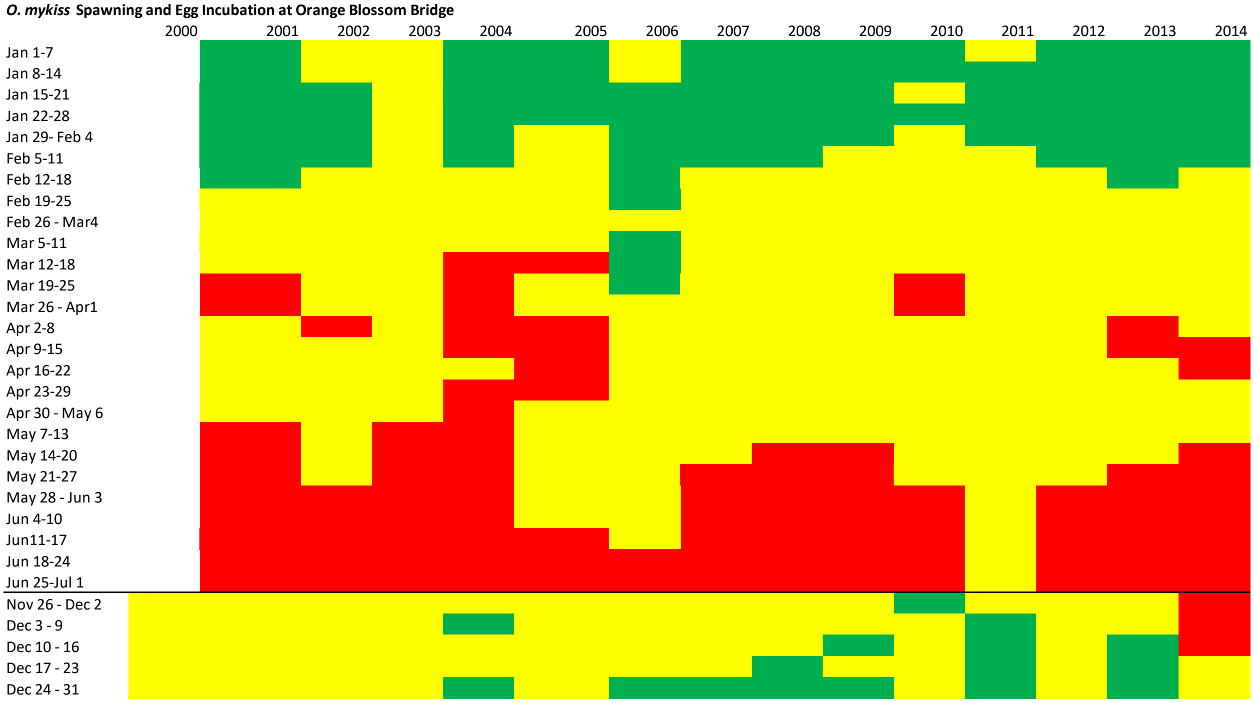
Notes:
– Stress and stressors (i.e., contributing factors to a particular stress) for *O. mykiss* spawning in the Stanislaus River for the near term (current conditions) and long term (assuming restored abundance goals and higher air temperatures). Scores for each stress were evaluated and assigned based on the scores for contributing stressors.
– Location: Spawning Reach; When: late August through October
– M: Magnitude assesses the size or level of the impact from a stressor. Magnitude can be assigned using consideration of population or habitat effects, and higher scores require consideration of the scale or extent.
– C: Certainty describes the scientific basis for scoring the scale and magnitude of a particular stressor. Certainty considers both the predictability and understanding of linkages in the driver-linkage-outcome pathway from the stressor to the impact.
– Blank space denotes that stressor that is listed for the cell was not scored for the associated row because it is not believed to contribute to the stress identified in that row.
Scoring:
4: High
3: Medium
2: Low
1: Minimal
LT: long term
NT: near term

Magnitude for the inadequate availability of high-quality habitat stress was considered "low" in the near term because an evaluation of the habitat component stressors revealed that temperature was the only concern, and it was rated as a "medium" magnitude stressor. Temperatures are potentially stressful throughout the spawning reach upstream of Orange Blossom Bridge during at least part of the October to June spawning season (Figure 18). The downstream extent of currently available spawning habitat (near Orange Blossom Bridge) is expected to have higher temperatures than the upper reaches near Goodwin Dam during early and late spawning (fall and late spring). Spawning may frequently be restricted by unsuitable temperatures early (October to November) and later (March to June) in the spawning season. The certainty is "low" for this stressor because of the complex life history of *O. mykiss*, the lack of information on steelhead spawning success in the Stanislaus River, and the lack of spatially explicit temperature data in the spawning reach. Lack of segregation from fall-run is not expected to adversely affect most *O. mykiss*, as the peak spawning season is expected to begin in December when most fall-run have spawned. Additionally, *O. mykiss* preferentially use slightly smaller gravel size, so redd superimposition is expected to be minimal. Contaminants were rated as a "low" magnitude stressor. Together, the many stressors combine to make the availability of habitat a "low" magnitude stress.

***O. mykiss* Spawning and Egg Incubation at Knights Ferry**




***O. mykiss* Spawning and Egg Incubation at Orange Blossom Bridge**



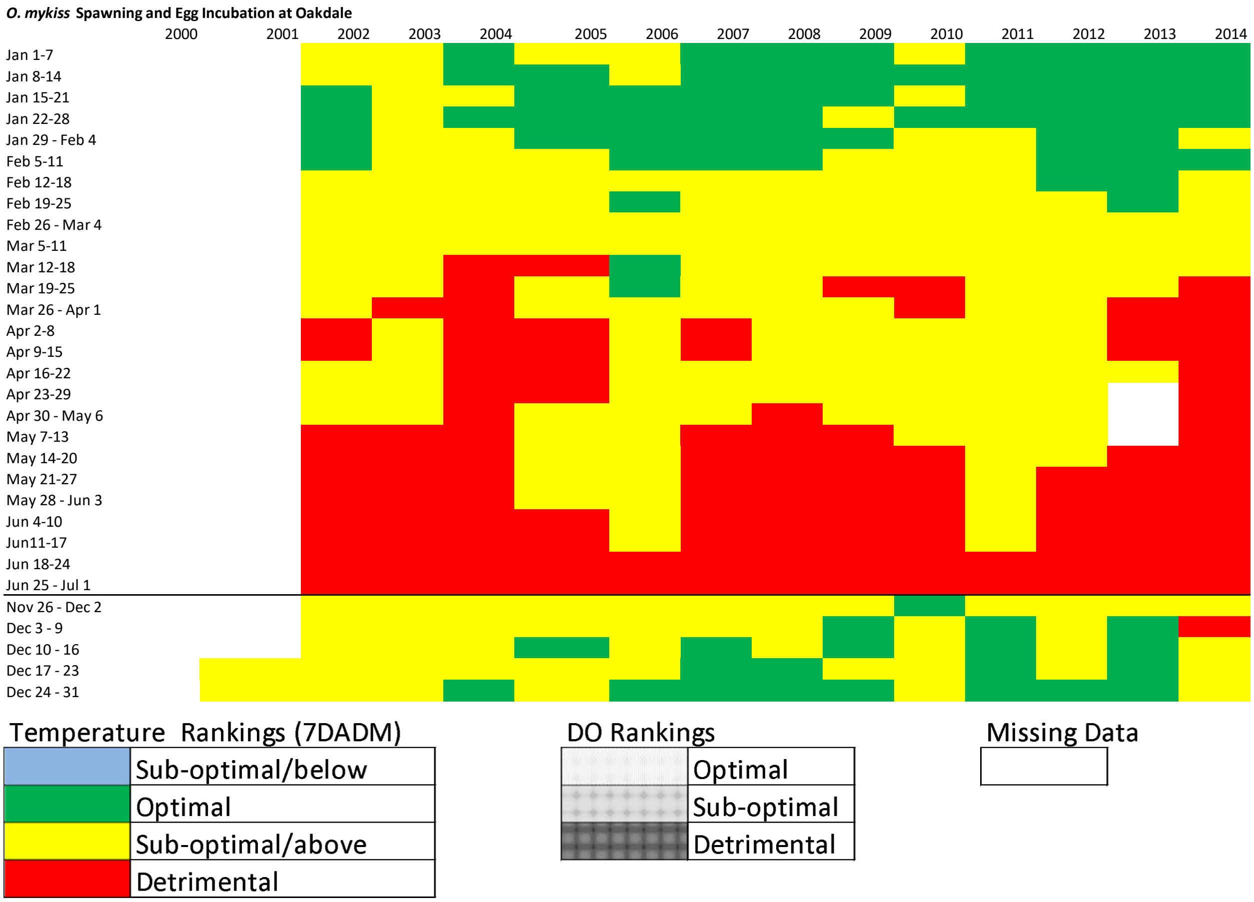



**Figure 18**

***O. mykiss* Spawning and Egg Development**

Notes:
Temperature and DO rankings are based on observed data during periods of spawning. Time periods with rankings of stressful or detrimental provide evidence for the potential for delayed spawning, increased pre-spawn mortality, and/or reduced egg viability. Rankings reflect the Environmental Objectives for temperature and DO (Section 7). Data are from CDEC for each location.

Certainty for the aggregate stress—the amount of available habitat—was considered to be "low." Similar to Chinook salmon, understanding is "high" with regard to temperatures during the spawning season (Figure 18); it is "medium" for *O. mykiss* requirements and spawning habitat availability on the Stanislaus River because spawning habitat availability has only been estimated for Chinook (Peterson et al. 2014). Information on DO, contaminants, and predation and poaching in the Stanislaus River was based largely on professional judgment rather than Stanislaus River-specific studies. Insufficient information exists regarding large classes of contaminants, and potential impacts in the upstream reaches are unknown. The only data for DO are from a gage located at Ripon, which is far from the current spawning area. Additionally, although the temperature data for current conditions came from long-term data from CDEC gages (Figure 18), there is no information as to whether poor temperature conditions are contributing to spawning delays or failure to spawn.

Without corrective action, the lack of high-quality habitat will likely increase to a "medium" magnitude stress (minor population-level effect) in the long term due to several factors. Similar to fall-run Chinook salmon, climate change scenarios predicting warmer water temperatures in the future will likely result in stressful temperature conditions for spawners (Dettinger et al. 2004; Cayan et al. 2008). Negative effects from DO are expected to increase in magnitude in the long term with increases in temperature. Increased numbers of fall-run Chinook salmon may impact *O. mykiss* redds through superimposition. In the long term, there will likely not be enough habitat for spawning adults due to the increased number of spawners and lack of spawning gravel replenishment downstream of the dam.

The certainty for this stress in the long term remains "low." There is substantial evidence for increased temperatures in the future and a lack of spawning gravel replenishment downstream of dams.

## *8.4.4 Stress: Interactions with Hatchery Fish and Other Runs (Spawning)*

Introgression between ESUs or between hatchery-spawned and naturally produced salmon can have negative impacts on life history adaptation and population viability from reduced fitness (Section 3.2). To attain SEP Biological Objectives for genetic integrity of each population, high-quality spawning habitat for each population must be spatially or temporally segregated from other runs or species to prevent introgression and support local adaptation.

### 8.4.4.1 Fall-run Chinook Salmon

Interbreeding stress was scored as "high" magnitude with "high" certainty in the near term, from October through December, within the spawning reach (Table 57).

In the long term, without aggressive hatchery management and segregation from spring-run Chinook salmon, this stress will remain "high" in magnitude. The certainty will become "medium" because the outcome is dependent on future management actions (Table 57).

There is no spatial segregation of habitat to prevent naturally produced fall-run Chinook salmon from interbreeding with hatchery strays and spring-run Chinook salmon. Near-term "high" magnitude rankings, indicating a major population effect, are based on evidence that hatchery fish negatively impact wild Chinook salmon populations and the large proportion of hatchery fish that reproduce in the Stanislaus River. In addition, reducing introgression between fall-run and spring-run Chinook salmon ESUs is a major goal for the maintenance and restoration of fall-run Chinook salmon in the Central Valley (Sections 3.2 and 6.2.2). The certainty is "high" for this stress because of the recent robust data on the prevalence of hatchery-spawned adults returning to spawn in the Stanislaus River (Kormos et al. 2012; Palmer-Zwalen and Kormos 2013). Although no site-specific studies have verified negative population-level effects from hatchery fish on the Stanislaus River, introgression is considered a major stressor system-wide (Section 3.2). Additionally, fall-run and spring-run Chinook salmon ESUs are currently restricted to roughly the same spawning areas due to Goodwin Dam.

Without intervention, this stressor will remain “high” magnitude in the long term because hatchery and wild fish and spring-run and fall-run Chinook salmon will interbreed unless physical or temporal barriers to reproduction are established. Increased numbers of spring-run spawners will increase interbreeding among ESUs and cause additional interbreeding stress (Section 6.2.2). The certainty decreases to “medium” because the outcome is dependent on many variables for which the SEP Group had no expectation such as hatchery practices, land use conditions that may change available habitat, and future management actions.

#### 8.4.4.2 Spring-run Chinook Salmon

Interbreeding stress was scored as “high” magnitude and “high” certainty in the near term, during late August to October, within the spawning reach (Table 58).

In the long term, without access to spawning habitat above Goodwin Dam or segregation from fall-run Chinook salmon, this stress will remain “high” in magnitude. The certainty will become “low” because the outcome is highly dependent on future management actions (Table 58).

Near-term “high” magnitude rankings, indicating a major population effect, are based on the lack of spatial segregation for spring-run spawning habitat that would prevent interbreeding with fall-run Chinook salmon. The certainty is “high” for this stressor for the following reasons:

- Recent studies verifying negative population-level effects from interbreeding of ESUs system-wide (Section 3.2)
- Hybridization and introgression among Central Valley runs, resulting from dam construction and hatchery management practices, is well known (e.g., Smith et al. 1995)

Lack of spatial and temporal segregation between spring-run and fall-run Chinook salmon will also lead to high rates of redd superimposition for spring-run, which spawn earlier than fall-run.

In the long term, this stress will remain “high” magnitude because as numbers of fall-run and spring-run adults increase, interbreeding among ESUs is likely to increase. The certainty decreases to “medium” because the outcome is dependent on uncertain variables such as future hatchery practices, land use conditions that may change available habitat, and future management actions on the Stanislaus River that could include passage around Goodwin Dam or segregation weirs.

#### 8.4.4.3 O. mykiss

Interbreeding stress was scored as “medium” magnitude and “low” certainty in the near term, during October through June, within the spawning reach (Table 59).

In the long term, this stress will remain "medium" in magnitude. The certainty will remain "low" because little is known about *O. mykiss* reproduction on the Stanislaus River (Table 59).

In many Central Valley rivers, the steelhead are dominated by hatchery fish (Garza and Pearse 2008), and the negative effects on fitness of interbreeding between wild and hatchery fish are well studied and can be genetically based (Hansen 2002; Araki et al. 2007). In 3 of the last 5 years of weir operation on the Stanislaus River, more than 50% of the steelhead counted were classified as hatchery origin, indicating potential for substantial introgression with hatchery-origin stock (Johnson 2014, pers. comm.). However, gene flow from hatchery fish in steelhead populations can be buffered by wild resident rainbow trout populations with better fitness (Christie et al. 2011). The certainty is "low" for this stress in the near term because of the complex life history strategies of *O. mykiss* and the lack of information on population-level effects of this stress on Stanislaus River *O. mykiss*.

In the long term, this stress will remain a "medium" magnitude stress because, even with increased numbers of wild-spawned *O. mykiss*, current hatchery management practices are likely to contribute to introgression. The certainty remains "low" for the same reasons as those described for the near term.

## *8.4.5 Stress: Compression of the Spawning Window due to Delayed Spawning*

Ensuring opportunities for full expression of potential life history traits by salmonids is an important consideration in the SEP's life history diversity objectives (Section 3.2). Compression of the life history cycle resulting from delayed spawning was evaluated for Chinook salmon and *O. mykiss* as a potential stress related to the diversity objectives.

### 8.4.5.1 Fall-run Chinook Salmon

Compression of the spawning window due to delayed spawning was scored as a "low" magnitude and "low" certainty stress in the near term, primarily due to stressful temperatures (Table 57).

In the long term, this stress will increase to "high" in magnitude due to climate change model projections of increasing water temperature. The certainty will remain "low" for reasons similar to the near term (Table 57).

Near-term "low" magnitude rankings are based on detrimental and stressful conditions that occur regularly at the beginning of the fall-run spawning season throughout the current spawning reach. The downstream extent of currently available spawning habitat (near Orange Blossom Bridge) is restricted by unsuitable temperatures early in the spawning season (late October to early November; Figure 16). Unsuitable temperatures may contribute to delayed spawning or failure to spawn (Section 8.5). Although the effects of temperatures on Chinook salmon are well studied and temperature data are available from robust long-term datasets within the current spawning reach (i.e., CDEC gages at Goodwin Dam, Knights Ferry, and Orange Blossom Bridge), the certainty is "low" for this stressor because the nature of the outcome is not predictable. The effect of delayed spawning on the time available for subsequent development of a portfolio of life history types among juvenile outmigrants is attenuated by conditions in the egg development and juvenile rearing life history stages. Thus, even though the spawning season for fall-run Chinook salmon is potentially constrained, conditions during egg development and juvenile rearing stages still influence the timing and size (life history) distribution of the subsequent cohort of outmigrating juveniles.

In the long term, this stressor will increase to "high" magnitude because projected climate change scenarios show more rain, less snow, and warmer water temperatures in the future, which will exacerbate current temperature conditions. The certainty remains "low" for similar reasons as those described for the near term. However, there is an established, well-understood trend suggesting that near-term temperature conditions are likely to continue or increase over the next 20 years (Dettinger et al. 2004; Cayan et al. 2008).

### 8.4.5.2 Spring-run Chinook Salmon

Compression of the freshwater life cycle due to delayed spawning was scored as a "medium" magnitude, "low" certainty stress during late August through October in the near term within the spawning reach (Table 58)

In the long term, this stress will become "high" in magnitude. The certainty will remain "low" for reasons similar to those in the near term (Table 58).

Near-term "medium" magnitude rankings are due to observed temperatures that are often detrimental or stressful upstream of Orange Blossom Bridge during late August to early November (Figure 17). The downstream extent of currently available spawning habitat (near Orange Blossom Bridge) is restricted by unsuitable temperatures early and late in the spawning season (late August to early November and late March). Goodwin Dam blocks higher elevation spawning habitat historically used by spring-run. Although the effects of temperatures on Chinook salmon are well studied and temperature data is available from robust long-term datasets within the current spawning reach (CDEC gages at Goodwin Dam, Knights Ferry, and Orange Blossom Bridge), the certainty is "low" for this stressor because the nature of the outcome can be attenuated by conditions during the egg development and rearing life history stages.

In the long term, this stressor will increase to "high" magnitude because projected climate change scenarios show more rain, less snow, and warmer water temperatures in the future that will exacerbate current conditions. The certainty remains "low" for reasons described for the near term. However, there is an established, well-understood trend suggesting that the near-term temperature conditions are likely to continue or increase over the next 20 years (Dettinger et al. 2004; Cayan et al. 2008).

#### 8.4.5.3 O. mykiss

Compression of the freshwater life cycle due to delayed spawning was rated a “low” magnitude stress and a “minimal” certainty in the near term during the main spawning window, December through April, within the spawning reach (Table 59).

Over the long term, without corrective action, the magnitude will increase to “medium” magnitude; certainty will remain “minimal.” Not much is known about the potential for delayed spawning on the Stanislaus River; however, evidence from other streams does not suggest that delayed spawning would have significant population-level effects for *O. mykiss* (Table 59).

Near-term “low” magnitude rankings, indicating periodic population effects, are based primarily on temperatures. Temperatures are usually stressful upstream of Orange Blossom Bridge in early fall and late spring (Figure 18). The downstream extent of currently available spawning habitat (near Orange Blossom Bridge) is frequently restricted by unsuitable temperatures early (October to November) and later (March to June) in the spawning season. Temperatures at Goodwin Dam can be stressful throughout the spawning season, with the exception of January when temperatures are generally supportive. The certainty is “minimal” for this stressor because of the complex life history form and lack of information on *O. mykiss* spawning success in the Stanislaus River. In the long term, this stress will become “medium” magnitude because increased temperatures may restrict spawning in some or most months. The certainty remains “minimal” for similar reasons to those described for the near term.

### *8.4.6 Contributing Management Factors*

Resolution of negative interactions among salmonid populations during the spawning period may include some mix of changes to hatchery operations, river management practices, and potential implementation of actions to create physical reproductive barriers among target populations. These issues will require a basin-wide (or perhaps, Central Valley-wide) response.

Dams block access to historic high elevation spawning habitats, particularly for spring-run Chinook salmon and *O. mykiss*. Thus, spawning for all salmonids is currently restricted to warmer, lower elevation tailwaters below Goodwin Dam. This reduces the total area of available spawning habitat and forces the different salmonid populations (spring-run, fall-run, and *O. mykiss*) to utilize the same area, which may increase impacts due to redd superimposition. In addition, dams limit recruitment of spawning gravel from upstream and high-volume flows that produce geomorphic work. Without continuing gravel amendments and actions to modify or maintain riverbed and riverbank habitat elements, the dams cause a gradual decline of available spawning habitat.

Reservoir operations are also a major driver of the environmental factors that control stressors on spawning adult salmonids. For example, flow rates and coldwater pool management regulate critical elements of spawning habitat, including water temperature, water depth, water velocity, and DO levels. In addition, high temperatures that inhibit the onset of spawning by spring-run Chinook salmon tend to increase the temporal overlap between spring-run and fall-run spawning periods. The environmental factors that drive availability of spawning habitat are often coupled and work synergistically (e.g., temperature affects both DO concentration and fish demand for DO).

Other non-flow management practices may exacerbate or alleviate stressors on adult spawning. Gravel augmentation and bank modifications may increase available spawning habitat, at least in the short term. Also, land use modifications and sediment control activities can affect the ability of available spawning gravel to support spawning and egg development. Destruction of riparian habitat along the Stanislaus River has likely reduced the amount of shade in the river corridor; this can increase temperatures. Groundwater depletion has likely affected hyporheic inputs that probably buffered the Stanislaus River against warm temperatures in late spring, summer, and early fall. Groundwater recharge programs may help to reestablish this benefit and reduce water temperatures in the river during critical months.

## 8.5 Stressors on Egg Development

The egg development stage—which includes the time period between when a female salmonid deposits her eggs in a redd and when fry emerge from the gravel/sediment into the water column—represents the first stage of the salmonid life cycle. In general, salmonid populations are most vulnerable during the egg development life history stage because all of the individuals in a year-class are in a relatively small area, and they cannot move in order to avoid a stressor (e.g., warm water temperatures). Stressors during egg development of salmonids may result in direct mortality or impacted rates of development, disease, or physical alterations that may be critical to the development of subsequent life history stages. The SEP Group evaluated one type of stress during the egg development phase: inadequate development conditions (i.e., conditions that result in egg or larval mortality).

Physical stressors that can negatively impact populations during egg development were evaluated in the near term and long term for the following: water temperature, DO, contaminants, fine sediment, flow fluctuations, and trampling or disturbance. Trampling or disturbance by anglers or other river users was not expected to be a significant stressor and thus was not further considered. Flow fluctuation is a multifaceted stressor because unusually high flows could cause redd scour, whereas decreased flows during the spawning or egg development period could cause redd dewatering. Pesticides and metalloids (i.e., mercury and selenium) were analyzed as contaminants that could potentially impact target populations at this life history stage. Evaluation of near-term stressors analyzed those that would impede attainment of Environmental or Biological Objectives under current conditions; evaluation of these stressors in the long term assumed that global and regional warming trends would occur as anticipated and that more fish of each target population would be spawning in the Stanislaus River.

## *8.5.1 Current Egg Development Timing Patterns*

Egg development in the Stanislaus River generally occurs from late October through March for fall-run Chinook salmon and from December through June for *O. mykiss.* For spring-run Chinook salmon in the Sacramento River basin, egg development generally occurs from September through March; SEP objectives for spring-run Chinook salmon in the Stanislaus River include successful spawning throughout this time period.

Monitoring that directly examines success of developing eggs does not currently occur on the Stanislaus River. Some monitoring related to the emergence of salmonids on the Stanislaus River occurs via snorkel surveys, spawning surveys, beach seining, and the operation of RSTs near Caswell and Oakdale. However, direct measurement of egg mortality is challenging because it is difficult to observe the number of eggs deposited by individual females or the number of fry that emerge from a redd without affecting egg development conditions.

## *8.5.2 Stress: Inadequate Egg Development Conditions*

Salmonid egg mortality rates can have a strong influence on population growth rates. Generally, salmon display high rates of investment in their eggs, a strategy associated with relatively high egg development success (Winemiller and Rose 1992). Thus, even small changes in survival of developing eggs can represent significant changes in return on parental investment, producing substantial population-level effects. Gravel augmentation projects have been implemented on the Stanislaus River in order to improve the availability of high-quality spawning and egg development habitat.

Various factors, acting alone and in combination, may make egg development conditions unsuitable and lead to elevated rates of egg and alevin mortality. The SEP Group assessed water temperature, DO, pesticides, mercury and selenium levels, fine sediments, and redd dewatering and scour as stressors that may lead to inadequate egg development conditions for target salmonid populations developing in the Stanislaus River.

### 8.5.2.1 Fall-run Chinook Salmon

Inadequate egg development conditions were judged to cause a “medium” level of stress (sustained minor population-level effect) with a “high” degree of certainty in the near term (Table 60).

Unless measures are taken to improve egg development conditions, the stress of inadequate conditions was estimated to become a “high” stress on the population in the long term; certainty will remain “high” (Table 60).

**Table 60**
**Egg Development Stressors for Fall-run Chinook Salmon**

| Stress | NT M | NT C | LT M | LT C | Temperature NT | Temperature LT | DO NT | DO LT | Pesticides NT | Pesticides LT | Contaminants: Mercury, Selenium NT | Contaminants: Mercury, Selenium LT | Fine Sediments NT | Fine Sediments LT | Flow Fluctuation: Redd Dewatering NT | Flow Fluctuation: Redd Dewatering LT | Flow Fluctuation: Redd Scour NT | Flow Fluctuation: Redd Scour LT |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Inadequate Development Conditions | 3 | 4 | 4 | 4 | M: 2<br>C: 4 | M: 3<br>C: 4 | M: 1<br>C: 4 | M: 1<br>C: 4 | M: 2<br>C: 2 | M: 2<br>C: 2 | M: 1<br>C: 4 | M: 1<br>C: 4 | M: 2<br>C: 2 | M: 2<br>C: 1 | M: 1<br>C: 3 | M: 1<br>C: 3 | M: 2<br>C: 2 | M: 2<br>C: 1 |

Notes:
– Stress and stressors (i.e., contributing factors to a particular stress) for fall-run egg development in the Stanislaus River for the near term (current conditions) and long term (assuming restored abundance goals and higher air temperatures). Scores for each stress were evaluated and assigned based on the scores for contributing stressors.
– Location: Oakdale to Riverbank; When: early in egg development season (October)
– M: Magnitude assesses the size or level of the impact from a stressor. Magnitude can be assigned using consideration of population or habitat effects, and higher scores require consideration of the scale or extent.
– C: Certainty describes the scientific basis for scoring the scale and magnitude of a particular stressor. Certainty considers both the predictability and understanding of linkages in the driver-linkage-outcome pathway from the stressor to the impact.
Scoring:
4: High
3: Medium
2: Low
1: Minimal
LT: long term
NT: near term

The near-term stress score synthesizes the effect of numerous egg development stressors, some of which act synergistically to increase the level of impact. Water temperatures represent a low magnitude stressor in the near term. The effect on egg survival of exposure to different temperatures has been extensively described in the scientific literature (Appendix C), reflecting a high scientific understanding of this effect. Comparison of Stanislaus River water temperatures to the SEP Group's Environmental Objectives indicates that conditions for fall-run Chinook salmon egg development generally are supportive for most of the development period in most years at and upstream of Knights Ferry. However, conditions for fall-run Chinook salmon egg development deteriorate downstream at Orange Blossom Bridge and Oakdale, where stressful and detrimental temperatures occur in the early weeks of the egg development period in most years (Figure 16). Given that the relationship between salmon egg survival and temperature is highly understood and predictable and that temperature monitoring near current spawning grounds on the Stanislaus River is robust and ongoing, a "high" certainty score is justified. Modeling predictions indicate that temperatures are expected to increase in the southern Sierra in the long term (i.e., climate change; Dettinger et al. 2004; Cayan et al. 2008). Thus, the effect of temperature on egg development in the Stanislaus River is expected to increase to a "medium" magnitude stressor in the long term, and the certainty of that characterization is expected to remain "high."

The overall stress on fall-run Chinook egg development in the Stanislaus River is elevated by the action of stressors in addition to high water temperature. The likelihood that the additional stressors would exacerbate temperature stress caused the SEP Group to raise the overall magnitude score to reflect "medium" stress on fall-run egg development in the near term and "high" stress in the long term.

The effect of pesticide-derived contaminants was scored as a "low" magnitude stressor with a "low" degree of certainty in the near term. Overall, eggs and alevins developing in the Stanislaus River will have low exposures to pesticides, except for portions of the populations that are developing late in the season or in the downstream end of the spawning distribution. Developing eggs will be relatively unaffected by pesticides because the vitelline membrane, enveloping layer, and chorion provide defense from metals, pathogens, and xenobiotic chemicals (Finn 2007). However, exposure to toxic compounds is of some concern for fall-run alevins developing between Riverbank and Oakdale between December and March, when winter storms can produce runoff that may have high (potentially detrimental) concentrations of toxins. The SEP Group's analysis of pesticide impacts relied on pesticide modeling developed using pesticide-use data; however, for any one pesticide exceedance, the frequency of exceedance is estimated and does not consider additional impacts from multiple pesticides occurring simultaneously (i.e., cumulative pesticide effects were not analyzed; Appendix C).

The conditions were estimated from qualitative assessments of model outputs. However, quantitative values of pesticide concentrations could be calculated from numerical model outputs if necessary in the future. In addition, the degree of adverse impacts to egg and alevin development assumes that there is an analogous adverse impact, as during rearing. There is a high probability that contaminants will elicit a physiological or behavior response; however, there is uncertainty whether these will result in development impairments (e.g., deformities or reduced growth) or mortality. Limitations of monitoring pesticide concentrations in the Stanislaus River as well as limited information on the effect of pesticides on developing salmonid eggs result in a low degree of certainty regarding the impacts of this stressor. The SEP group found no reason to believe that magnitude or certainty of pesticide impacts would change in the long term.

As with pesticide concentrations, the effect of fine sediment on egg development was scored a “low” magnitude and “low” certainty stressor on fall-run egg development when considered in isolation. However, the action of this stressor contributed to the overall stress score. The Knights Ferry Gravel Replenishment Project Phase II report states the following:

> The egg survival studies also suggest that egg survival in the downstream reaches may have been reduced by the combined effects of near lethal water temperatures that fluctuated greatly in early November, excessive fines that reduce dissolved oxygen concentrations, and intragravel turbidity that presumably coated the eggs with clay-sized particles that reduced the egg’s abilities to absorb oxygen. (Carl Mesick Consultants and KDH Environmental Services 2009, introduction at v)

The Carl Mesick Consultants and KDH Environmental Services (2009) study’s implication is that negative impacts of excessive fines are limited to a small fraction of the population, which, in this case, would be the eggs in the most downstream reaches. However, the certainty for the magnitude of this stressor is “low” because it is primarily based on non-peer-reviewed research within the Stanislaus River. In the future, the effect of fine sediment on salmonid egg development in the Stanislaus River is expected to remain a “low” magnitude stressor, but the certainty of that characterization decreases to “minimal.”

The effect of high flows that may scour redds was scored as a “low” magnitude stressor with a “low” degree of certainty in the near term. A Stanislaus riverbed mobility analysis described in Kondolf et al. (2001) found that flows around 5,000 to 8,000 cfs are necessary to mobilize the $D_{50}$ of the channel bed material. Therefore, for the purposes of the SEP stressor analysis, 5,000 cfs was assumed to represent a minimum flow for which redd scour may begin to be a problem. The SEP Group evaluated the frequency of flows below Goodwin Dam that were greater than 5,000 cfs from January 2000 to September 2014. Flows below Goodwin Dam exceeded the 5,000 cfs threshold for just two events during this period. One of those events occurred during the fall-run Chinook salmon egg development period (January 2006, maximum flow 6,300 cfs, duration 11 days). The other event occurred during the spring-run Chinook salmon egg development time period (April 2006, maximum flow 5,510 cfs, duration 14 days). Overall, only 1 of 14 year-classes of fall-run Chinook salmon and spring-run Chinook salmon were potentially impacted by redd scour due to high flows. Given the low frequency of flows that could scour salmon redds, this stressor is believed to have only a small effect on salmon populations. The overall certainty of this stressor in the near term is "low" due to a lack of information on the relationship in the Stanislaus River among flow, scour depth, egg burial depths, and egg survival. Presumably, egg survival at flows that just begin riverbed mobilization will be high relative to egg survival at much higher flows, but the specific relationship is not well understood.

In the long term, the effect of high flows that may scour redds is expected to remain a "low" magnitude stressor. Due to climate change, more variable precipitation is expected in the long term, with more frequent very wet periods and drought periods. Given the large storage capacity in the Stanislaus River relative to the size of the watershed, it may be the case that the more frequent very wet periods will not result in an increase in the frequency of flows that can scour redds below New Melones and Goodwin dams. However, there is enough uncertainty involved to render the outcome certainty "minimal."

The SEP Group's analyses determined that several factors initially considered to be potential stressors on egg development success were likely to have "minimal" impact on successful egg development of fall-run Chinook salmon on the Stanislaus River. These included DO concentrations, mercury and selenium concentrations, and redd dewatering.

#### 8.5.2.2 Spring-run Chinook Salmon

Inadequate conditions for egg development of spring-run Chinook salmon were judged to be a "high" magnitude stressor with a "high" degree of certainty in the near term (Table 61).

Unless measures are taken to improve egg development conditions, the stress of inadequate conditions will remain a sustained major impact on the spring-run Chinook salmon population in the long term; certainty will remain "high" (Table 61).

**Table 61**
**Egg Development Stressors for Spring-run Chinook Salmon**

| | | | | | Stressors | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | NT | | LT | | Temperature | | DO | | Pesticides | | Contaminants: Mercury, Selenium | | Fine Sediments | | Flow Fluctuation: Redd Dewatering | | Flow Fluctuation: Redd Scour | |
| Stress | M | C | M | C | NT | LT | NT | LT | NT | LT | NT | LT | NT | LT | NT | LT | NT | LT |
| Inadequate Development Conditions | 3 | 4 | 4 | 4 | M: 3<br>C: 4 | M: 4<br>C: 4 | M: 1<br>C: 4 | M: 1<br>C: 4 | M: 2<br>C: 2 | M: 2<br>C: 2 | M: 1<br>C: 4 | M: 1<br>C: 4 | M: 2<br>C: 2 | M: 2<br>C: 1 | M: 1<br>C: 3 | M: 1<br>C: 3 | M: 2<br>C: 2 | M: 2<br>C: 1 |

Notes:
– Stress and stressors (i.e., contributing factors to a particular stress) for spring-run egg development in the Stanislaus River for the near term (current conditions) and long term (assuming restored abundance goals and higher air temperatures). Scores for each stress were evaluated and assigned based on the scores for contributing stressors.
– Location: downstream of Knights Ferry; When: early in spawning season (September – October)
– M: Magnitude assesses the size or level of the impact from a stressor. Magnitude can be assigned using consideration of population or habitat effects, and higher scores require consideration of the scale or extent.
– C: Certainty describes the scientific basis for scoring the scale and magnitude of a particular stressor. Certainty considers both the predictability and understanding of linkages in the driver-linkage-outcome pathway from the stressor to the impact.
Scoring:
4: High
3: Medium
2: Low
1: Minimal
LT: long term
NT: near term

The near-term stress score synthesizes the effect of numerous egg development stressors, some of which act synergistically to increase the level of impact. The effect of adverse water temperature conditions on the egg development stage of spring-run Chinook salmon was scored as a “medium” magnitude stressor with a “high” degree of certainty in the near term. Stanislaus River water temperatures are high relative to the SEP Group’s Environmental Objectives (Figure 17). A sustained minor population effect is expected because of repeated impacts to eggs deposited at and downstream of Knights Ferry. The effect on egg survival of exposing salmonid eggs to different temperatures has been extensively described in the scientific literature, and the water temperature objectives reflect a high scientific understanding. Given that the relationship between salmon egg survival and temperature is highly understood and predictable, a “high” certainty score is justified. Modeling predictions associated with climate change indicate elevated temperatures in the long term; thus, the effect of temperature on egg development in the Stanislaus River is expected to increase to a “high” magnitude stressor, and the certainty of that effect is expected to remain “high” in the future.

The overall stress on spring-run Chinook egg development in the Stanislaus River is elevated by the operation of other stressors in addition to that caused by temperatures. Although each of the other stressors had lower certainty scores than the temperature stressor, the likelihood that they would exacerbate temperature stress caused the SEP Group to raise the overall magnitude score to reflect high stress on spring-run egg development during the near term.

The effect of pesticide-derived contaminants was scored as a “low” magnitude stressor with a “low” degree of certainty in the near term. Overall, eggs and alevins developing in the Stanislaus River will have low exposures to pesticides, except for portions of the populations that are developing late in the season or in the downstream end of the spawning distribution. Exposure to toxic compounds is of some concern for spring-run alevins developing between Knights Ferry and Riverbank between August and September. Upstream of Knights Ferry and during months other than August and September, there should be minimal impacts to alevins. See Section 8.5.2.1 for an overview of how pesticide impacts were modeled.

The effect of fine sediment on spring-run egg development was scored as a “low” magnitude and “low” certainty stressor when considered in isolation; however, the action of this stressor contributed to the overall stress score. In the future, the effect of fine sediment on spring-run salmon egg development in the Stanislaus River is expected to remain a “low” magnitude stressor, but the certainty of that characterization decreases to “minimal.” See Section 8.5.2.1 for an overview of how fine sediment effects were determined.

The effect of high flows that may scour spring-run Chinook salmon redds was scored as a “low” magnitude stressor with a “low” degree of certainty in the near term. The overall certainty of this stressor in the near term is low because there is a lack of information on the relationship in the

Stanislaus River among flow, scour depth, egg burial depths, and egg survival. See Section 8.5.2.1 for an overview of how scour effects were determined. The magnitude of this effect on spring-run Chinook salmon egg development is expected to remain “low” in the long term, but certainty of the effect declines to “minimal.”

The SEP Group’s analyses determined that several factors initially thought to be potential stressors on egg development success were likely to have “minimal” impact on successful egg development of spring-run Chinook salmon on the Stanislaus River. These included DO concentrations, mercury and selenium concentrations, and redd dewatering.

#### 8.5.2.3 O. mykiss

Inadequate egg development conditions for *O. mykiss* were judged to be a “high” magnitude stressor with a “high” degree of certainty in the near term (Table 62).

Unless measures are taken to improve egg development conditions, the stress of inadequate conditions will remain a sustained major impact on the *O. mykiss* population in the long term; certainty will remain “high” (Table 62).

**Table 62**
**Egg Development Stressors for *O. mykiss***

| | | | | | Stressors | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | NT | | LT | | Temperature | | DO | | Pesticides | | Contaminants: Mercury, Selenium | | Fine Sediments | | Flow Fluctuation: Redd Dewatering | | Flow Fluctuation: Redd Scour | |
| Stress | M | C | M | C | NT | LT | NT | LT | NT | LT | NT | LT | NT | LT | NT | LT | NT | LT |
| Inadequate Development Conditions | 3 | 4 | 4 | 4 | M: 3<br>C: 4 | M: 4<br>C: 4 | M: 1<br>C: 4 | M: 1<br>C: 4 | M: 2<br>C: 2 | M: 2<br>C: 2 | M: 1<br>C: 4 | M: 1<br>C: 4 | M: 2<br>C: 2 | M: 2<br>C: 1 | M: 1<br>C: 3 | M: 1<br>C: 3 | M: 2<br>C: 2 | M: 2<br>C: 1 |

Notes:
– Stress and stressors (i.e., contributing factors to a particular stress) for *O. mykiss* egg development in the Stanislaus River for the near term (current conditions) and long term (assuming restored abundance goals and higher air temperatures). Scores for each stress were evaluated and assigned based on the scores for contributing stressors.
– Location: downstream of Knights Ferry; When: after March
– M: Magnitude assesses the size or level of the impact from a stressor. Magnitude can be assigned using consideration of population or habitat effects, and higher scores require consideration of the scale or extent.
– C: Certainty describes the scientific basis for scoring the scale and magnitude of a particular stressor. Certainty considers both the predictability and understanding of linkages in the driver-linkage-outcome pathway from the stressor to the impact.
Scoring:
4: High
3: Medium
2: Low
1: Minimal
LT: long term
NT: near term

The near-term stress score synthesizes the effect of numerous egg development stressors, some of which act synergistically to increase the level of impact. The effect of adverse water temperature conditions on the egg development stage of *O. mykiss* was scored as a "medium" magnitude stressor with a "high" degree of certainty in the near term. The comparison of Stanislaus River water temperatures to the Environmental Objectives indicates that conditions for *O. mykiss* egg development are primarily stressful (and, in some cases, detrimental) throughout much of the lower Stanislaus River from March through August (Figure 18). Given that temperatures are expected to be stressful or detrimental over a large portion of the *O. mykiss* spawning habitat in the lower river throughout most of the egg development period, a sustained minor population effect is expected. The effect on egg survival of exposing *O. mykiss* eggs to different temperatures has been extensively described in the scientific literature (Section 7.2.4.1), and the water temperature objectives reflect a high degree of scientific understanding justifying a high certainty score. Given modeling predictions associated with climate change, the effect of temperature on egg development in the Stanislaus River is expected to increase to a "high" magnitude stress. A sustained major population effect is expected as temperature increases are likely to result in detrimental water temperatures for egg development throughout most of the life history stage and most, if not all, of the lower Stanislaus River spawning habitat. The certainty of that major population effect occurring in the long term is "high."

The overall stress on *O. mykiss* egg development in the Stanislaus River is elevated by the operation of other stressors in addition to that caused by temperatures. Although each of the other stressors had lower certainty scores than the temperature stressor, the likelihood that they would exacerbate temperature stress caused the SEP Group to raise the overall magnitude score to reflect "high" stress on *O. mykiss* egg development during the near term.

The effect of pesticide-derived contaminants was scored as a "low" magnitude stressor with a "low" degree of certainty in the near term. *O. mykiss* alevins will be exposed to detrimental pesticide concentrations from March to August from Riverbank to Oakdale (Appendix C); this may adversely impact alevins that are still developing. The river between Oakdale and Knight's Ferry experiences stressful conditions from December to April, but they become detrimental from May to August. See Section 8.5.2.1 for an overview of how pesticide impacts were modeled.

The effect of fine sediment on *O. mykiss* egg development was scored as a "low" magnitude and "low" certainty stressor when considered in isolation; however, the action of this stressor increased the overall stress score. In the future, the effect of fine sediment on *O. mykiss* egg development in the Stanislaus River is expected to remain a "low" magnitude stressor, but the certainty of its effect decreases to "minimal." See Section 8.5.2.1 for an overview of how fine sediment effects were determined.

The effect of high flows that may scour redds during the *O. mykiss* egg development stage was scored as a "low" magnitude stressor with a "low" degree of certainty in the near term. Only 1 *O. mykiss* year-class out of 14 was potentially impacted by redd scour due to high flows. The overall certainty of this stressor in the near term is "low" because there is a lack of information on the relationship in the Stanislaus River among flow, scour depth, egg burial depths, and egg survival. See Section 8.5.2.1 for an overview of how fine sediment effects were determined. The magnitude of this effect on *O. mykiss* egg development is expected to remain "low" in the long term, but certainty of the effect declines to "minimal."

The SEP Group's analyses determined that several factors initially considered to be potential stressors on egg development success were likely to have a "minimal" impact on successful egg development of Stanislaus River *O. mykiss*. These included DO concentrations, mercury and selenium concentrations, and redd dewatering.

### *8.5.3 Contributing Management Factors*

Dams blocking access to high-elevation egg development habitats are a major factor contributing to stressors on the egg development process by limiting access to coldwater habitat. This effect is particularly evident for spring-run Chinook salmon and *O. mykiss*, which historically migrated to habitats beyond existing dams to spawn.

Reservoir operation is a major driver of the environmental factors that control the impact of stressors that may lead to mortality during the egg development life history stage of salmonids. For example, flow rates and coldwater pool management regulate water temperature. In addition, the volume of water released from the reservoir will regulate sediment loads and the dilution of contaminant discharges to the river. The environmental factors that drive the failure of eggs to develop into emergent fry are coupled and work synergistically (e.g., temperature affects both DO concentration and egg/alevin demand for DO; temperature also modulates the impact of certain contaminants on developing eggs and alevin). Additionally, flows (and fluctuations in flows) determine the availability of development habitat even within the area where temperatures are acceptable (e.g., scour and dewatering).

Other non-flow management practices may exacerbate or alleviate stressors on egg development. For example, the destruction of riparian habitat along the Stanislaus River has likely reduced the amount of shade in the river corridor; this can increase temperatures and primary productivity in the river. Urban and agricultural developments in the watershed have increased contaminant loads to the river and periodic fine sediment inputs. Adjustments to land use practices or the development of contaminant control programs may reduce contaminant and sediment inputs and the stress they generate on eggs and alevin. Groundwater depletions have likely terminated the hyporheic inputs that probably supplemented Stanislaus River surface flows and buffered the river against warm temperatures in late spring, summer, and early fall. Groundwater recharge programs may help to reestablish this benefit and reduce water temperatures in the Stanislaus River during critical months.

## 8.6 Stressors on Juvenile Rearing and Migration

Juvenile rearing occurs in the salmonid life cycle after emergence from the redd and lasts until the fish leaves freshwater. Juvenile migration occurs over the same period as rearing and consists of the fish moving downstream towards the marine environment. Central Valley salmonids evolved in river systems with vast wetland habitats, including floodplains and tidal marshes that inundated during high flows in spring and summer, providing highly complex shallow-water habitats for juvenile rearing and migration (Williams 2006). These habitats have nearly all been lost in the Stanislaus River and lower San Joaquin River corridor due to changes in the hydrograph, sediment availability, and channel modification resulting from the construction of dams and levees.

The SEP Group evaluated the following six categories of stress in the near term and long term for juvenile salmonids rearing and migrating in the Stanislaus River:

- Compression of rearing and migration time window
- Lack of suitable rearing habitat
- Lack of suitable migratory conditions
- Lack of suitable migratory cues
- Lack of suitable over-summering habitat
- Lack of fitness/genetic maladaptation

Stressors to juvenile rearing include stressful or detrimental ranges of water temperature, DO, flow volume, flow velocity, depth, cover, prey density, predator density, contaminants, coarse sediment input, hatchery straying, and disease. Inadequate distribution of suitable rearing habitats (i.e., along the river corridor) may also stress salmonid populations on the Stanislaus River.

Near-term stresses reflect those that would impede attainment of Environmental or Biological Objectives under current conditions. Evaluation of these stresses in the long term incorporated analysis of current conditions and assumed that juvenile salmon densities would increase substantially and that global and regional warming trends occur as anticipated (Dettinger et al. 2004; Cayan et al. 2008).

### *8.6.1 Current Rearing and Migration Timing Patterns*

Scoring of stress is based on the potential exposure to stressors across the full range of each population's rearing and migration timing window (Figure 8). Current temporal distribution of fall-run Chinook juveniles in the Stanislaus River occurs after egg development is completed—from the end of January through June (Figure 8)—until water temperatures warm sufficiently to prevent smoltification, which usually occurs between May and July for Chinook salmon (Figure 19). Spring-run Chinook salmon begin rearing and migration in winter, though some are known to rear longer and outmigrate the following fall, winter, or spring (Williams 2006). Spring-run are also unable to successfully migrate when water temperatures in the migratory corridor become unsuitable. For *O. mykiss*, rearing occurs year-round and includes a robust population of resident rainbow trout, which are a source population for threatened steelhead. Steelhead juveniles generally migrate during the same temporal windows as Chinook salmon. However, the anadromous steelhead life form displays tremendous behavioral plasticity that extends to migration timing (Moyle 2002; Doctor et al. 2014; Kendall et al. 2014). Because of their low population numbers and ESA listing status, little monitoring of steelhead rearing and migration has occurred on the Stanislaus River with the exception of incidental collection in RSTs and some snorkel survey observations.

## *8.6.2 Stress: Compression of Rearing and Migration Time Window (Juvenile Rearing and Migration)*

Rearing and migration opportunities for juvenile salmonids are limited on the Stanislaus River by the deterioration of conditions in spring. This may limit the life history diversity (e.g., the timing of and body size at entry into subsequent environments) present in each annual cohort. In particular, production of larger fish and those that migrate later in the season may be limited by deteriorating conditions as the spring progresses (e.g., Zeug et al. 2014; Sturrock et al. 2015).

### 8.6.2.1 Fall-run Chinook Salmon

Rearing and migration opportunities for juvenile fall-run Chinook salmon are constrained by deteriorating conditions in spring. The stress on the population was rated “high” magnitude with “high” certainty in the near term (Table 63).

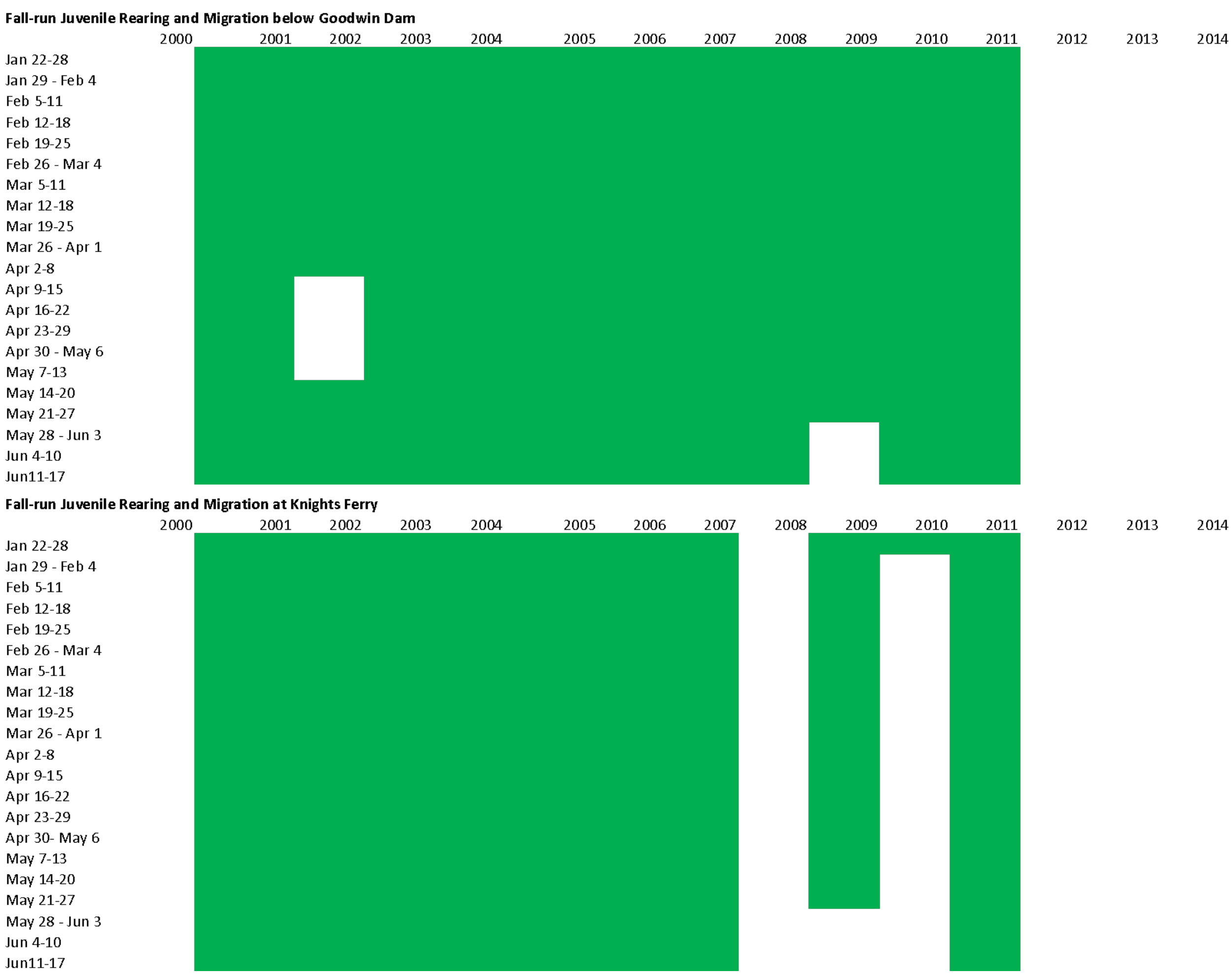
Without corrective action, temporally constrained rearing and migration opportunities will remain a “high” magnitude stress with “high” certainty over the long term (Table 63).

**Table 63**
**Scoring Stressors for Juvenile Rearing and Migration of Fall-run Chinook Salmon**

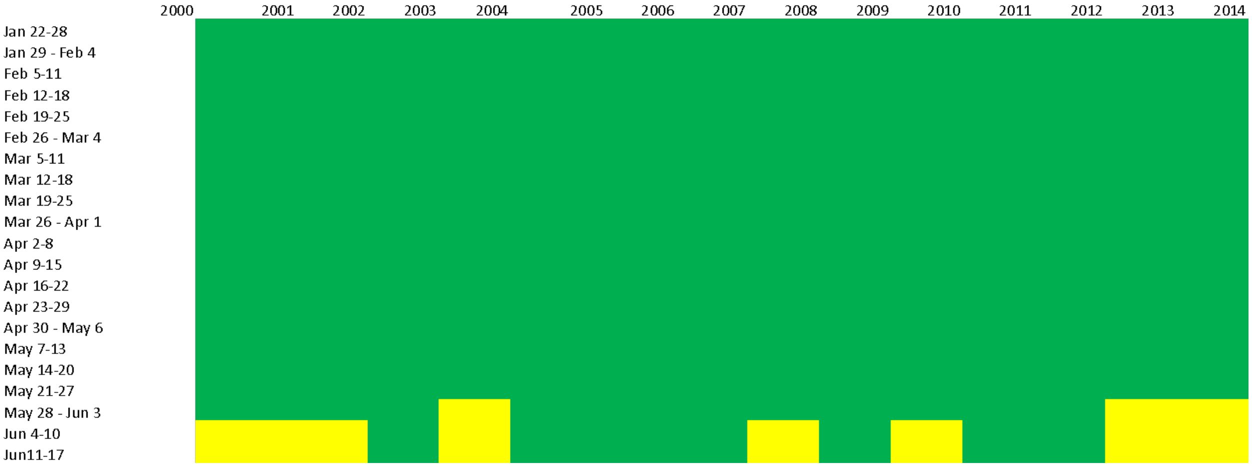
| | | | | | | Stressors | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | NT | | LT | | When | Temperature | | DO | | Flow Volume | | Velocity | | Turbidity | | Depth | | Cover | | Prey Density | | Predator Density | | Contaminants | | Coarse Sediment Input | | Hatchery Straying | | Disease | | Habitat Distribution | |
| Stress | M | C | M | C | | NT | LT | NT | LT | NT | LT | NT | LT | NT | LT | NT | LT | NT | LT | NT | LT | NT | LT | NT | LT | NT | LT | NT | LT | NT | LT | NT | LT |
| Compression of rearing and migration time window | 4 | 4 | 4 | 4 | Apr-July | M: 4 C: 4 | M: 4 C: 4 | M: 2 C: 3 | M: 3 C: 3 | | | | | | | | | | | | | | | | | | | | | | | | |
| Lack of suitable rearing habitat | 4 | 4 | 4 | 4 | Jan-Jun | M: 3 C: 4 | M: 4 C: 4 | M: 1 C: 2 | M: 1 C: 2 | M: 4 C: 3 | M: 4 C: 4 | M: 2 C: 2 | M: 2 C: 2 | M: 2 C: 2 | M: 2 C: 2 | M: 3 C: 3 | M: 3 C: 3 | M: 3 C: 3 | M: 3 C: 3 | M: 2 C: 2 | M: 3 C: 2 | M: 3 C: 2 | M: 3 C: 2 | M: 4 C: 3 | M: 4 C: 3 | M: 4 C: 4 | M: 4 C: 4 | | | M: 2 C: 2 | M: 3 C: 2 | M: 3 C: 2 | M: 4 C: 2 |
| Lack of suitable migratory conditions | 4 | 4 | 4 | 4 | Jan-Jun | M: 3 C: 4 | M: 4 C: 4 | M: 1 C: 2 | M: 1 C: 2 | M: 4 C: 3 | M: 4 C: 4 | M: 3 C: 2 | M: 3 C: 2 | M: 2 C: 2 | M: 2 C: 2 | M: 3 C: 3 | M: 3 C: 2 | M: 3 C: 2 | M: 3 C: 2 | M: 2 C: 2 | M: 3 C: 2 | M: 3 C: 1 | M: 3 C: 1 | M: 2 C: 3 | M: 2 C: 3 | M: 4 C: 2 | M: 4 C: 2 | | | | | | |
| Lack of suitable migratory cues | 4 | 3 | 4 | 3 | Jan-Jun | M: 3 C: 2 | M: 4 C: 2 | M: 1 C: 1 | M: 1 C: 1 | M: 4 C: 3 | M: 4 C: 3 | M: 4 C: 3 | M: 4 C: 3 | M: 3 C: 2 | M: 2 C: 2 | | | | | M: 2 C: 2 | M: 3 C: 2 | | | | | | | | | | | | |
| Lack of suitable over-summering habitat | 1 | 3 | 2 | 3 | May-Sep | M: 1 C: 3 | M: 2 C: 3 | M: 1 C: 1 | M: 1 C: 1 | M: 1 C: 2 | M: 2 C: 2 | M: 1 C: 2 | M: 2 C: 2 | M: 1 C: 1 | M: 1 C: 1 | M: 1 C: 1 | M: 1 C: 1 | M: 2 C: 1 | M: 2 C: 1 | M: 2 C: 2 | M: 3 C: 2 | M: 2 C: 2 | M: 2 C: 2 | M: 1 C: 2 | M: 1 C: 2 | | | | | | | | |
| Lack of fitness/ genetic maladaptation | 4 | 3 | 4 | 3 | Jan-Jun | | | | | | | | | | | | | | | | | | | | | | | M: 4 C: 4 | M: 4 C: 3 | | | | |

Notes:
– Stress and stressors (i.e., contributing factors to a particular stress) for fall-run juvenile migration and rearing in the Stanislaus River for the near term (current conditions) and long term (assuming restored abundance goals and higher air temperatures). Scores for each stress were evaluated and assigned based on the scores for contributing stressors.
– Location: Whole river
– M: Magnitude assesses the size or level of the impact from a stressor. Magnitude can be assigned using consideration of population or habitat effects, and higher scores require consideration of the scale or extent.
– C: Certainty describes the scientific basis for scoring the scale and magnitude of a particular stressor. Certainty considers both the predictability and understanding of linkages in the driver-linkage-outcome pathway from the stressor to the impact.
Scoring:
4: High
3: Medium
2: Low
1: Minimal
LT: long term
NT: near term

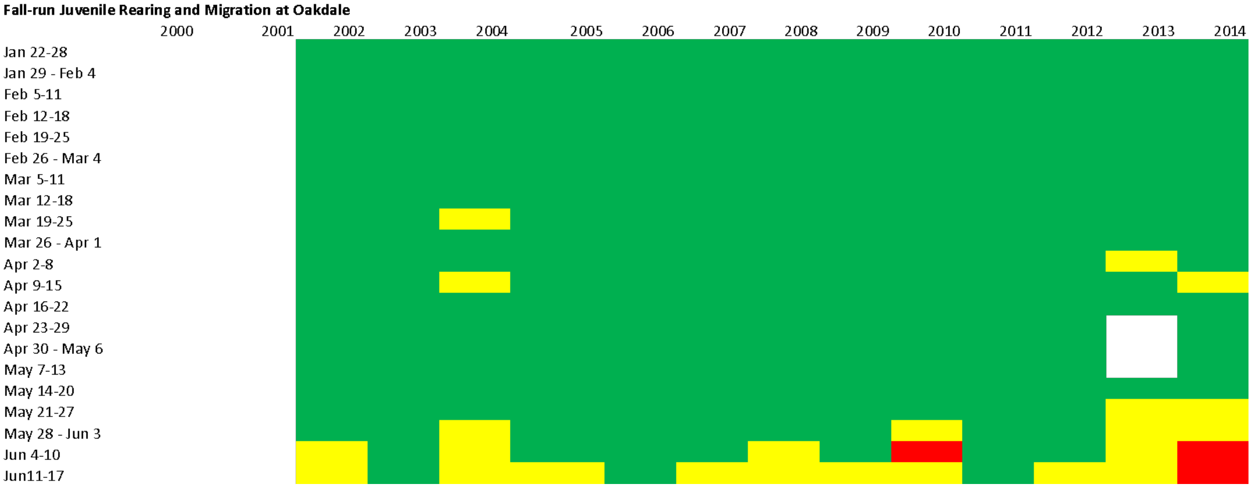
The residence time in freshwater of fall-run Chinook salmon migrating from the Stanislaus River is constrained by water temperature. Warm water temperatures in spring and early summer can prevent smoltification (e.g., Marine and Cech 2004; Section 7.2.5.1.2), truncating the time in freshwater. Although, larger juveniles are typically better able to avoid predators, recent studies on the Stanislaus River show parr-sized juvenile outmigrants had a higher rate of return as adults than either fry- or smolt-sized outmigrants (Sturrock et al. 2015). It is believed that smolt-sized fish from the Stanislaus River die at a higher rate because they are unable to physiologically adapt to salt water (smoltify) due to high water temperatures (Appendix C, Table C-2). Stressful temperatures for smoltification (17°C to 20°C 7DADM [62.6°F to 68°F]) are common during June at Orange Blossom Bridge and points downstream, and they begin to occur in March at Ripon and downstream (Figure 19). Detrimental temperatures are common starting in June at Ripon and by mid to late May at Vernalis. Adding to the stress caused by high temperatures, migrating fall-run Chinook salmon are also negatively affected by stressful DO levels at Ripon and Vernalis that become more frequent later in the spring (Figure 19).



**Fall-run Juvenile Rearing and Migration at Orange Blossom Bridge**




**Fall-run Juvenile Rearing and Migration at Oakdale**




**Fall-run Juvenile Rearing and Migration at Ripon**

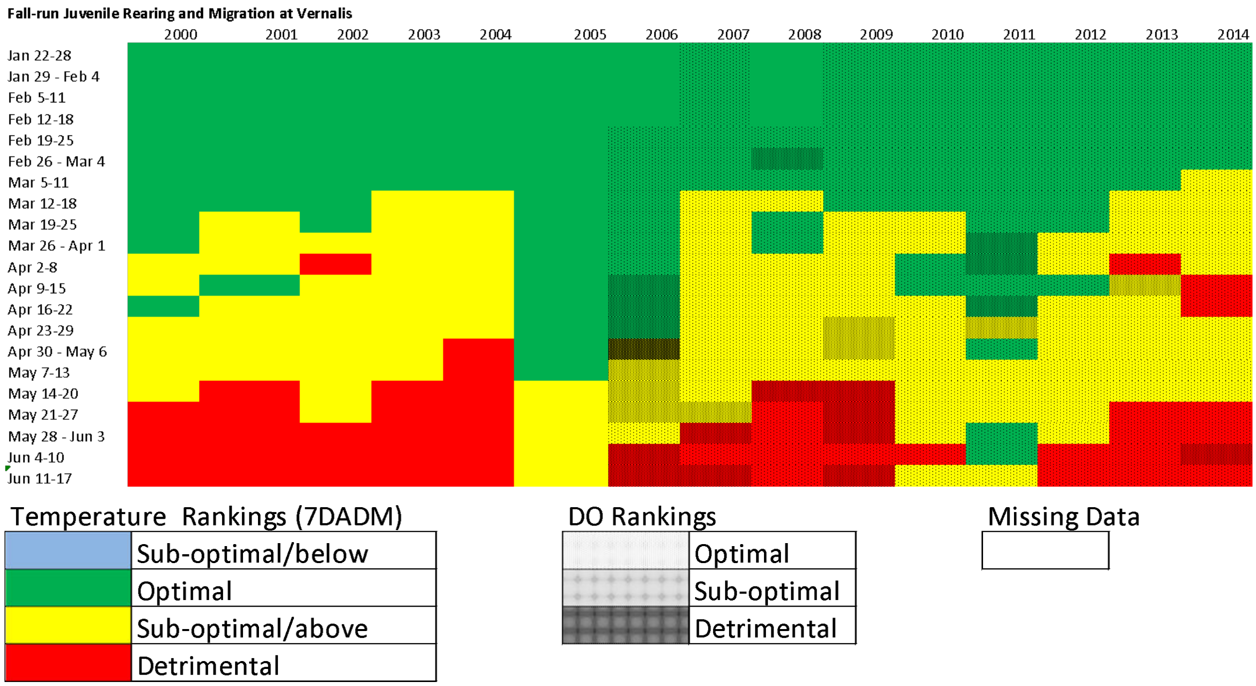



**Figure 19**

**Juvenile Rearing and Migration for Fall-run Chinook Salmon**

Notes:

Temperature and DO rankings based on observed data during periods of juvenile rearing and migration. Rankings reflect the Environmental Objectives for temperature and DO (Section 7). Data are from CDEC for each location.

In the near term, this truncation of the juvenile migration window represents a sustained, major population-level effect on life history diversity of outmigrants from the Stanislaus River. In the long term, warming associated with climate change is likely to maintain this stress as a result of increases in water temperature (Dettinger et al. 2004; Cayan et al. 2008) and corresponding potential decreases in DO.

### 8.6.2.2 Spring-run Chinook Salmon

Rearing and migration opportunities for juvenile spring-run Chinook salmon are constrained by deteriorating conditions in the spring. The stress on the population was rated "medium" magnitude with "high" certainty in the near term (Table 64).

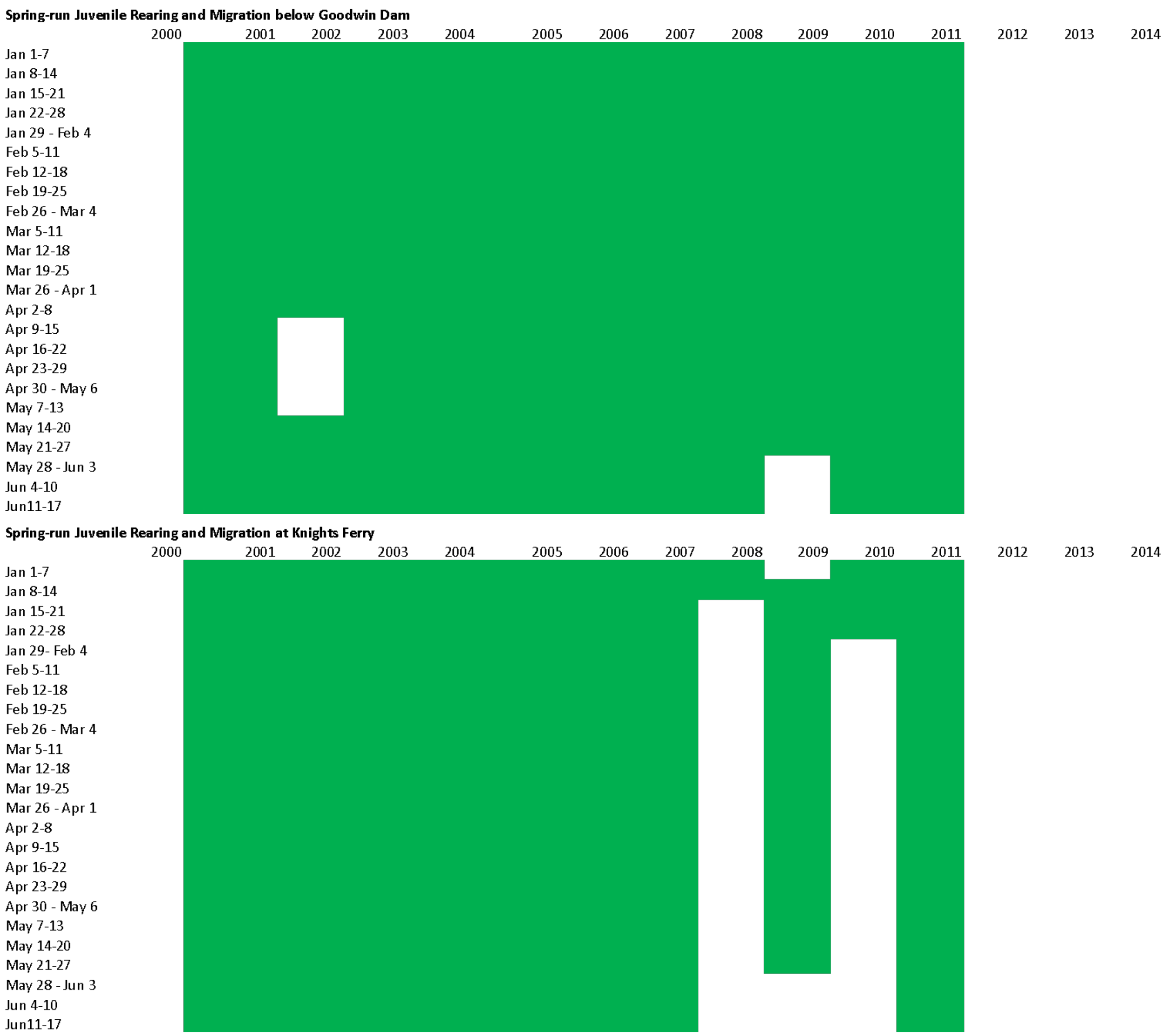
Without corrective action, temporally constrained rearing and migration opportunities will remain a "medium" magnitude stress with "high" certainty over the long term (Table 64).

**Table 64**
**Scoring Stressors for Juvenile Rearing and Migration of Spring-run Chinook Salmon**

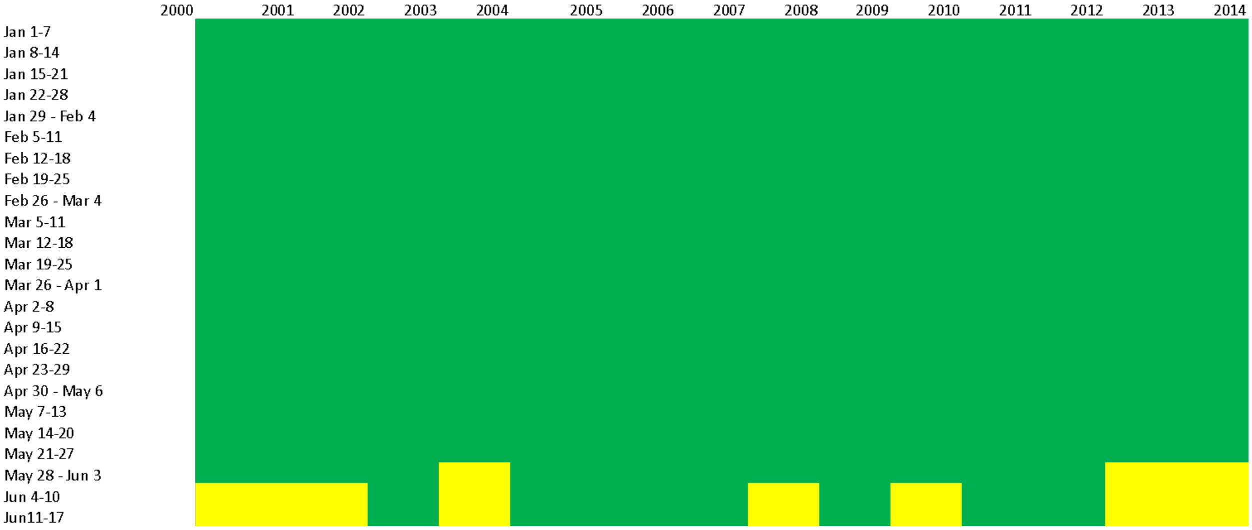
| | | | | | | Stressors | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | NT | | LT | | When | Temperature | | DO | | Flow Volume | | Velocity | | Turbidity | | Depth | | Cover | | Prey Density | | Predator Density | | Contaminants | | Coarse Sediment Input | | Hatchery Straying | | Disease | | Habitat Distribution | |
| Stress | M | C | M | C | | NT | LT | NT | LT | NT | LT | NT | LT | NT | LT | NT | LT | NT | LT | NT | LT | NT | LT | NT | LT | NT | LT | NT | LT | NT | LT | NT | LT |
| Compression of rearing and migration time window | 3 | 4 | 3 | 4 | Apr-July | M: 3 C: 4 | M: 3 C: 4 | M: 1 C: 2 | M: 1 C: 2 | | | | | | | | | | | | | | | | | | | | | | | | |
| Lack of suitable rearing habitat | 4 | 4 | 4 | 4 | Jan-Jun | M: 3 C: 3 | M: 4 C: 3 | M: 1 C: 2 | M: 1 C: 2 | M: 4 C: 3 | M: 4 C: 4 | M: 2 C: 2 | M: 2 C: 2 | M: 2 C: 2 | M: 2 C: 2 | M: 3 C: 3 | M: 3 C: 3 | M: 3 C: 3 | M: 3 C: 3 | M: 2 C: 1 | M: 2 C: 1 | M: 3 C: 2 | M: 3 C: 2 | M: 4 C: 3 | M: 4 C: 3 | M: 4 C: 4 | M: 4 C: 4 | | | M: 2 C: 2 | M: 3 C: 2 | M: 3 C: 2 | M: 4 C: 2 |
| Lack of suitable migratory conditions | 4 | 4 | 4 | 4 | Jan-Jun | M: 3 C: 4 | M: 4 C: 4 | M: 1 C: 2 | M: 1 C: 2 | M: 4 C: 3 | M: 4 C: 4 | M: 3 C: 2 | M: 3 C: 2 | M: 2 C: 2 | M: 2 C: 2 | M: 3 C: 3 | M: 3 C: 3 | M: 3 C: 2 | M: 3 C: 2 | M: 2 C: 1 | M: 2 C: 1 | M: 3 C: 1 | M: 3 C: 1 | M: 2 C: 3 | M: 2 C: 3 | M: 4 C: 2 | M: 4 C: 2 | | | | | | |
| Lack of suitable migratory cues | 4 | 3 | 4 | 3 | Jan-Jun | M: 4 C: 3 | M: 4 C: 2 | M: 1 C: 1 | M: 1 C: 1 | M: 4 C: 3 | M: 4 C: 3 | M: 4 C: 3 | M: 4 C: 3 | M: 3 C: 2 | M: 2 C: 2 | | | | | | | | | | | | | | | | | | |
| Lack of suitable over-summering habitat | 1 | 3 | 3 | 3 | May-Sep | M: 1 C: 3 | M: 2 C: 3 | M: 1 C: 1 | M: 1 C: 1 | M: 1 C: 2 | M: 2 C: 2 | M: 1 C: 2 | M: 2 C: 2 | M: 1 C: 1 | M: 1 C: 1 | M: 1 C: 1 | M: 1 C: 1 | M: 2 C: 1 | M: 2 C: 1 | | | M: 2 C: 2 | M: 2 C: 2 | M: 3 C: 3 | M: 3 C: 3 | | | | | M: 1 C: 1 | M: 1 C: 1 | | |
| Lack of fitness/ genetic maladapt-ation | 1 | 1 | 3 | 3 | Jan-Jun | M: 1 C: 3 | M: 3 C: 3 | M: 1 C: 3 | M: 1 C: 3 | | | | | | | | | | | | | | | | | | | M: 1 C: 1 | M: 3 C: 3 | | | | |

Notes:
– Stress and stressors (i.e., contributing factors to a particular stress) for spring-run juvenile rearing and migration in the Stanislaus River for the near term (current conditions) and long term (assuming restored abundance goals and higher air temperatures). Scores for each stress were evaluated and assigned based on the scores for contributing stressors.
– Location: Whole river
– M: Magnitude assesses the size or level of the impact from a stressor. Magnitude can be assigned using consideration of population or habitat effects, and higher scores require consideration of the scale or extent.
– C: Certainty describes the scientific basis for scoring the scale and magnitude of a particular stressor. Certainty considers both the predictability and understanding of linkages in the driver-linkage-outcome pathway from the stressor to the impact.
Scoring:
4: High
3: Medium
2: Low
1: Minimal
LT: long term; NT: near term

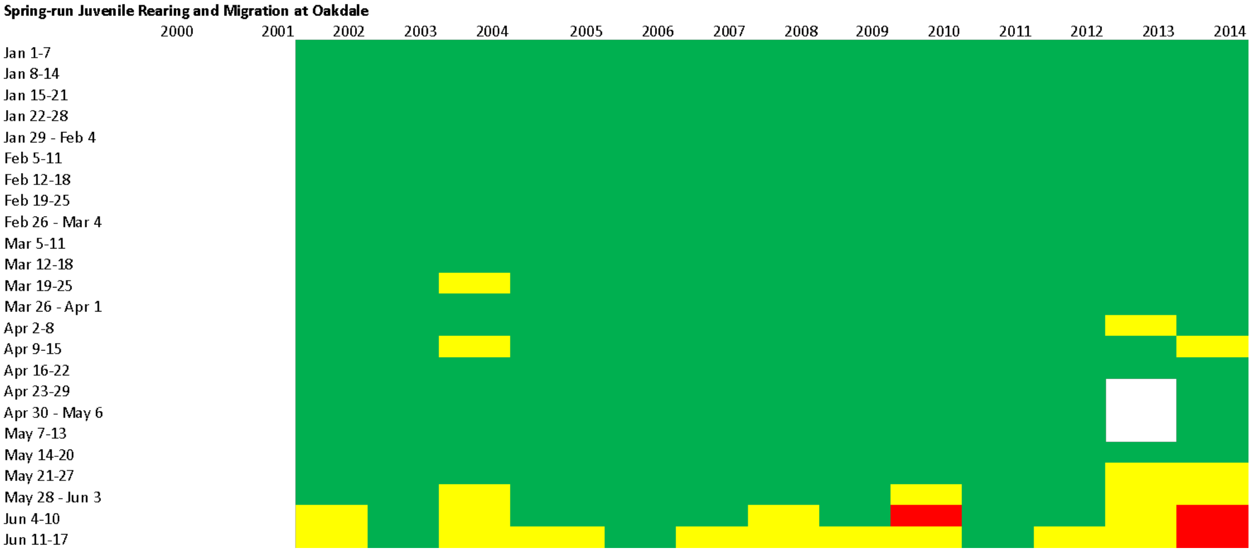
Similar to fall-run Chinook salmon, successful spring-run juvenile migration will be constrained by warm temperatures that impair or prevent smoltification in the near term (Figure 20). The magnitude of this stressor is expected to be less than that for fall-run, since spring-run smolts tend to migrate slightly earlier than fall-run (Moyle 2002; Williams 2006). The certainty of this stress is "high" based on the SEP Group's understanding of the impacts of high temperature and low DO on migrating juvenile Chinook salmon, robust temperature and DO data, and recent publications regarding impairment to late-outmigrating Chinook salmon on the Stanislaus River (Zeug et al. 2014; Sturrock et al. 2015).



**Spring-run Juvenile Rearing and Migration at Orange Blossom Bridge**




**Spring-run Juvenile Rearing and Migration at Oakdale**




**Spring-run Juvenile Rearing and Migration at Ripon**

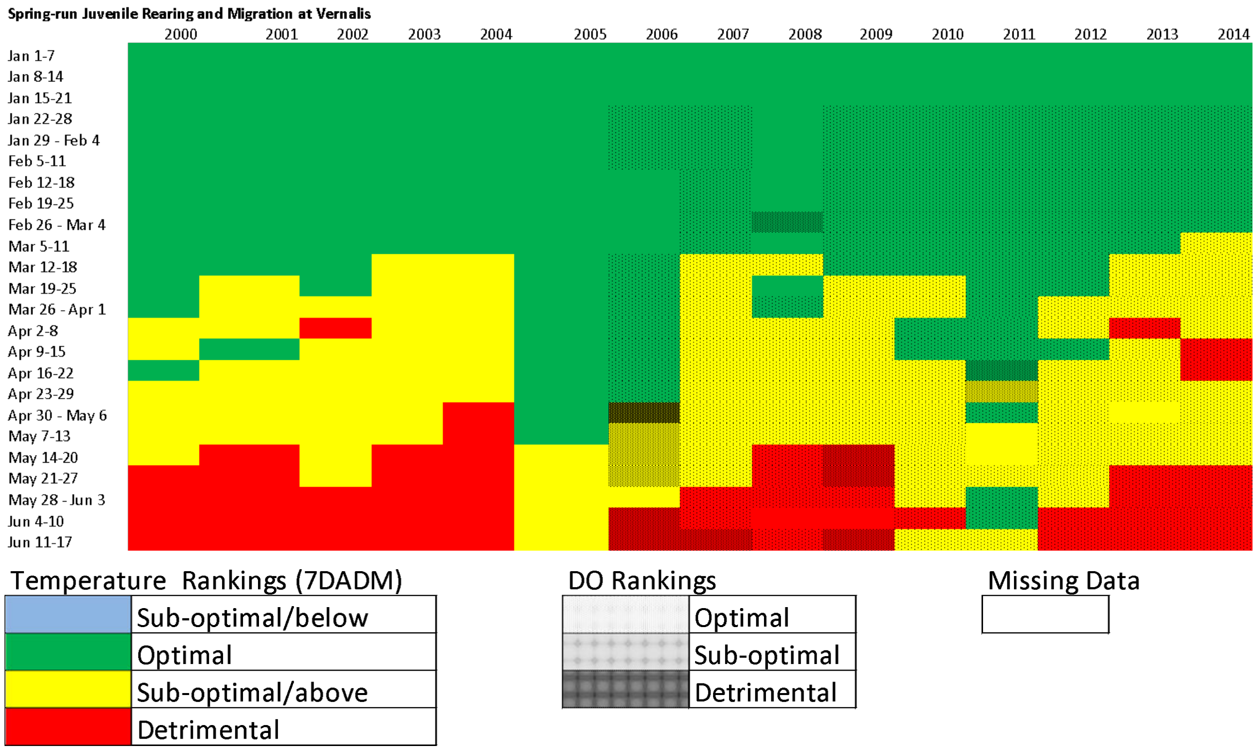



**Figure 20**
**Juvenile Rearing and Migration for Spring-run Chinook Salmon**

Notes:
Temperature and DO rankings based on observed data during periods of juvenile rearing and migration. Rankings reflect the Environmental Objectives for temperature and DO (Section 7). Data are from CDEC for each location.

### 8.6.2.3 Steelhead

Temperatures that impair smoltification in a way that compresses the time window available for migration were rated "low" magnitude with "low" certainty for steelhead in the near term (Table 65).

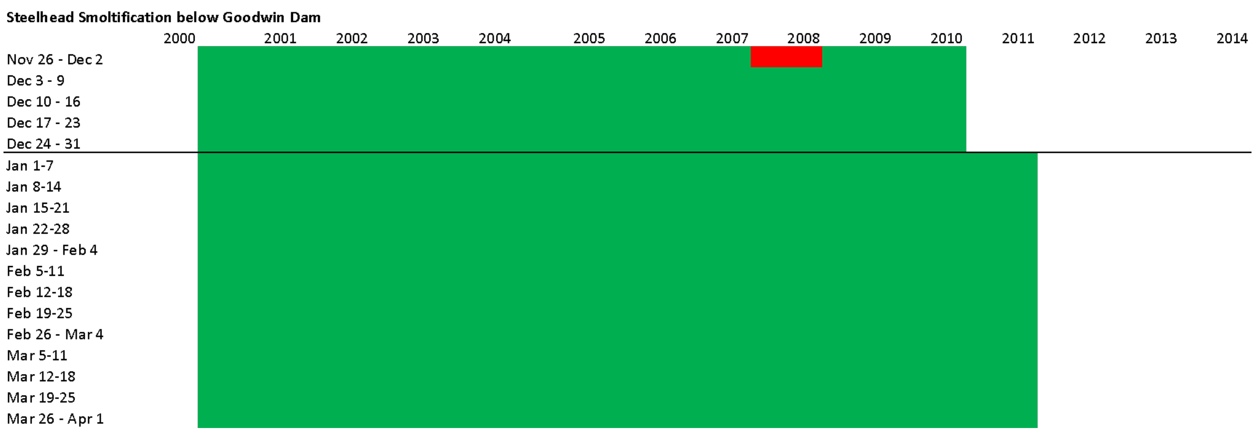
Without corrective actions, temporally constrained smoltification opportunities will remain a "medium" magnitude stress for steelhead in the long term; in addition, without better understanding of the timing and duration of exposure to low temperatures that are required to support smoltification, certainty will remain "low" (Table 65).

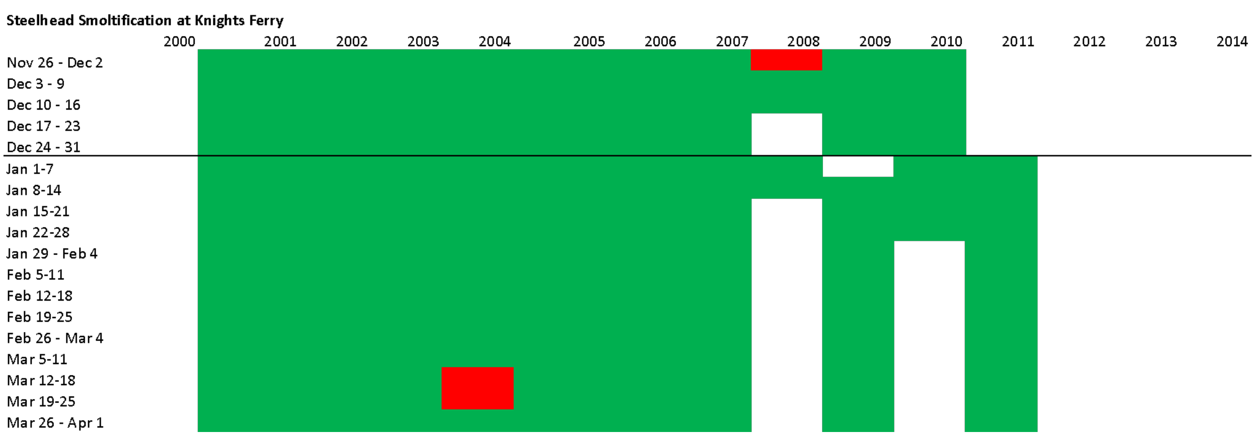
**Table 65**
**Scoring Stressors for Juvenile Rearing and Migration of *O. mykiss***

| | NT | | LT | | | Stressors | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | When | Temperature | | DO | | Flow Volume | | Velocity | | Turbidity | | Depth | | Cover | | Prey Density | | Predator Density | | Contaminants | | Coarse Sediment Input | | Hatchery Straying | | Disease | |
| Stress | M | C | M | C | | NT | LT | NT | LT | NT | LT | NT | LT | NT | LT | NT | LT | NT | LT | NT | LT | NT | LT | NT | LT | NT | LT | NT | LT | NT | LT |
| Compression of rearing and migration time window | 2 | 2 | 2 | 2 | Apr-July | M: 2<br>C: 2 | M: 2<br>C: 2 | M: 2<br>C: 2 | M: 2<br>C: 2 | | | | | | | | | | | | | | | | | | | | | | |
| Lack of suitable rearing habitat | 4 | 4 | 4 | 4 | Jan-Dec | M: 1<br>C: 4 | M: 2<br>C: 4 | M: 1<br>C: 2 | M: 1<br>C: 2 | M: 4<br>C: 3 | M: 4<br>C: 4 | M: 4<br>C: 3 | M: 4<br>C: 4 | M: 2<br>C: 2 | M: 2<br>C: 2 | M: 3<br>C: 3 | M: 3<br>C: 3 | M: 3<br>C: 3 | M: 3<br>C: 3 | M: 2<br>C: 1 | M: 2<br>C: 1 | M: 3<br>C: 2 | M: 3<br>C: 2 | M: 4<br>C: 3 | M: 4<br>C: 3 | M: 4<br>C: 4 | M: 4<br>C: 4 | | | M: 2<br>C: 2 | M: 3<br>C: 2 |
| Lack of suitable migratory conditions | 4 | 4 | 4 | 4 | Jan-Dec | M: 2<br>C: 4 | M: 2<br>C: 4 | M: 1<br>C: 2 | M: 1<br>C: 2 | M: 4<br>C: 3 | M: 4<br>C: 4 | M: 4<br>C: 3 | M: 4<br>C: 4 | M: 2<br>C: 2 | M: 2<br>C: 2 | M: 3<br>C: 3 | M: 3<br>C: 3 | M: 3<br>C: 2 | M: 3<br>C: 2 | M: 2<br>C: 1 | M: 2<br>C: 1 | M: 3<br>C: 1 | M: 3<br>C: 1 | M: 2<br>C: 3 | M: 2<br>C: 3 | M: 4<br>C: 2 | M: 4<br>C: 2 | | | | |
| Lack of suitable migratory cues | 4 | 3 | 4 | 3 | Jan-Jun | M: 4<br>C: 2 | M: 4<br>C: 2 | M: 1<br>C: 1 | M: 1<br>C: 1 | M: 4<br>C: 3 | M: 4<br>C: 3 | M: 4<br>C: 3 | M: 4<br>C: 3 | M: 3<br>C: 2 | M: 2<br>C: 2 | | | | | M: 3<br>C: 1 | M: 3<br>C: 1 | | | | | | | | | | |
| Lack of suitable over-summering habitat | 1 | 4 | 1 | 4 | May-Sep | M: 1<br>C: 4 | M: 1<br>C: 4 | M: 1<br>C: 1 | M: 1<br>C: 1 | M: 1<br>C: 2 | M: 2<br>C: 2 | M: 1<br>C: 2 | M: 2<br>C: 2 | M: 1<br>C: 1 | M: 1<br>C: 1 | M: 3<br>C: 2 | M: 3<br>C: 2 | M: 2<br>C: 1 | M: 2<br>C: 1 | M: 3<br>C: 1 | M: 3<br>C: 1 | M: 2<br>C: 2 | M: 2<br>C: 2 | M: 3<br>C: 3 | M: 3<br>C: 3 | M: 3<br>C: 1 | M: 3<br>C: 1 | | | | |
| Lack of fitness/ genetic maladaptation | 3 | 1 | 3 | 1 | Jan-Dec | | | | | | | | | | | | | | | | | | | | | | | M: 3<br>C: 1 | M: 3<br>C: 1 | | |

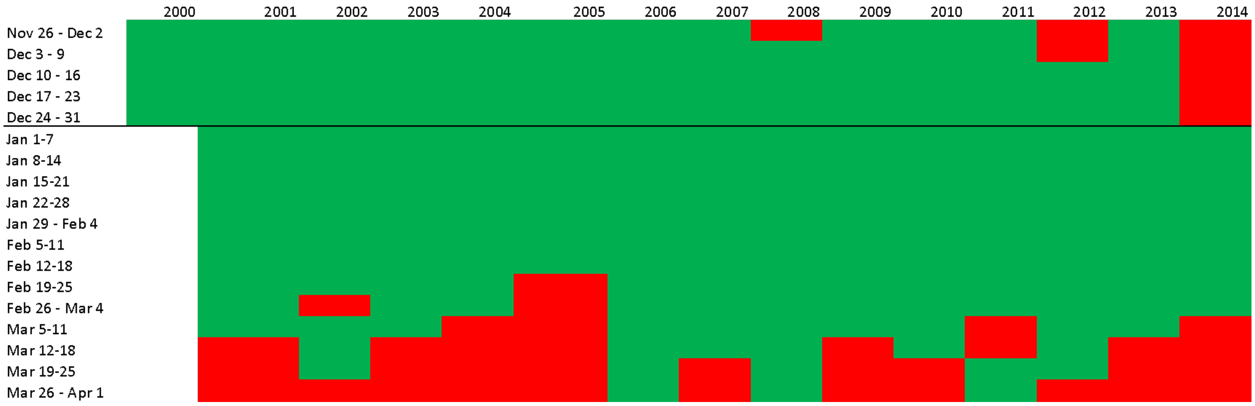
Notes:
– Stress and stressors (i.e., contributing factors to a particular stress) for *O. mykiss* juvenile rearing and migration in the Stanislaus River for the near term (current conditions) and long term (assuming restored abundance goals and higher air temperatures). Scores for each stress were evaluated and assigned based on the scores for contributing stressors.
– Location: Whole river
– M: Magnitude assesses the size or level of the impact from a stressor. Magnitude can be assigned using consideration of population or habitat effects, and higher scores require consideration of the scale or extent.
– C: Certainty describes the scientific basis for scoring the scale and magnitude of a particular stressor. Certainty considers both the predictability and understanding of linkages in the driver-linkage-outcome pathway from the stressor to the impact.
Scoring:
4: High
3: Medium
2: Low
1: Minimal
LT: long term
NT: near term

Steelhead smoltification requires exposure to temperatures colder than those required by Chinook salmon (Appendix C, Table C-6); *O. mykiss* will not metamorphose into anadromous smolts unless they are exposed to temperatures less than 11°C (51.8°F) during the winter prior to outmigration (Myrick and Cech 2005). Steelhead juveniles can tolerate substantially higher temperatures later in their migration phase (Appendix C, Table C-5). Temperatures that impair steelhead smoltification occur through most of March at Orange Blossom Bridge and are common after mid-February at Ripon; *O. mykiss* in those areas of the river at those times are unlikely to smoltify, but *O. mykiss* may experience suitable temperatures to initiate smoltification upstream of Orange Blossom Bridge and at locations downstream earlier in winter (Figure 21). The literature is not clear regarding the precise duration and timing of exposure required to support subsequent smoltification among steelhead; thus, the certainty related to compression of the rearing and migration window is low. Research is needed to identify the necessary timing, duration, and location of exposure to temperatures that allow for smoltification among steelhead.

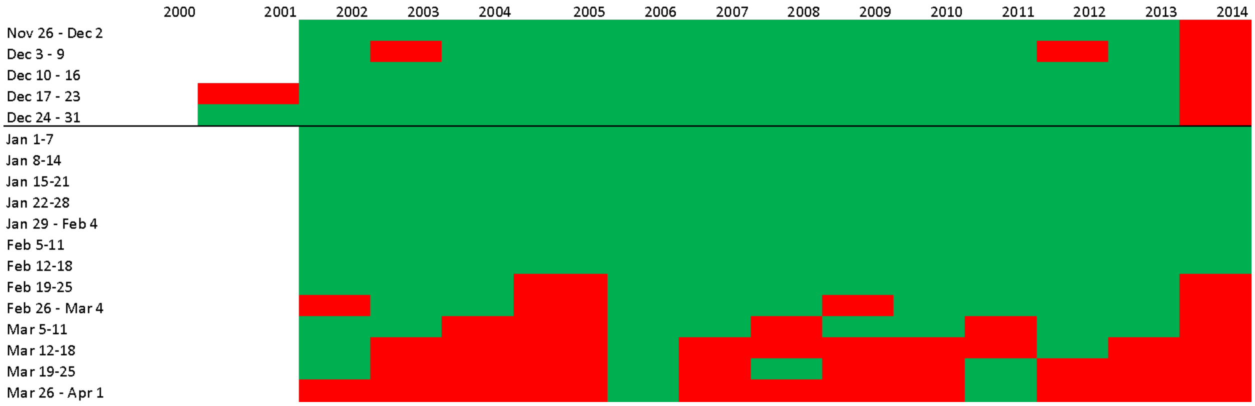


Steelhead Smoltification at Orange Blossom Bridge




Steelhead Smoltification at Oakdale




Steelhead Smoltification at Ripon

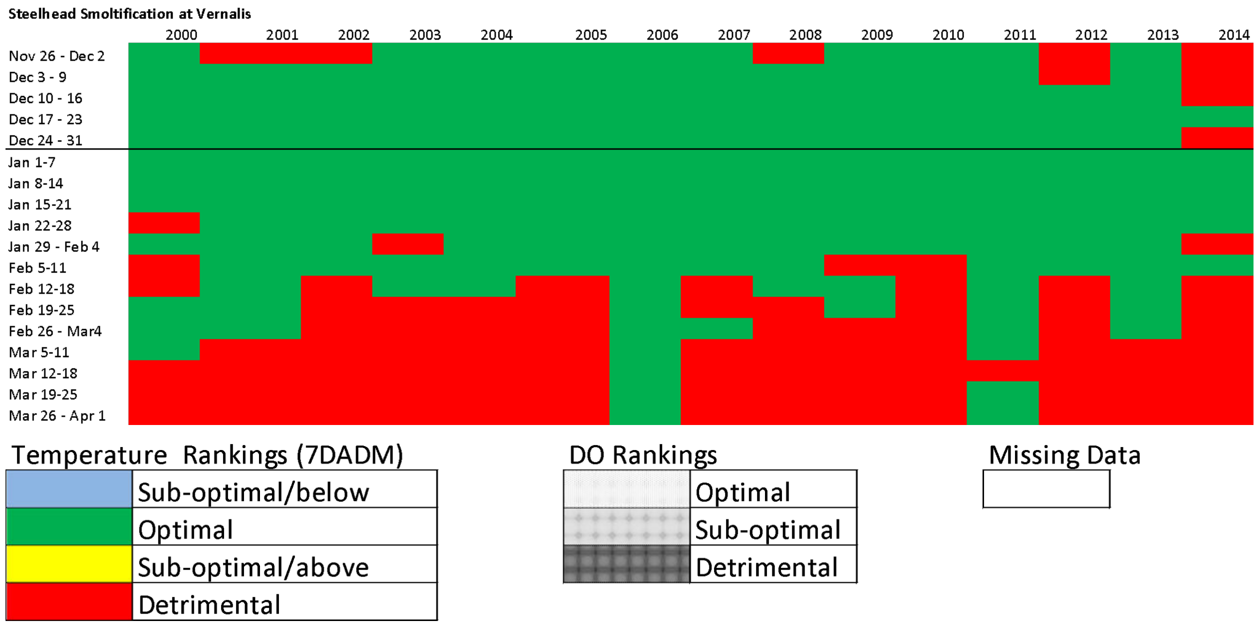



**Figure 21**
**Steelhead Smoltification**

Notes:
Temperature and DO rankings based on observed data during peak periods of steelhead smoltification. Rankings reflect the Environmental Objectives for temperature and DO (Section 7). Data are from CDEC for each location.

## *8.6.3 Stress: Lack of Suitable Rearing Habitat (Juvenile Rearing and Migration)*

Inadequate rearing habitat can limit the productivity of salmonid populations. Historically, the Central Valley had extensive, seasonally inundated, shallow-water habitat that allowed for salmonid rearing (TBI 1998; Moyle 2002; Williams 2006). This habitat is associated with increased growth and survival of juvenile salmonids (e.g., Sommer et al. 2001b, 2004, 2005; Jeffres et al. 2008) as is shallow side channel habitat (Appendix A of NMFS 2014). Most of these historic shallow-water rearing habitats have been eliminated throughout the Central Valley. In the Stanislaus River, in particular, recent modeling suggests currently available wetted floodplain is a small fraction of the estimated acreage of functional inundated habitat the SEP Group estimates is necessary to support current or future populations (Section 7.2.5.5.6) and a small fraction of the area originally available in the watershed.

### 8.6.3.1 Fall-run Chinook Salmon

Current estimates show that the Stanislaus River has a deficit of suitable rearing habitat even at current population levels. Therefore, lack of adequate space with suitable conditions for rearing along the Stanislaus River corridor is a "high" magnitude and "high" certainty stress in the near term (Table 63).

Without corrective action, factors that led to the current lack of rearing habitat will increase in intensity; in addition, the population of juveniles requiring rearing space is expected to increase. As a result, stress imposed by lack of suitable rearing space will remain "high" magnitude, with "high" certainty in the long term (Table 63).

Fall-run Chinook salmon lack access to suitable rearing habitat on the Stanislaus River. The SEP Group estimates that current fall-run Chinook salmon populations on the Stanislaus River require 69 acres of functional inundated habitat (Section 7.2.5.5). Applying a correction for habitat suitability developed for the SJRRP (2012), this translates into a need for 230 to 986 total wetted acres. Modeling by FlowWest indicates that currently available wetted floodplain is approximately 133 acres.[13] In other words, even if the percentage of suitable habitat per acre of wetted floodplain on the Stanislaus River were equivalent to the high end of the suitability range observed on the San Joaquin River (30%), the current acreage would still represent only approximately 58% of what is necessary to support current salmon populations. This strongly suggests that fall-run Chinook salmon juveniles lack adequate off-channel rearing habitat and survival rates in the Stanislaus River and downstream are negatively impacted by this lack of habitat.

Salmon populations are expected to grow in the near term and long term, and these larger populations will require more rearing habitat. SEP Group objectives call for 707 acres of functional inundated rearing habitat to support future populations. Using the conversions developed by the SJRRP (2012), this suggests the need for between approximately 2,360 acres and 10,100 acres of actual inundated floodplain (Section 7.2.5.5). Currently available habitat is less than 6% of the habitat required, even under the best case for the relationship between wetted floodplain area and quality rearing habitat.

The frequency and extent of inundation of off-channel habitats have decreased substantially on the Stanislaus River as a result of several fundamental changes. Construction of dams on the Stanislaus River block the supply of alluvial sediment, resulting in scour of the main channel bed. Reservoir operations greatly reduced channel-forming flows, which led to steep armored banks. The combination of armored banks and an incised channel increased the volume of flow necessary to connect the river to riparian floodplains and side channels (Kondolf 1997; Furniss and Guntle 2004; Grant 2012). These effects, combined with levee construction and flattening of the hydrograph (i.e., limiting magnitude and variation in river flows), have disconnected the river and rearing salmonids from important floodplain and side channel habitats. Finally, there is inadequate distribution of

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[13] FlowWest SRH2d Model, Available from: http://public.tableau.com/profile/mark.tompkins#!/vizhome/20160203_CVPIA_Floodplain/Floodplain

shallow productive habitats along the river's course. Most of the available habitats of this type are located upstream of Orange Blossom Bridge, resulting in very few rest areas, predator avoidance pathways, or rearing opportunities in the lower half of the Stanislaus River and in the lower San Joaquin River downstream of its confluence with the Stanislaus River.

In-stream rearing habitat has also been degraded by channel modifications (e.g., former gravel pits), flow modifications, and lack of cover (i.e., structure and turbidity). Disconnection of the channel from the floodplain also increases the percentage of fine sediments (i.e., sand and silt) in gravel beds. This degrades in-channel rearing opportunities, as preferred food items (drifting macroinvertebrates) are replaced by less favorable, sand-dwelling species. Loss of high-quality in-channel and off-channel habitats has left juveniles vulnerable to predators in most years.

### How the SEP Group Addressed Predation Stress on Juvenile Salmonids

In recent forums where management of Central Valley fishes is being considered, and in the media, much attention has focused on the need to reduce "predation" on native fishes, including salmonids, and what are perceived to be high rates of predation on native fishes, especially by a suite of non-native predatory fishes such as striped bass [*Morone saxatilis*] and species in the family Centrarchidae (Lindley and Mohr 2003; Cavallo et al. 2012; Grossman et al. 2013).

Predation is a natural process. In natural populations, more juveniles are produced than can survive, and predation eliminates many less-fit individuals (Darwin 1861). In the absence of large egg or fish kills caused by disease and/or lethal water quality, predation is almost always the proximate mechanism for juvenile salmon mortality (and, by extension, for natural selection). The observation that predation rates are "too high" in a river is really the same as saying that survival is "too low" to achieve a Biological Objective. Therefore, the SEP Group's productivity objectives (i.e., improvements in survival rates) are intimately tied to creating conditions that will reduce predation and effects. Specifically, the Environmental Objectives describe habitat conditions that favor juvenile salmon survival over predator success.

Predation is the interaction of the following:

- *Predation susceptibility*: a function of factors including juvenile salmon size, juvenile salmon condition, juvenile salmon abundance, life history diversity across a population, habitat conditions that expose juveniles to predators, and habitat conditions that support evolutionarily developed predator avoidance mechanisms of juvenile salmon
- *Predation pressure*: a function of factors including predator density, predator activity and metabolic rates, and habitat conditions that drive activity and metabolic rates (e.g., temperature)

Environmental conditions that favor juvenile salmon survival may reduce rates of predation or reduce the adverse physiological or behavior effects of predator presence (e.g., temperature; Kuehne at al. 2012). This occurs because optimal habitat conditions reduce predation susceptibility and pressure. The SEP Group's Environmental Objectives define supportive, stressful, and detrimental habitat conditions for each target population in ways that account for the effect of habitat conditions on predator susceptibility and on predators themselves. Optimal temperature ranges for Chinook salmon can also suppress predator metabolism (e.g., smallmouth bass [*Micropterus dolomieu*] stopped feeding when temperatures dropped below 10°C (50°F) on the John Day River (Oregon; Lawrence et al. 2015). To be clear, attaining supportive temperatures for salmonids will not eliminate predation effects; however, attaining supportive levels of environmental conditions will create habitats that reduce predation susceptibility and predation pressure.

The SEP Group included "predator density" in its stressor rankings for juvenile rearing because there is no Environmental Objective for "predator density." Theoretically, such an objective could be set using bioenergetic models and assumptions regarding habitat conditions (e.g., temperature, turbidity) in each reach, but stressor reduction would still require progress towards meeting the other habitat objectives. Note that progress towards attaining all Environmental Objectives relevant to juvenile rearing and migration will naturally reduce predator density over time (i.e., less predation equals reduced biomass of predators). Nevertheless, the SEP Group scored predator density levels as a stressor because there are other more immediate means of reducing predator density (e.g., removal of unnatural structures where predators tend to aggregate, direct predator removal, expansion of habitat area) that may be proposed as conservation measures to benefit salmon migration and rearing on the Stanislaus River.

Contaminants are also a major stressor on habitat quality for migrating and rearing fall-run Chinook salmon. Pesticides and herbicides can disrupt the salmonid food web through direct mortality of plants and invertebrates, reducing growth of juvenile fish. Pesticides and herbicides may also reduce feeding efficiency and disrupt salmon olfaction and, as a result, the ability of surviving outmigrants to return to natal waters as adults (Appendix C, Section 1.3.3.1). Metabolic costs of detoxifying contaminants can retard growth rates. Cumulative pesticide exposure of salmon in the Stanislaus River (Hoogeweg et al. 2011) is stressful throughout the year between Knights Ferry and Caswell State Park (and likely further downstream). Exposure reaches levels that are detrimental (primarily through their effect on juvenile olfaction) by March at Knights Ferry and points downstream (Appendix C, Figure C-1 and Table C-13).

High temperatures currently impact fall-run Chinook salmon rearing. Chinook salmon tolerate and can even benefit from temperatures up to approximately 25°C (77°F) in off-channel habitat with high food production. In the absence of habitats with slow moving water and high prey densities, temperatures close to 25°C (77°F) are detrimental to rearing fish (Section 7.2.5.1). As shown on Figure 19, temperatures become stressful for rearing and migrating fall-run Chinook salmon by June at Orange Blossom Bridge and points downstream; temperatures are stressful in April of most years at Ripon and by late March at Vernalis. Temperatures become detrimental to rearing and migrating salmon by late May at Ripon. Unless shallow, slow-moving, and prey-dense habitats (in which salmon can tolerate higher temperatures) are created, these conditions will be exacerbated by regional warming trends in the long term.

As part of the stressor evaluation and prioritization process, the SEP Group assumed that habitat extent in the future would permit fall-run Chinook salmon populations to increase to levels associated with larger planning goals such as CVPIA and AFRP (USFWS 2001) production targets. Attainment of those targets is not a Biological Objective for the Stanislaus River because attainment relies on changes to habitat conditions beyond the Stanislaus; however, provision of habitat space necessary to support those production levels is an Environmental Objective for the Stanislaus River (Section 7.2.5.5). Producing the number of juveniles that would be consistent with Central Valley Goals and Objectives for the Stanislaus River would generate increased demand for quality juvenile rearing habitat. Thus, there is high certainty that habitat limitations will persist in the future unless management actions to increase habitat availability are implemented.

#### 8.6.3.2 Spring-run Chinook Salmon

Lack of rearing habitat for juvenile spring-run Chinook salmon is a “high” magnitude, “high” certainty stress to recovering spring-run Chinook salmon populations in the near term (Table 64).

Without corrective action, lack of rearing habitat will remain a “high” magnitude stress with “high” certainty in the long term (Table 64).

All of the same stressors limiting availability of suitable rearing habitat described for fall-run Chinook salmon apply to spring-run. Spring-run juveniles are expected to begin migrating earlier than fall-run, and thus some fraction of their population may avoid the most severe impacts of stressors like high temperature and pesticide concentrations. However, the current limits on high-quality rearing habitat space and the increased demand for that space in the future will create stress that impedes the recovery of spring-run Chinook salmon on the Stanislaus River.

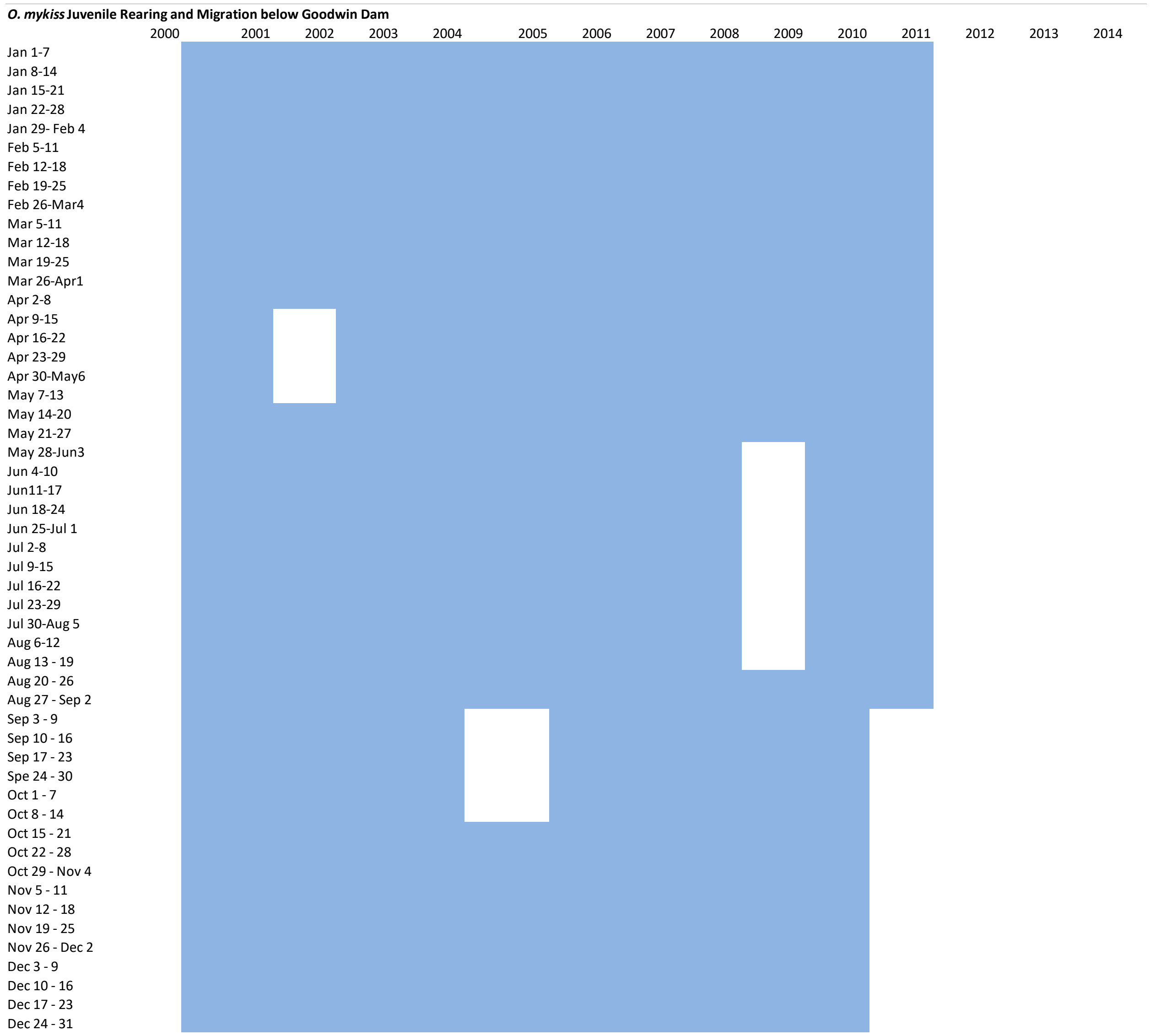
#### 8.6.3.3 O. mykiss

Lack of rearing habitat for juvenile *O. mykiss* is a "high" magnitude, "high" certainty stress to recovering steelhead populations in the near term (Table 65).

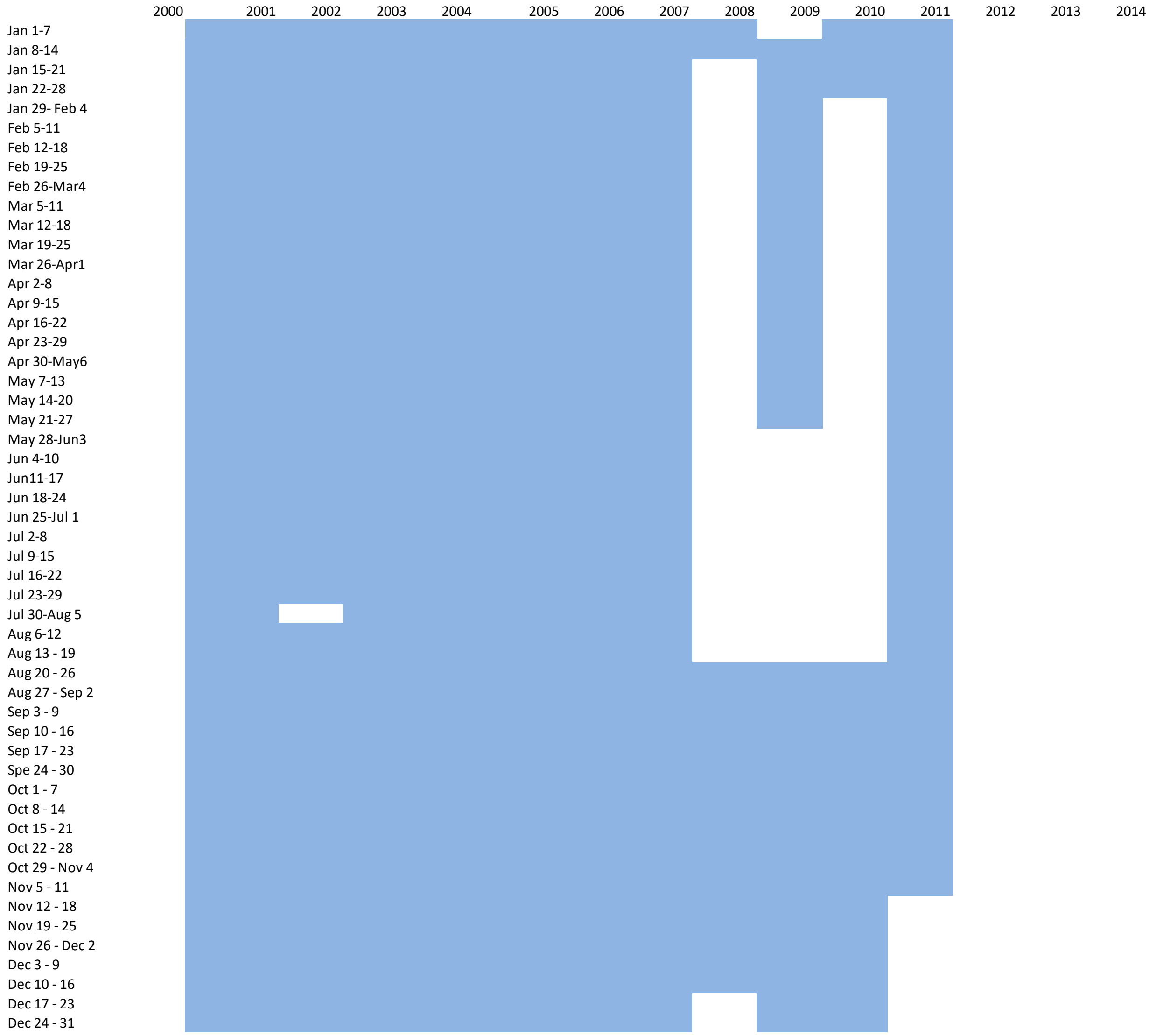
Without corrective action, lack of rearing habitat will remain a "high" magnitude stress with "high" certainty in the long term (Table 65).

Production of anadromous phenotypes in the local *O. mykiss* population is likely to be discouraged by a lack of adequate food resources to promote rapid somatic growth. The degree of anadromy in *O. mykiss* populations is dependent on juvenile growth rates; faster individual growth rates are associated with greater anadromy (Satterthwaite et al. 2010; Kendall et al. 2014). Factors that limit inundation of shallow habitats (e.g., floodplains, side channels, riparian margins)—which export productivity to in-channel habitats; formation and maintenance of in-channel bars; and limited in-channel productivity (lack of coarse sediment input, pesticides, and other contaminants)—reduce availability of and access to dense food supplies. Similarly, throughout half the year, pesticide concentrations are high enough to impair juvenile olfactory abilities at levels that would be detrimental to population growth rates, and they are stressful in the other 6 months of the year (Hoogeweg et al. 2011 and Appendix C Section 1.3.3.1, Figure C-1, and Table C-13).

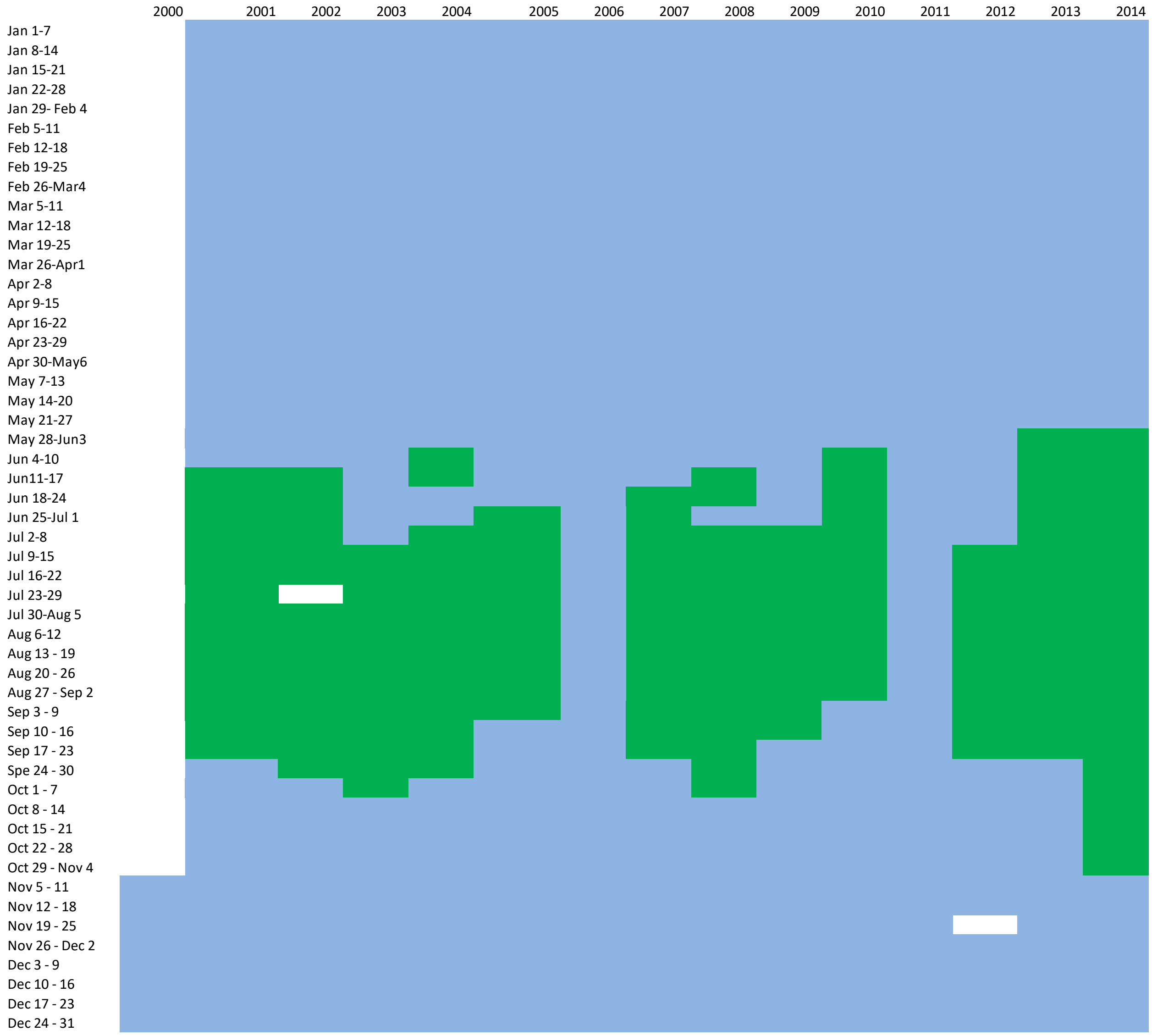
In contrast to Chinook salmon, temperatures in the Stanislaus River are supportive for rearing and migrating *O. mykiss*, at least between Orange Blossom Bridge and Oakdale (and probably several RMs on either side of those gage locations) from mid-May to early October (Figure 22). Section 8.6.2 describes the onset of temperatures that may limit smoltification in steelhead (greater than 11°C (51.8°F) from December through March). However, (prior to or after smoltifying) rearing and migrating *O. mykiss* can experience supportive conditions at higher temperatures than Chinook salmon. Temperatures rarely exceed the *O. mykiss* rearing and migration supportive threshold at Oakdale or upstream; indeed, the persistence of temperatures lower than the *O. mykiss* optimum may represent a lack of an important migration cue (migration cues are discussed in Section 8.6.5.)


*O. mykiss* Juvenile Rearing and Migration below Goodwin Dam
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
Jan 1-7
Jan 8-14
Jan 15-21
Jan 22-28
Jan 29- Feb 4
Feb 5-11
Feb 12-18
Feb 19-25
Feb 26-Mar4
Mar 5-11
Mar 12-18
Mar 19-25
Mar 26-Apr1
Apr 2-8
Apr 9-15
Apr 16-22
Apr 23-29
Apr 30-May6
May 7-13
May 14-20
May 21-27
May 28-Jun3
Jun 4-10
Jun11-17
Jun 18-24
Jun 25-Jul 1
Jul 2-8
Jul 9-15
Jul 16-22
Jul 23-29
Jul 30-Aug 5
Aug 6-12
Aug 13 - 19
Aug 20 - 26
Aug 27 - Sep 2
Sep 3 - 9
Sep 10 - 16
Sep 17 - 23
Spe 24 - 30
Oct 1 - 7
Oct 8 - 14
Oct 15 - 21
Oct 22 - 28
Oct 29 - Nov 4
Nov 5 - 11
Nov 12 - 18
Nov 19 - 25
Nov 26 - Dec 2
Dec 3 - 9
Dec 10 - 16
Dec 17 - 23
Dec 24 - 31

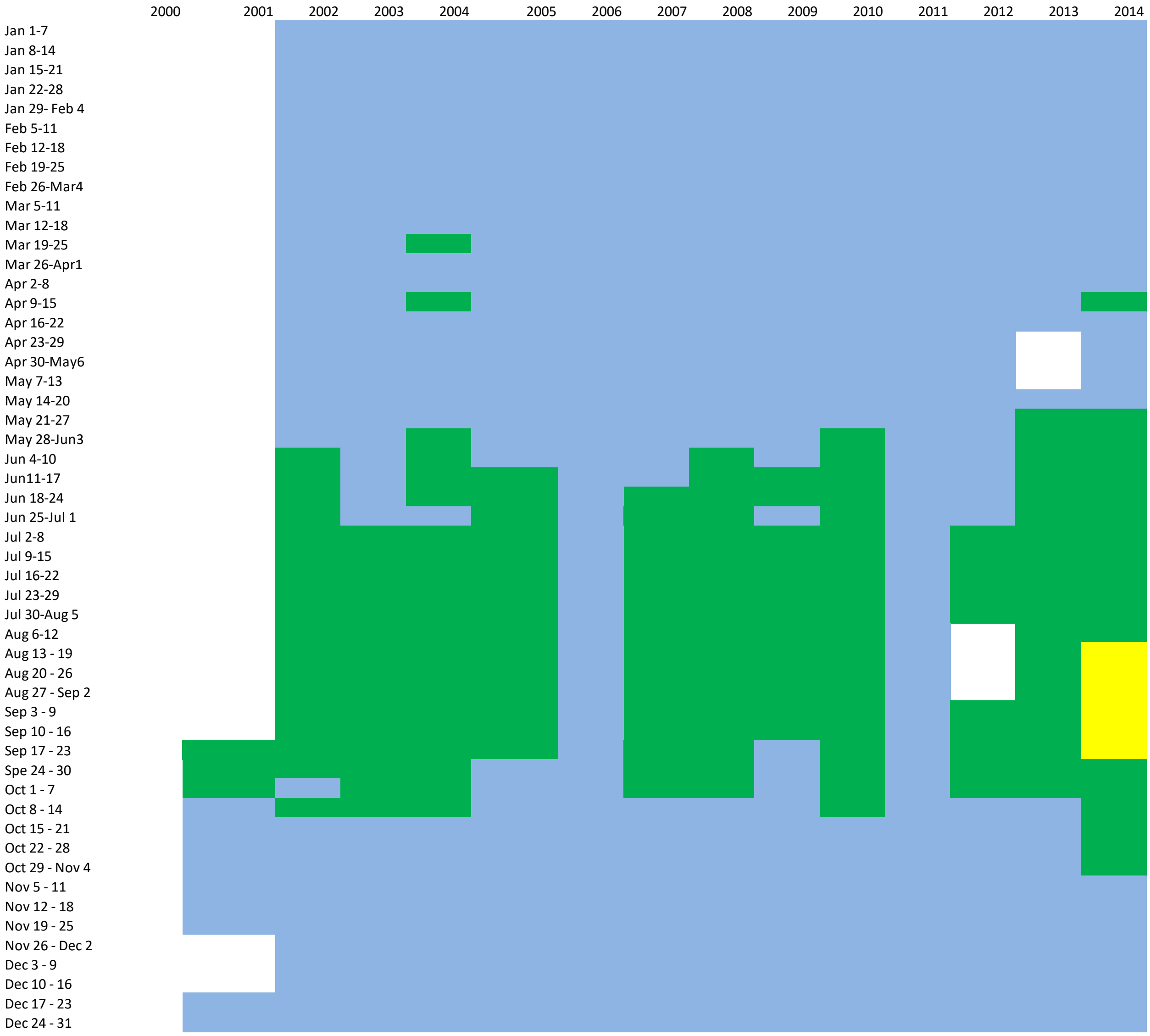
***O. mykiss* Juvenile Rearing and Migration at Knights Ferry**



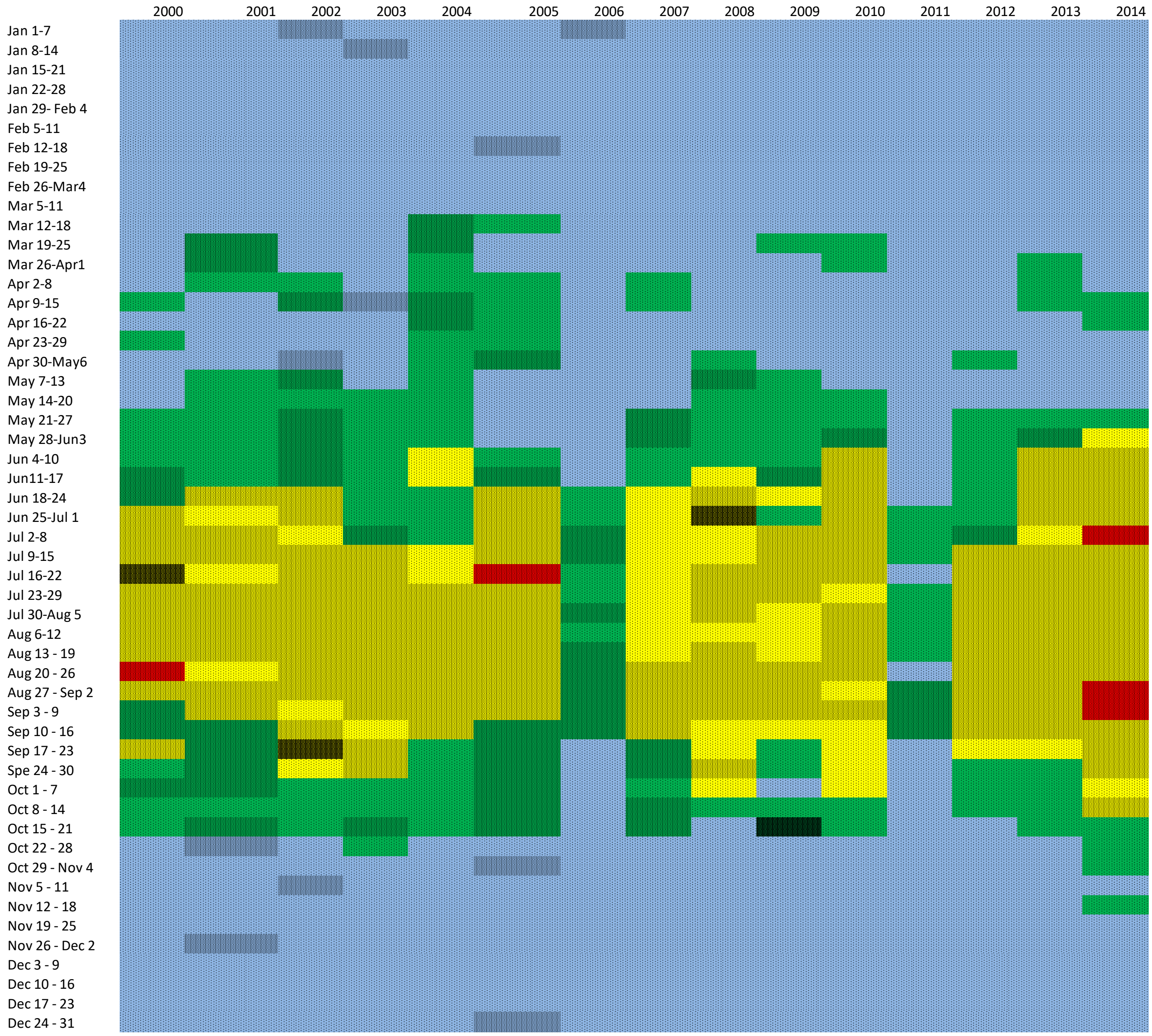
***O. mykiss* Juvenile Rearing and Migration at Orange Blossom Bridge**



***O. mykiss* Juvenile Rearing and Migration at Oakdale**



***O. mykiss* Juvenile Rearing and Migration at Ripon**



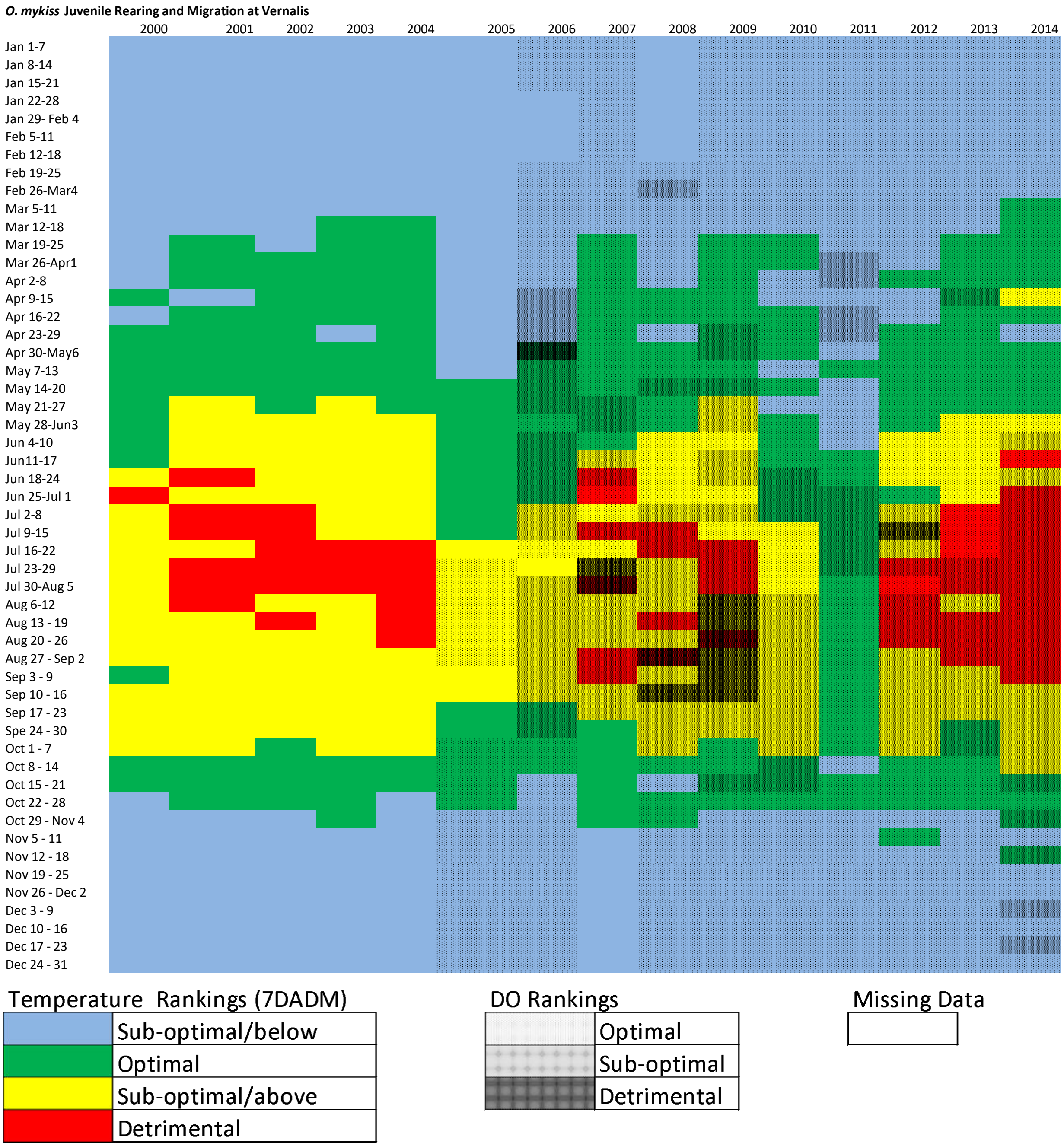



**Figure 22**

***O. mykiss* Juvenile Rearing and Migration for all Weeks of Year**

Notes:
Temperature and DO rankings based on observed data during periods of *O. mykiss* juvenile rearing and migration. Rankings reflect the Environmental Objectives for temperature and DO (Section 7). Data are from CDEC for each location.

## *8.6.4 Stress: Lack of Suitable Migratory Conditions (Juvenile Rearing and Migration)*

All anadromous fish must have suitable conditions, during the proper season, to allow juveniles to migrate out of the river environment of the Stanislaus and lower San Joaquin rivers into the tidal environment of the Delta on their way to the marine environment of the Pacific Ocean. A variety of water quality and physical habitat conditions must be in suitable ranges to allow for successful migration.

### 8.6.4.1 Fall-run Chinook Salmon

Fall-run Chinook salmon juveniles encounter inhospitable migratory conditions along the Stanislaus River corridor. This is a "high" magnitude and "high" certainty stress in the near term (Table 63).

Without corrective action, several of the stressors that lead to inhospitable migratory conditions will increase in intensity, meaning that this stress will remain "high" magnitude with "high" certainty in the long term (Table 63).

Changes in the hydrograph attributable to dam construction, water diversion, and disconnection of functional riparian habitats (Section 8.6.8) have contributed to deterioration in migratory conditions for fall-run Chinook salmon juveniles. Flow volume and channel geometry are insufficient over most of the Stanislaus River's course to provide suitably complex, shallow-water habitats that migrating salmon use for cover, resting, and feeding.[13] Higher flows would also provide increased access to currents that can significantly reduce the energetic expenditure of downstream migration for juvenile salmonids. Additionally, in-channel habitats have been deepened and simplified through dredging, channel scour, and removal of large woody debris (to improve navigation), creating deep, low-velocity pools that are excellent habitat for salmon predators and require significant energy expenditure for juvenile salmon attempting to transit.

Contaminants in agricultural runoff can also harm migrating juveniles. Pesticide runoff impairs salmonid olfaction to an extent that is considered detrimental to the population (Hoogeweg et al. 2011; Appendix C, Section 1.3.3.1, Figure C-1, and Table C-13) and can impair predator-avoidance behavior. Nutrients from runoff and agricultural water returns to the Stanislaus River can stimulate non-native aquatic macrophytes that harbor predators. The magnitude of effect of contaminants on migrating salmon was lower than for rearing salmon because food-web impacts of contaminants were incorporated in the score for rearing salmon, but not migrating salmon. In addition, to the extent that migration and rearing are distinct behaviors, the duration of exposure during migration activities is expected to be less than the exposure duration for rearing fish.

Temperature conditions in late spring to early summer constrict access to in-stream migratory habitat, especially in lower reaches of the Stanislaus and the lower San Joaquin rivers (Figure 19). Temperatures regularly exceed stressful and detrimental levels during the spring.

#### 8.6.4.2 Spring-run Chinook Salmon

Lack of suitable migratory conditions for juvenile spring-run Chinook salmon is a "high" magnitude, "high" certainty stress to recovering spring-run Chinook salmon populations in the near term (Table 64).

Without corrective action, lack of suitable conditions during migration will remain a "high" magnitude stress with "high" certainty in the long term (Table 64).

All of the same stressors on suitable migratory conditions described for fall-run Chinook salmon (Section 8.6.4.1) apply to spring-run Chinook salmon.

#### 8.6.4.3 Steelhead

Lack of suitable migratory conditions for juvenile steelhead is a "high" magnitude, "high" certainty stress to recovering steelhead populations in the near term (Table 65).

Without corrective action, lack of rearing habitat will remain a "high" magnitude stress with "high" certainty in the long term (Table 65).

Most of the stressors on suitable migratory conditions described for fall-run Chinook salmon also apply to steelhead. An exception is that temperatures required for rearing and migrating *O. mykiss* are supportive throughout most of the spring in both the Stanislaus and lower San Joaquin rivers (Figure 22). Temperatures become stressful in the lower Stanislaus River (at and around Ripon) during the summer months when the fraction of steelhead migrating is likely to be very small relative to the total annual outmigrant cohort. Similarly, temperatures at Vernalis become stressful (and detrimental) from late spring through the summer, but this is not expected to affect most of the outmigrant class. In addition, steelhead that experience inhospitable migration conditions may not be lost (as would be the case for migrating Chinook salmon) because *O. mykiss* are facultatively anadromous, and it may be possible for them to delay an anadromous migration (or reverse it) when migration is not possible.

### *8.6.5 Stress: Lack of Suitable Migratory Cues (Juvenile Rearing and Migration)*

Several factors may trigger or facilitate onset of migration among juvenile salmonids. Variability in flow can trigger juveniles to leave off-channel habitat and proceed downstream in the main channel (Zeug et al. 2014). Outmigration of juvenile fall-run Chinook salmon often coincides with large increases in flow associated with rain events and spring and summer snowmelt in the Stanislaus River (Melgo et al. 2015 and earlier Caswell RST Reports[14]). Høgåsen (1998) as cited in Williams (2006) found that rainfall and increased flow and turbidity influenced the onset of migration for juvenile Chinook salmon. In unimpaired systems, runoff from spring rain events adds complexity to the seasonal snowmelt hydrograph. Rain runoff pulses, when added to the base flows provided by snowmelt, offer triggers to stimulate outmigration and assist outmigrants by providing higher velocities to speed migration and higher turbidity to provide visual cover from predators (Gregory 1993; Gregory and Levings 1998). Removal or storage of large volumes of water from the Stanislaus River alters its hydrograph in ways that hamper outmigration, including through loss of inundation of off-channel resting areas in most years and through reduced turbidity.

#### 8.6.5.1 Fall-run Chinook Salmon

Lack of suitable migratory cues for fall-run Chinook salmon juveniles is a "high" magnitude and "medium" certainty stress in the near term (Table 63).

Without corrective action, this stress will remain "high" magnitude, with "medium" certainty in the long term (Table 63).

Changes in the hydrograph attributable to dam construction, water diversion, and management of dam releases have greatly reduced both the volume of water and the variability in flow that help to trigger outmigration in fall-run Chinook salmon (Zeug et al. 2014). Flow pulses are scheduled in the lower San Joaquin River as part of the WQC Plan, but the planned flow pulses are often inadequate to provide sufficient outmigration cues or support for successful migration (CDFG 2010; SWRCB 2010). Furthermore, pulse flows called for the in the WQC Plan have been reduced, under "temporary urgency changes" during recent drought years, meaning little or no migratory cues were provided for entire year-classes of migrating juvenile fall-run Chinook salmon. Finally, pulse flows required under the WQC Plan are scheduled for the same calendar period ending in mid-May every year; such calendar-based flow scheduling may undermine life history diversity (e.g., migration timing) in ways that severely impair run viability (McElhany et al. 2000; Satterthwaite et al. 2014; Zeug et al. 2014; Sturrock et al. 2015). Until recently, fluctuations in flow volume that cue juvenile migration have been largely absent from the hydrograph. However, current efforts to manage reservoir releases to mimic natural variability may be inadequate because releases of water from reservoirs may not provide sufficient turbidity, and mismatches with scheduled releases and natural storm events may limit the success of these attempts (Wikert 2014, pers. comm.).

[14] Available from https://www.fws.gov/cno/fisheries/CAMP/Documents-Reports/

### 8.6.5.2 Spring-run Chinook Salmon

Lack of suitable migratory cues for juvenile spring-run Chinook salmon is a "high" magnitude and "medium" certainty stress to recovering spring-run Chinook salmon populations in the near term (Table 64).

In the future, lack of suitable cues to stimulate migration will remain a "high" magnitude stress with "medium" certainty in the long term (Table 64).

All stressors on suitable migratory cues described for fall-run Chinook salmon (Section 8.6.5.1) apply to spring-run Chinook salmon.

### 8.6.5.3 Steelhead

Lack of suitable migratory cues for juvenile steelhead is a "high" magnitude and "low" certainty stress to recovering steelhead populations in the near term (Table 65).

In the long term, lack of rearing habitat will become a "medium" magnitude stress with "low" certainty in the long term (Table 65).

The factors that trigger anadromy in *O. mykiss* populations are somewhat uncertain. As Kendall et al. (2014) wrote:

> Anadromy and residency appear to reflect interactions among genetics, individual condition, and environmental influences. … [p]atterns in anadromy and residency among and within populations suggested a wide range of possible environmental influences at different life stages… [Abstract].

The following environmental influences have been correlated with potentially driving anadromy (Kendall et al. 2014; see citations in Kendall et al. 2014):

- Water temperature (higher temperatures generally related to greater proportions of anadromous fish)
- Food availability (higher food availability associated with lower proportions of anadromous fish)
- Stream flow and flow variability (anadromy most common in streams with greatest flow and greatest flow variability)
- Density dependence (higher density related to greater proportion of anadromous fish)

These correlations, though reported from various studies, were characterized as uncertain with regard to mechanism by Kendall et al. (2014) and were acknowledged to be in a context of scant data on the extent of residency and anadromy across populations of *O. mykiss*.

Given this overview, it is most likely that low temperatures (i.e., generally in the supportive range for *O. mykiss* or lower; Figure 22), generally low flows, low variance in flow velocity during much of the year, and relatively low density of *O. mykiss* contribute to low rates of anadromy among the Stanislaus River's *O. mykiss* population. Each of these factors has a low certainty (and the rate of anadromy seems likely to be responsive to numerous ecosystem processes, in addition to unknowns such as the genetic makeup of the population) and should probably be the subject of research on *O. mykiss* populations for each tributary to the San Joaquin River.

### *8.6.6 Stress: Lack of Suitable Over-Summering Habitat (Juvenile Rearing and Migration)*

Some fraction of fall-run and spring-run Chinook salmon over-summer in their natal streams as juveniles and are affected by conditions in the Stanislaus River through the summer and fall months. Spring-run Chinook salmon show a greater predisposition to this over-summering behavior, and spring-run Chinook populations typically produce a small, but measurable percentage of "yearling" migrants each year (Healey 1991; Moyle 2002). Steelhead (and resident rainbow trout) can spend several years (or even their entire life) in freshwater, so over-summering habitat is vitally important. Water temperature plays the largest role in this stress.

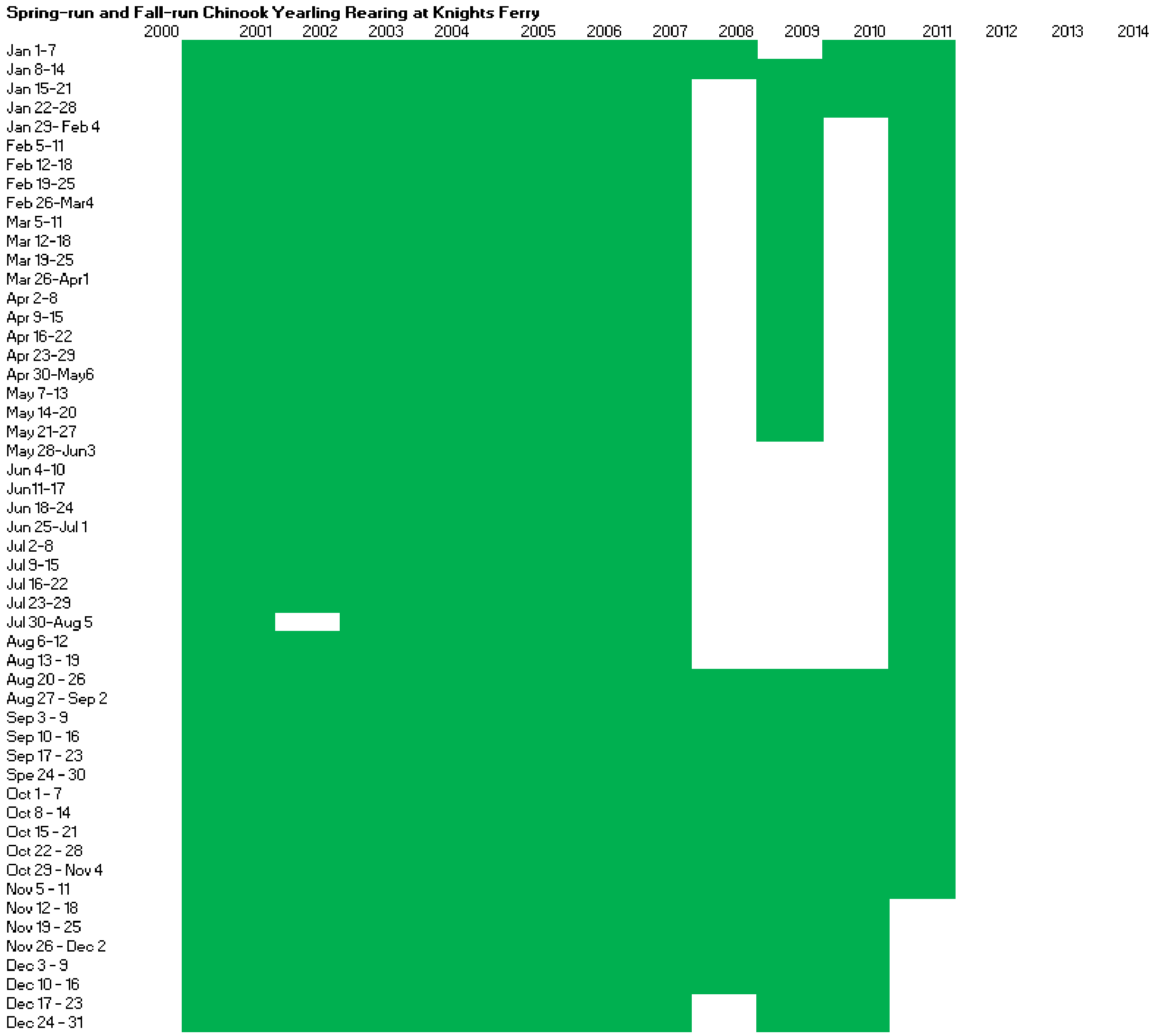
#### 8.6.6.1 Fall-run Chinook Salmon

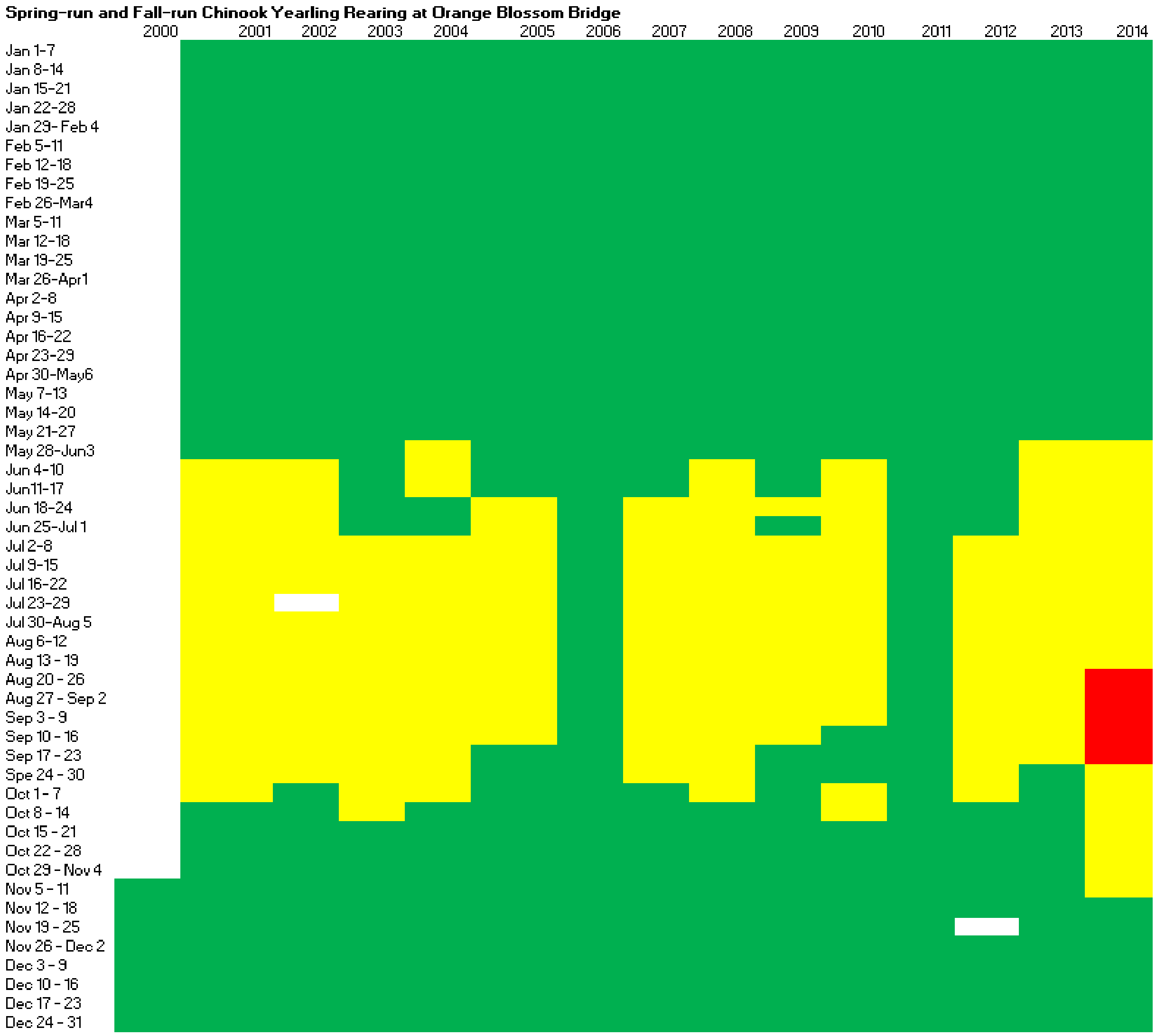
A lack of habitat in which fall-run Chinook salmon juveniles can rear over the summer is a "minimal" magnitude stress with "medium" certainty in the near term (Table 63).

This stress is likely to remain "minimal" magnitude in the long term because only a small fraction of the fall-run population is expected to display this behavior; certainty remains "medium" (Table 63).

The amount of habitat available for over-summering is largely a function of temperature. As water temperatures warm, suitable habitat contracts in an upstream direction (Figure 23). Only a small portion of the fall-run juvenile production is thought to over-summer. Evidence for this behavior comes from RST sampling in which salmon substantially larger than expected outmigrate in early spring. There is uncertainty as to which run (fall, late fall, or spring) these large outmigrants belong. The SEP Group assumed this behavior was infrequent among fall-run; yet this assumption is uncertain because larger fish are better able to avoid the traps. Limitations of the extent of habitat are likely to increase in the future with larger fish populations and warmer water temperatures projected by climate change models. Contaminants could be a large stressor if the over-summering population was larger or water temperatures allowed over-summering in the lower river where substantial urban, industrial, and agricultural runoff occurs.

Spring-run and Fall-run Chinook Yearling Rearing below Goodwin Dam


Spring-run and Fall-run Chinook Yearling Rearing at Knights Ferry
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
Jan 1-7
Jan 8-14
Jan 15-21
Jan 22-28
Jan 29- Feb 4
Feb 5-11
Feb 12-18
Feb 19-25
Feb 26-Mar4
Mar 5-11
Mar 12-18
Mar 19-25
Mar 26-Apr1
Apr 2-8
Apr 9-15
Apr 16-22
Apr 23-29
Apr 30-May6
May 7-13
May 14-20
May 21-27
May 28-Jun3
Jun 4-10
Jun11-17
Jun 18-24
Jun 25-Jul 1
Jul 2-8
Jul 9-15
Jul 16-22
Jul 23-29
Jul 30-Aug 5
Aug 6-12
Aug 13 - 19
Aug 20 - 26
Aug 27 - Sep 2
Sep 3 - 9
Sep 10 - 16
Sep 17 - 23
Spe 24 - 30
Oct 1 - 7
Oct 8 - 14
Oct 15 - 21
Oct 22 - 28
Oct 29 - Nov 4
Nov 5 - 11
Nov 12 - 18
Nov 19 - 25
Nov 26 - Dec 2
Dec 3 - 9
Dec 10 - 16
Dec 17 - 23
Dec 24 - 31


Spring-run and Fall-run Chinook Yearling Rearing at Orange Blossom Bridge
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
Jan 1-7
Jan 8-14
Jan 15-21
Jan 22-28
Jan 29- Feb 4
Feb 5-11
Feb 12-18
Feb 19-25
Feb 26-Mar4
Mar 5-11
Mar 12-18
Mar 19-25
Mar 26-Apr1
Apr 2-8
Apr 9-15
Apr 16-22
Apr 23-29
Apr 30-May6
May 7-13
May 14-20
May 21-27
May 28-Jun3
Jun 4-10
Jun11-17
Jun 18-24
Jun 25-Jul 1
Jul 2-8
Jul 9-15
Jul 16-22
Jul 23-29
Jul 30-Aug 5
Aug 6-12
Aug 13 - 19
Aug 20 - 26
Aug 27 - Sep 2
Sep 3 - 9
Sep 10 - 16
Sep 17 - 23
Spe 24 - 30
Oct 1 - 7
Oct 8 - 14
Oct 15 - 21
Oct 22 - 28
Oct 29 - Nov 4
Nov 5 - 11
Nov 12 - 18
Nov 19 - 25
Nov 26 - Dec 2
Dec 3 - 9
Dec 10 - 16
Dec 17 - 23
Dec 24 - 31

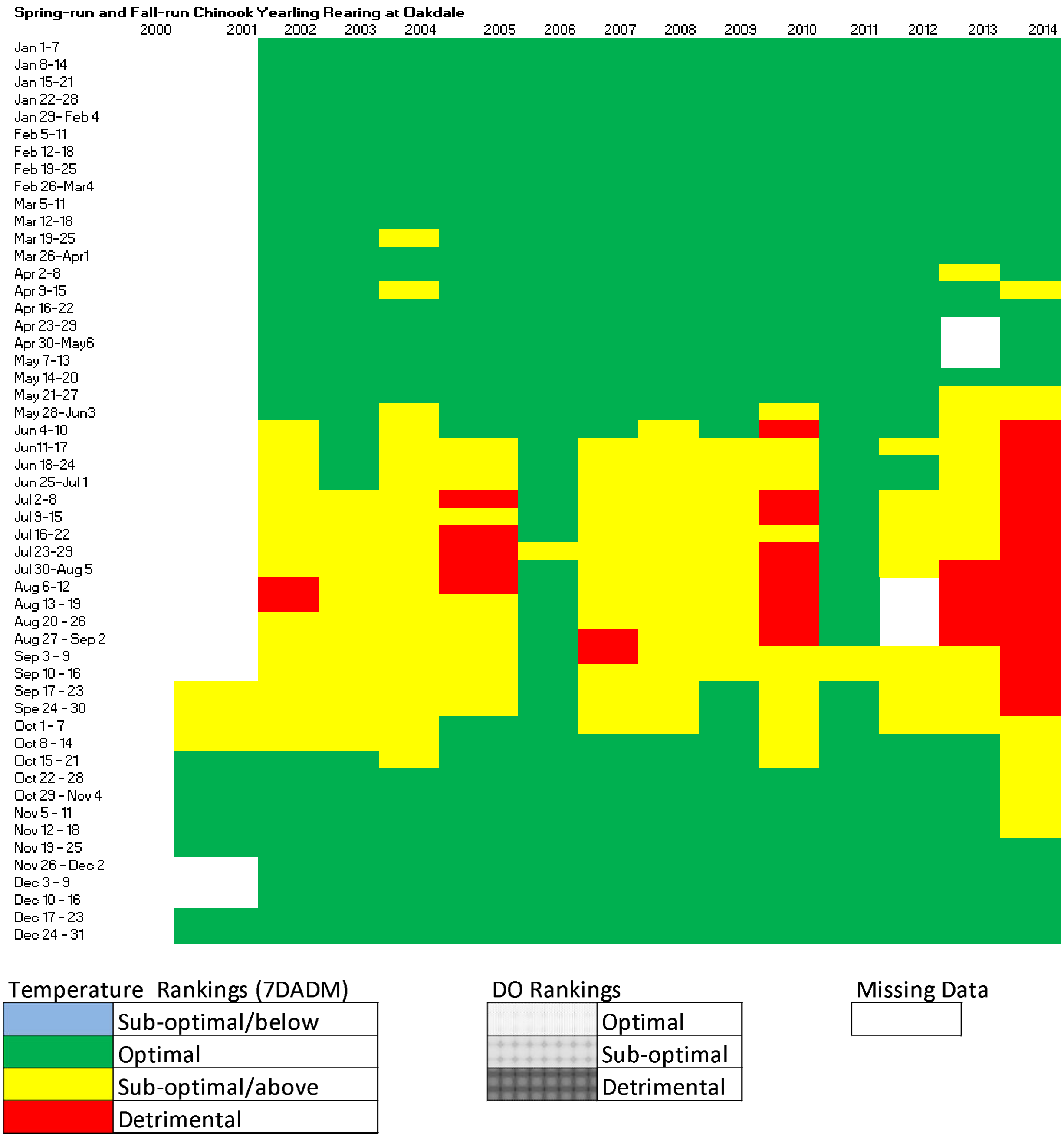



**Figure 23**

**Spring-run and Fall-run Chinook Yearling Rearing**

Notes:
Temperature and DO rankings based on observed data during periods of yearling rearing. Rankings reflect the Environmental Objectives for temperature and DO (Section 7). Data are from CDEC for each location.

#### 8.6.6.2 Spring-run Chinook Salmon

Lack of habitat in which juvenile spring-run Chinook salmon can rear over summer months is a "minimal" magnitude stress in the near term with "medium" certainty (Table 64).

In the long term, lack of over-summer habitat will increase to a "medium" magnitude stress with "medium" certainty (Table 64). Over-summering of a portion of the spring-run Chinook salmon population is essential to production of a key life history type (yearlings) that are characteristic of successful spring-run Chinook salmon populations.

All stressors on lack of suitable over-summering habitat described for fall-run Chinook salmon (Section 8.6.6.1) apply to spring-run Chinook salmon (Figure 23). However, the fraction of the population affected by poor over-summering conditions is expected to be larger for spring-run Chinook salmon than it is for fall-run Chinook salmon. Additionally, the yearling life history strategy is expected to be a key element of spring-run life history diversity on the Stanislaus River (as it is elsewhere in the Central Valley; Moyle 2002; Williams 2006). Although there appears to be adequate over-summering habitat for spring-run Chinook salmon in the near term (i.e., a "minimal" magnitude stress), over the long term, the magnitude of this stress is expected to increase because of rising temperatures and a dramatic increase in the number of spring-run Chinook salmon in the Stanislaus River. Both of these factors are assumptions of this stressor-ranking exercise. Loss of over-summering habitat in the long term (e.g., during drought cycles when reservoir coldwater storage is low) would represent a significant impact to an important life history strategy for the spring-run population. The SEP Group notes that there may be synergies between efforts to provide for over-summer holding habitat for adult spring-run Chinook salmon and efforts to provide suitable over-summer habitat for rearing yearling Chinook salmon.

#### 8.6.6.3 Steelhead

Lack of suitable habitat for juvenile steelhead to rear over the summer is a "minimal" magnitude stress to recovering steelhead populations in the near term with "high" certainty (Table 65).

In the long term, lack of summer rearing habitat will remain a "minimal" magnitude stress with "high" certainty (Table 65).

As shown in Figure 22, temperatures appear to be supportive for rearing *O. mykiss* between Oakdale and Orange Blossom Bridge throughout the summer of most years. At other times of year in and upstream of this area, temperatures are cooler than what would be supportive for rearing *O. mykiss*. Thus, there does not appear to be a lack of over-summering habitat for juvenile *O. mykiss*, and it seems unlikely that there will be significant loss of *O. mykiss* rearing habitat due to regional warming that may occur over the next 25 years (i.e., the "long term" in this exercise). It is possible that in the long term, stressful over-summer temperatures could occasionally prevail throughout the river corridor below Goodwin Dam in the later years of a prolonged drought, but this seems unlikely to result in lasting damage to the *O. mykiss* population.

## *8.6.7 Stress: Lack of Fitness/Genetic Maladaptation (Juvenile Rearing and Migration)*

Hatchery practices within the Central Valley have resulted in a large amount of straying of adult salmonids. Numerous studies have found negative fitness consequences when hatchery-origin adults reproduce with either other hatchery-origin adults or natural-origin adults in the wild (Heath et al. 2003; Araki et al. 2007; Christie et al. 2012). Traits that have been selected for in the hatchery environment can be passed to offspring, resulting in changes in behavior that are maladaptive. High straying rates that persist through time may lead to a wild population that is unable to adapt to the local conditions. Conversely, when the local population is very small, straying from hatchery sources can provide an opportunity to establish a local spawning population.

### 8.6.7.1 Fall-run Chinook Salmon

Lack of juvenile fitness due to continued influence of hatchery-selected genotypes is a "high" magnitude and "medium" certainty stress in the near term (Table 63).

Without corrective action, this stress will remain "high" magnitude, with "medium" certainty in the long term (Table 63).

High rates of straying prevent the Stanislaus River population of fall-run Chinook salmon from adapting to local conditions. The proportion of hatchery-origin fall-run Chinook salmon in the Stanislaus River escapement has been moderate to high. Sturrock et al. (2015) found 18% and 51% hatchery origin in 2000 and 2003, respectively. Constant fractional marking reports compiled by CDFW found 50% hatchery-origin fall-run Chinook in the 2010 escapement (Kormos et al. 2012), 83% in 2011 (Palmer-Zwahlen and Kormos 2013), and 83% in 2012 (Palmer-Zwahlen and Kormos 2015). These straying rates are well above the Hatchery Scientific Review Group's recommendations for managing an integrated (hatchery- and natural-origin fish are managed as a single population) salmon population (HSRG 2014).

### 8.6.7.2 Spring-run Chinook Salmon

Hatchery influence on the genetics of natural-origin spring-run Chinook salmon is believed to be a "minimal" magnitude stress in the near term; however, certainty of this stress is "minimal" as well (Table 64).

In the future, genetic influence on the fitness of spring-run Chinook salmon will become a "medium" magnitude stress with "medium" certainty in the long term (Table 64) unless corrective actions are implemented.

In the near term, reestablishment of spring-run Chinook salmon may benefit from straying of hatchery-origin and/or natural-origin spring-run produced elsewhere in the Central Valley. Straying Chinook salmon with genotypes needed to produce the spring-run phenotype can help to establish populations in non-natal watersheds. However, in the long term, after a substantial spring-run population has been established on the Stanislaus River, introgression of natural-spawned spring-run Chinook salmon with hatchery-origin spring-run, natural-origin fall-run, or hatchery-origin fall-run Chinook salmon is expected to become a problem that limits adaptation of spring-run Chinook salmon to conditions on the Stanislaus River along with the resulting production of juveniles that are maladapted to the local environment.

#### 8.6.7.3 Steelhead

The genetic influence of hatcheries on juvenile steelhead is a "medium" magnitude stress in the near term, but certainty regarding this magnitude is "minimal" (Table 65).

In the long term, stress on the steelhead population associated with continuing input of hatchery genotypes will remain a "medium" magnitude stress. Without additional research into this issue, certainty will remain "minimal" certainty (Table 65).

Evaluation of steelhead genetics is complicated by the fact that resident and anadromous forms can freely interbreed. The Stanislaus River currently supports a robust resident population augmented with small numbers of returning adults. Weir monitoring for fall-run Chinook salmon adults has occasionally been extended into other months. In the 5 years that weir monitoring has occurred (2011 to 2015), 0 to 32 steelhead up-migrants have been observed (mean is 8.2, median is 5). The weir data also revealed that in 3 of 5 years, the percentage of adipose fin-clipped (hatchery-origin) steelhead exceeded 50% (annual percentages: 61.5%, 57.1%, 34.6%, 12.5%, and 80%). Because of these high numbers, it is assumed that the genetic influence of hatchery-origin fish on the Stanislaus River population is high. Introduction of a larger fraction of anadromous genes into the mostly resident population may help to increase anadromy, though possibly at the expense of local adaptation. With a larger anadromous population assumed for the future, the stress of hatchery-origin immigrants is expected to remain "medium."

### *8.6.8 Contributing Management Factors*

Contributing management factors for each stressor on juvenile rearing and migration are provided in Sections 8.6.8.1 through 8.6.8.5.

#### 8.6.8.1 Compression of the Rearing and Migration Time Window

Changes in the hydrograph attributable to dam construction, reservoir operations, and water diversion have reduced the duration of suitable temperature conditions required for successful salmonid smoltification. Large reservoirs and their current operations have changed the timing of natural river flows. Large snowmelt pulses in the unimpaired hydrograph are captured by reservoirs in the spring rather than providing suitable conditions and cues for migration. Dams block sediment transport and greatly attenuate flood flows, resulting in the following (Ock and Kondolf 2012):

- Scoured and armored channels
- Disconnected floodplains and side channels
- Reduced recruitment of riparian trees (which would provide local cooling)
- Reduction of thermal refugia created by slower passage of water through gravel bars and islands

In addition, destruction of functional riparian and inundated floodplain habitats along the Stanislaus River limits growth opportunities that might allow juvenile salmonids to attain sufficient size and growth rates that would support earlier smoltification (i.e., earlier in the season when temperatures would still support smoltification and successful migration).

#### 8.6.8.2 Lack of Suitable Rearing Habitat and Migratory Conditions

Reservoir operation is a major driver of the environmental factors controlling the impact of stressors that may lead to rearing failure among juvenile salmonids. Flow volume directly controls the amount of floodplain and side channel inundation as well as maintenance of gravel quality through sediment transport dynamics. Relatively high flow volume positively impacts the migratory speed of juveniles leaving the system as well as increased turbidity, which can increase visual cover for migrants. High flow volumes also dilute contaminants and moderate warmer temperatures in late spring or early summer. Lack of channel-forming flows has allowed willows to armor banks and resulted in loss of channel elevation—disconnecting the river from floodplains and side channels—leaving migrants in homogenous, in-channel habitats largely devoid of cover. Long-term management will need to ensure that cold water is available for temperature management during prolonged droughts. Conveyance of spring-run Chinook salmon to habitats upstream of currently impassable dams is a possible solution to this (and other) stressors. Providing groundwater recharge in proximity to the river and promoting development of riparian forests may also offer some respite from higher temperatures. Habitat restoration in the form of gravel augmentation could improve food resources and provide thermal refugia.

Other non-flow management practices may exacerbate or alleviate stressors on juvenile rearing. For example, levees (especially in the lower portions of the river) limit spatial distribution and overall access to large areas of periodically inundated floodplain habitat that would support faster growth of salmon and would export prey items to the main-channel habitats of *O. mykiss* (leading to greater anadromy in the latter population). This lack of habitat constrains the overall carrying capacity for salmonid populations in the Stanislaus River.

Inundated floodplains also reduce predation rates on migrating salmonids (Sommer et al. 2001b, 2004). Fabricated structures have been found to provide predation hotspots where migrating juveniles have a much higher risk of being preyed upon (Sabal et al. 2016). These areas could be restored to provide safer migration pathways and discourage predators through habitat modification.

The destruction of riparian habitat along the Stanislaus River has likely reduced the amount of shade in the river corridor, which can increase temperatures in the river. Urban and agricultural developments in the watershed have increased contaminant loads to the river. Adjustments to land use practices or development of contaminant-control programs may reduce contaminant loads and the stress they generate for rearing juvenile salmonids. Groundwater depletions have likely terminated the hyporheic inputs that probably supplemented Stanislaus River surface flows and buffered the river against warm temperatures in late spring, summer, and early fall. Groundwater recharge programs may help to reestablish this benefit and reduce water temperatures in the river during critical months.

### 8.6.8.3 Lack of Suitable Migratory Cues

The major drivers of this stress include the presence of dams on the system, altering the natural hydrograph and its associated flow variability, and the disconnection of in-stream and off-channel habitats. Water managers are attempting to provide a more natural hydrograph, which includes simulated runoff events (NMFS 2009b, 2009c, Action III.1.3). However, the release of water from reservoirs may not provide sufficient turbidity, and mismatches with scheduled releases and natural storm events may limit the success of these attempts. Whenever possible, the Stanislaus Operations Group recommends timing release pulses to augment natural storm events so that peak flows coincide with periods of cloud cover and changes in barometric pressure that may contribute to migratory success (Wikert 2014, pers. comm.). Habitat modification to allow more frequent inundation, followed by rapid dewatering of temporarily inundated habitats, will likely help to cue juveniles to migrate.

### 8.6.8.4 Lack of Suitable Over-Summering Habitat

Reservoir operation is the largest management factor for insulating salmonids from the lack of suitable over-summering habitat. Long-term management must include ensuring that cold water is available for temperature management during prolonged droughts. Conveyance of spring-run Chinook salmon to habitats upstream of currently impassable dams is a possible solution to this (and other) stressors. Providing groundwater recharge in proximity to the Stanislaus River and promoting development of riparian forests may also offer respite from higher temperatures. Additionally, habitat restoration in the form of gravel augmentation could improve food resources and provide thermal refugia.

#### 8.6.8.5 Lack of Fitness/Genetic Maladaptation

The main drivers of lack of fitness/genetic maladaptation are current hatchery management practices combined with failure to provide suitable flows and environmental conditions needed to attract returning hatchery-origin adults into the watersheds where they were produced. Hatchery straying is largely a result of the following three factors (Marston et al. 2012):

- Large-scale production of hatchery fish (dwarfing natural production)
- Trucking fish (trucked juveniles lose the olfactory record needed to find their natal streams)
- Failure of many hatchery systems to provide sufficient flow to guide fish home (including massive water exports in the Delta)

Failure to provide an easily detectable mark on 100% of hatchery-origin fish prevents any opportunity to manage hatchery and natural populations separately.

## 8.7 Summary and Prioritization of Stressors and Stressor Responses

This section summarizes the results of stressor analyses for each target species across life history stages. As discussed at the beginning of Section 8, stressor priorities were assigned for individual life history stages based on the combination of magnitude and certainty scores. Because scores in these categories were applied consistently using the adapted DRERIP methodology, specific stressor scores are comparable across life history stages for a given species. With this in mind, stressor priorities presented in Section 8 have been summarized across life history stages for fall-run Chinook salmon, spring-run Chinook salmon, and *O. mykiss*, respectively.

All of the stressors considered for the different species and life history stages are deemed to be significant and of concern to the species and life history stage to which they have been assigned. However, to facilitate the application of the stressor analysis to development and sequencing of conservation measures to alleviate stressors, the stressors have been prioritized and grouped according to a suite of combined magnitude and certainty score-based stressor responses in three categories: actions, research, and monitoring. The severity of stressors was considered equal across life history stages, and final stressor scores were not weighted beyond the defined stressor magnitudes. For example, the final score assumed that major population effects that occur during adult spawning were equally as important as major population effects that occurred during juvenile rearing, and both stressors would have to be addressed to attain all Biological Objectives.

Stressors with both high magnitude and certainty scores are considered the highest priority for response in the form of conservation actions that will resolve the stressors and support attainment of Environmental Objectives (Figure 11). Low priority actions are defined as those actions with a lower magnitude and a high degree of certainty. Stressors with a high magnitude, but low degree of certainty, are considered the highest priority for research, with other research priorities decreasing based on their relative magnitude scores. Low magnitude stressors are prioritized under baseline monitoring needs, where higher certainty indicates a higher priority for monitoring, principally to ensure that the magnitude does not increase.

### *8.7.1 Stressor Prioritization Tables*

Stressor prioritization summary tables are presented for each species for coarse scale stresses (e.g., lack of suitable rearing habitat; Figures 24, 25, and 26) and fine scale stressors (e.g., lack of suitable rearing habitat as a function of temperature; Figures 27, 28, and 29). Each table is subdivided based on the three prioritized groups of stressor response types: actions, research, and monitoring. The three response type groups are staggered relative to one another to present their relative priority based on magnitude and certainty scores. For example, Priority 1 Research has the same relative priority as Priority 2 Actions. Four figures and tables—1) coarse and 2) fine scale priorities for both 3) near-term and 4) long-term populations—are presented for each of the three focal species (Figures 24 through 29 provide near term; long term is provided in Appendix D).

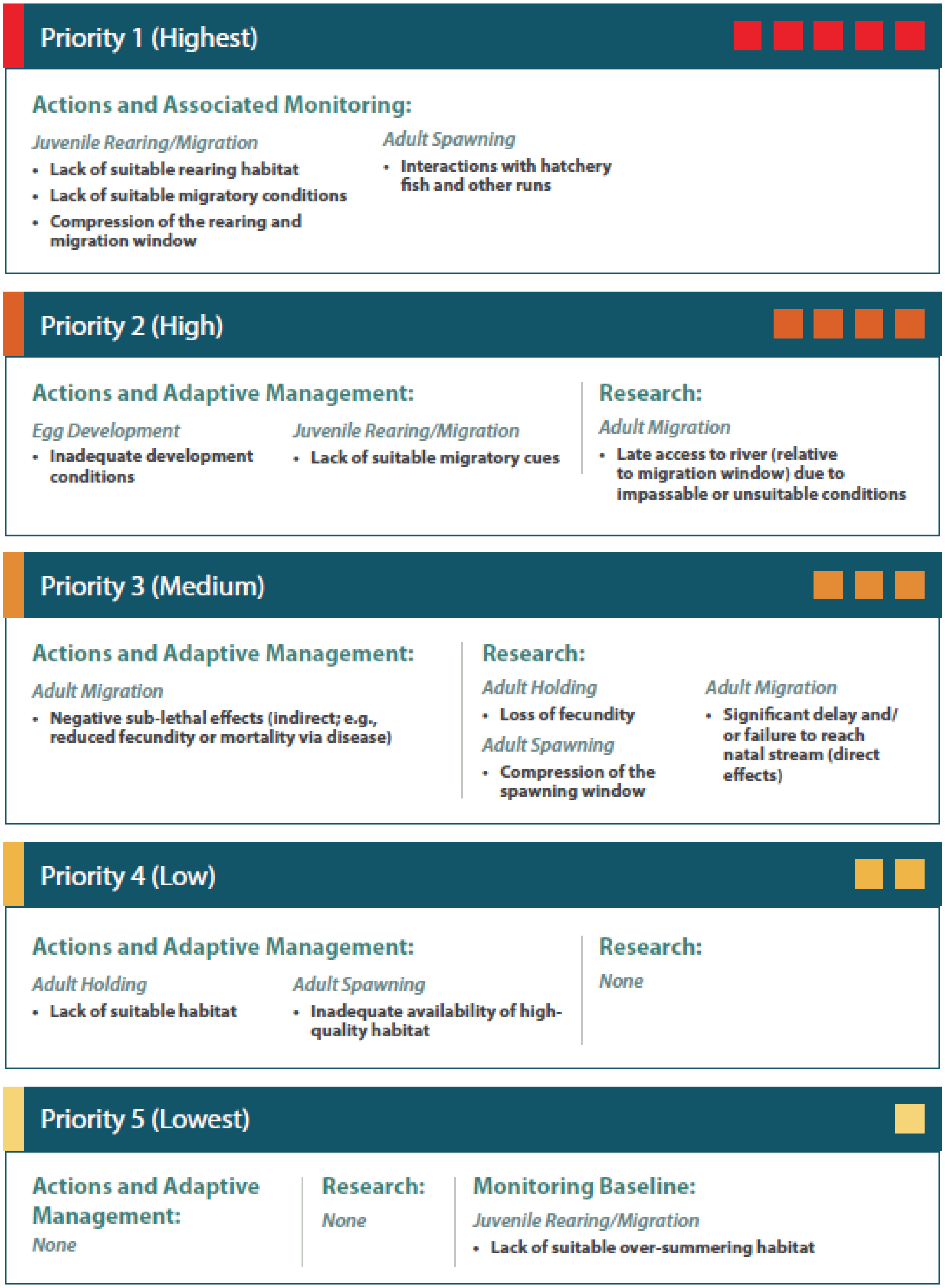



**Figure 24**

**Fall-run Chinook Salmon – Stressor Response Prioritization (Near Term/Coarse Scale)**

## Priority 1 (Highest)

**Actions and Associated Monitoring:**

*Adult Spawning*
- Interactions with hatchery fish and other runs

*Egg Development*
- Inadequate development conditions

*Juvenile Rearing/Migration*
- Lack of suitable rearing habitat
- Lack of suitable migratory conditions

## Priority 2 (High)

**Actions and Associated Monitoring:**

*Adult Holding*
- Lack of suitable habitat

**Actions and Adaptive Management:**

*Juvenile Rearing/Migration*
- Lack of suitable migratory cues

**Research:**

*Adult Holding*
- Loss of fecundity

*Adult Spawning*
- Compression of the spawning window

*Adult Migration*
- Negative sub-lethal effects (indirect; e.g., reduced fecundity or mortality via disease)

*Juvenile Rearing/Migration*
- Compression of the rearing and migration window

## Priority 3 (Medium)

**Actions and Adaptive Management:**

*Adult Spawning*
- Inadequate availability of high-quality habitat

**Research:**

*None*

## Priority 4 (Low)

**Actions and Adaptive Management:**

*None*

**Research:**

*Adult Migration*
- Significant delay and/or failure to reach natal stream (direct effects)

## Priority 5 (Lowest)

**Actions and Adaptive Management:**

*None*

**Research:**

*None*

**Monitoring Baseline:**

*Juvenile Rearing/Migration*
- Lack of suitable over-summering habitat

**Figure 25**

**Spring-run Chinook Salmon – Stressor Response Prioritization (Near Term/Coarse Scale)**

## Priority 1 (Highest)

### Actions and Associated Monitoring:

*Egg Development*

- **Inadequate developement conditions**

*Juvenile Rearing/Migration*

- **Lack of suitable rearing habitat**
- **Lack of suitable migratory conditions**

## Priority 2 (High)

### Actions and Associated Monitoring:

*Adult Holding*

- **Lack of suitable habitat**

### Actions and Adaptive Management:

*Juvenile Rearing/Migration*

- **Lack of suitable migratory cues**

## Priority 3 (Medium)

### Actions and Adaptive Management:

*None*

### Research:

*Adult Migration*

- **Negative Sub-lethal Effects (indirect; e.g., reduced fecundity or mortality via disease)**

*Adult Spawning*

- **Inadequate availability of high-quality habitat**

*Juvenile Rearing/Migration*

- **Compression of the rearing and migration window**

## Priority 4 (Low)

### Actions and Adaptive Management:

*None*

### Research:

*Adult Migration*

- **Significant delay and/or failure to reach natal stream (direct effects)**

*Adult Spawning*

- **Compression of the spawning window**

## Priority 5 (Lowest)

### Actions and Adaptive Management:

*None*

### Research:

*None*

### Monitoring Baseline:

*Juvenile Rearing/Migration*

- **Lack of suitable over-summering habitat**

**Figure 26**

**Steelhead – Stressor Response Prioritization (Near Term/Coarse Scale)**

## Priority 1 (Highest)

### Actions and Associated Monitoring:

*Adult Spawning*

- Interactions with hatchery fish and other runs – Hatchery

*Juvenile Rearing/Migration*

- Compression of the rearing and migration window – Temperature

## Priority 2 (High)

### Actions and Adaptive Management:

*Juvenile Rearing/Migration*

- Lack of fitness/genetic maladaptation – Hatchery introgression
- Lack of suitable migratory cues – Velocity
- Lack of suitable rearing habitat – Contaminants/toxins

### Actions and Associated Monitoring:

*Juvenile Rearing/Migration*

- Coarse sediment input
- Lack of suitable migratory conditions – Temperature

### Research to Inform Action Design:

*Adult Migration*

- Late access to river (relative to migration window) due to impassable or unsuitable conditions – Temperature, contaminants/attraction flow, DO
- Negative sub-lethal effects (indirect; e.g., reduced fecundity or mortality via disease) – Attraction flow, contaminants/toxins, DO

*Juvenile Rearing/Migration*

- Lack of suitable migratory conditions – Cover, velocity, habitat distribution
- Lack of suitable migratory cues – Temperature, turbidity

*Adult Spawning*

- Compression of the spawning window – Temperature

## Priority 3 (Medium)

### Actions and Adaptive Management:

*Adult Migration*

- Negative sub-lethal effects (indirect; e.g., reduced fecundity or mortality via disease) – Temperature

*Juvenile Rearing/Migration*

- Lack of suitable migratory conditions – Depth
- Lack of suitable rearing habitat – Cover, depth, temperature

### Actions and Associated Monitoring:

*Egg Development*

- Inadequate development conditions – Temperature

### Research to Inform Action Design:

*Adult Holding*

- Disease
- Lack of suitable habitat – Contaminants, cover
- Loss of fecundity – Contaminants, temperature
- Predator density

*Adult Spawning*

- Inadequate availability of high-quality habitat – Contaminants
- Coarse sediment input

*Egg Development*

- Inadequate development conditions – Fine sediments, flow fluctuation, redd scour, pesticides

*Juvenile Rearing/Migration*

- Disease
- Lack of suitable migratory conditions – Turbidity
- Lack of suitable rearing habitat – Turbidity, velocity

### Research to Confirm Need for Action:

*Adult Migration*

- Late access to river (relative to migration window) due to impassable or unsuitable conditions – Contaminants/ toxins
- Significant delay and/or failure to reach natal stream (direct effects) – Attraction flow

*Juvenile Rearing/Migration*

- Lack of suitable migratory conditions – Prey density
- Predator density

## Priority 4 (Low)

### Actions and Adaptive Management:

*Adult Holding*
- Lack of suitable habitat – Temperature

*Adult Spawning*
- Inadequate availability of high-quality habitat – Temperature

*Juvenile Rearing/Migration*
- Lack of suitable migratory conditions – Contaminants/toxins
- Compression of the rearing and migration window – DO

### Research to Evaluate Need for Action:

*Adult Migration*
- Negative sub-lethal effects (indirect; e.g., reduced fecundity or mortality via disease) – Passable physical barriers (including low water)
- Significant delay and/or failure to reach natal stream (direct effects) – DO, temperature

*Juvenile Rearing/Migration*
- Lack of suitable over-summering habitat – Cover
- Lack of suitable rearing habitat – Prey density

## Priority 5 (Lowest)

### Actions and Adaptive Management:

*None*

### Research to Confirm Action is Not Warranted:

*Adult Holding*
- Lack of suitable habitat – Depth, DO, velocity
- Loss of fecundity – Depth, DO, velocity
- Poaching

*Adult Spawning*
- Compression of the spawning window – DO
- Disease
- Inadequate availability of high-quality habitat – Cover, depth, velocity, DO
- Poaching

*Juvenile Rearing/Migration*
- Lack of suitable migratory conditions – DO
- Lack of suitable over-summering habitat – Contaminants/toxins, velocity
- Lack of suitable rearing habitat – DO

### Research to Understand Magnitude:

*Adult Migration*
- Significant delay and/or failure to reach natal stream (direct effects) – Contaminants/toxins, poaching

*Adult Spawning*
- Predator density

*Juvenile Rearing/Migration*
- Lack of suitable migratory cues – DO
- Lack of suitable over-summering habitat – Depth, DO, turbidity

### Monitoring to Ensure No Action is Warranted:

*Adult Holding*
- Coarse sediment input

*Egg Development*
- Inadequate development conditions – Flow fluctuation, redd dewatering

*Juvenile Rearing/Migration*
- Lack of suitable over-summering habitat – Temperature

### Monitoring to Track Magnitude:

*Adult Spawning*
- Interactions with hatchery fish and other runs – Run segregation
- Inadequate availability of high-quality habitat – Spatial distribution

*Egg Development*
- Inadequate development conditions – Contaminants/toxins, DO

**Figure 27**

**Fall-run Chinook Salmon – Stressor Response Prioritization (Near Term/Fine Scale)**

## Priority 1 (Highest)

### Actions and Associated Monitoring:

*Juvenile Rearing/Migration*
- Coarse sediment input

## Priority 2 (High)

### Actions and Associated Monitoring:

*Adult Holding*
- Lack of suitable habitat – Temperature

*Egg Development*
- Inadequate development conditions – Temperature

*Juvenile Rearing/Migration*
- Lack of suitable migratory conditions – Temperature

### Actions and Adaptive Management:

*Adult Spawning*
- Interactions with hatchery fish and other runs – Run segregation

*Juvenile Rearing/Migration*
- Lack of suitable migratory conditions – Velocity
- Lack of suitable migratory cues – Velocity
- Lack of suitable rearing habitat – Contaminants/toxins, velocity

### Research to Inform Action Design:

*Adult Holding*
- Loss of fecundity – Contaminants

*Adult Migration*
- Negative sub-lethal effects (indirect; e.g., reduced fecundity or mortality via disease – Temperature, attraction flow, DO

*Adult Spawning*
- Compression of the spawning window – Temperature

*Juvenile Rearing/Migration*
- Compression of the rearing and migration window – Temperature
- Lack of suitable migratory conditions – Cover, habitat distribution
- Lack of suitable migratory cues – Turbidity

## Priority 3 (Medium)

### Actions and Adaptive Management:

*Adult Spawning*
- Inadequate availability of high-quality habitat – Spatial distribution, temperature

*Juvenile Rearing/Migration*
- Lack of suitable migratory conditions – Depth
- Lack of suitable over-summering habitat – Contaminants/toxins
- Lack of suitable rearing habitat – Cover, depth, temperature

### Research to Inform Action Design:

*Adult Holding*
- Disease
- Lack of suitable habitat – Contaminants, cover
- Loss of fecundity – Temperature
- Predator density

*Egg Development*
- Inadequate development conditions – Fine sediments, flow fluctuation, redd scour, pesticides

*Adult Spawning*
- Inadequate availability of high-quality habitat – Contaminants

*Juvenile Rearing/Migration*
- Disease
- Lack of suitable migratory conditions – Turbidity
- Lack of suitable rearing habitat – Turbidity
- Predator density

## Priority 4 (Low)

### Actions and Adaptive Management:

*Adult Spawning*

- Interactions with hatchery fish and other runs – Hatchery

*Juvenile Rearing/Migration*

- Lack of suitable migratory conditions – Contaminants/toxins

### Research to Evaluate Need for Action:

*Adult Migration*

- Negative sub-lethal effects (indirect; e.g., reduced fecundity or mortality via disease) – Contaminants/toxins, passable physical barriers (including low water)
- Significant delay and/or failure to reach natal stream (direct effects) – Contaminants/toxins, DO, poaching, temperature, attraction flows

*Adult Spawning*

- Compression of the spawning window – DO

*Juvenile Rearing/Migration*

- Lack of suitable migratory conditions – Prey density
- Lack of suitable over-summering habitat – Cover
- Lack of suitable rearing habitat – Prey density

## Priority 5 (Lowest)

### Actions and Adaptive Management:

*None*

### Research to Confirm Action is Not Warranted:

*Adult Holding*

- Lack of suitable habitat – Depth, DO, velocity
- Loss of fecundity – Depth, DO, velocity
- Poaching

*Adult Spawning*

- Disease
- Inadequate availability of high-quality habitat – Cover, depth, velocity, DO
- Poaching
- Predator density

*Juvenile Rearing/Migration*

- Compression of the rearing and migration window – DO
- Lack of suitable migratory conditions – DO
- Lack of suitable over-summering habitat – Velocity
- Lack of suitable rearing habitat – DO

### Research to Understand Magnitude:

*Juvenile Rearing/Migration*

- Lack of fitness/genetic maladaptation – Hatchery introgression
- Lack of suitable migratory cues – DO
- Lack of suitable over-summering habitat – Depth, turbidity

### Monitoring to Ensure No Action is Warranted:

*Adult Holding*

- Coarse sediment input

*Adult Spawning*

- Coarse sediment input

*Egg Development*

- Inadequate development conditions – Flow fluctuation, redd dewatering

*Juvenile Rearing/Migration*

- Lack of suitable over-summering habitat – Temperature, DO
- Lack of suitable migratory cues – Temperature

### Monitoring to Track Magnitude:

*Egg Development*

- Inadequate development conditions – Contaminants/toxins, DO

**Figure 28**

**Spring-run Chinook Salmon – Stressor Response Prioritization (Near Term/Fine Scale)**

## Priority 1 (Highest)

### Actions and Associated Monitoring:

*Juvenile Rearing/Migration*

- Coarse sediment input

## Priority 2 (High)

### Actions and Associated Monitoring:

*Adult Holding*

- Lack of suitable habitat – Temperature

*Egg Development*

- Inadequate development conditions – Temperature

### Actions and Adaptive Management:

*Juvenile Rearing/Migration*

- Lack of suitable migratory conditions – Velocity
- Lack of suitable migratory cues – Velocity
- Lack of suitable rearing habitat – Contaminants/toxins, velocity

### Research to Inform Action Design:

*Adult Holding*

- Lack of suitable habitat – Contaminants

*Adult Spawning*

- Interactions with hatchery fish and other runs – Hatchery

*Juvenile Rearing/Migration*

- Predator density
- Lack of suitable migratory conditions – Cover
- Lack of suitable migratory cues – Turbidity, temperature
- Lack of suitable over-summering habitat – Depth

## Priority 3 (Medium)

### Actions and Associated Monitoring:

*Juvenile Rearing/Migration*

- Lack of suitable migratory conditions – Temperature

### Actions and Adaptive Management:

*Adult Holding*

- Coarse sediment input

*Juvenile Rearing/Migration*

- Lack of suitable migratory conditions – Depth, temperature
- Lack of suitable over-summering habitat – Contaminants/toxins
- Lack of suitable rearing habitat – Cover, depth

### Research to Inform Action Design:

*Adult Holding*

- Disease
- Lack of suitable habitat – Cover
- Poaching
- Predator density

*Adult Migration*

- Negative sub-lethal effects (indirect; e.g., reduced fecundity or mortality via disease) – Temperature, contaminants/toxins, attraction flows

*Egg Development*

- Inadequate development conditions – Flow fluctuation, redd scour, pesticides

*Adult Spawning*

- Inadequate availability of high-quality habitat – Contaminants, temperature
- Predator density

*Juvenile Rearing/Migration*

- Compression of the rearing and migration window – Temperature, DO
- Disease
- Lack of suitable migratory conditions – Turbidity
- Lack of suitable rearing habitat – Turbidity
- Lack of suitable migratory cues – Prey density
- Lack of fitness/genetic maladaptation – Hatchery introgression
- Lack of suitable habitat – Prey density

## Priority 4 (Low)

### Actions and Adaptive Management:

*Adult Spawning*

- Coarse sediment input

*Juvenile Rearing/Migration*

- Lack of suitable migratory conditions – Contaminants/toxins

### Research to Evaluate Need for Action:

*Adult Migration*

- Negative sub-lethal effects (indirect; e.g., reduced fecundity or mortality via disease) – DO
- Significant delay and/or failure to reach natal stream (direct effects) – DO, temperature, attraction flows

*Adult Spawning*

- Compression of the spawning window – DO, temperature

*Egg Development*

- Inadequate development conditions – Fine sediments

*Juvenile Rearing/Migration*

- Lack of suitable migratory conditions – Prey density
- Lack of suitable over-summering habitat – Cover
- Lack of suitable rearing habitat – Prey density

## Priority 5 (Lowest)

### Actions and Adaptive Management:

*None*

### Research to Confirm Action is Not Warranted:

*Adult Holding*

- Lack of suitable habitat – Depth, DO, velocity

*Adult Spawning*

- Disease
- Inadequate availability of high-quality habitat – Cover, depth, velocity
- Poaching

*Juvenile Rearing/Migration*

- Lack of suitable migratory conditions – DO
- Lack of suitable over-summering habitat – Velocity
- Lack of suitable rearing habitat – DO

### Research to Understand Magnitude:

*Adult Migration*

- Significant delay and/or failure to reach natal stream (direct effects) – Contaminants/toxins, poaching

*Adult Spawning*

- Inadequate availability of high-quality habitat – Spatial distribution

*Juvenile Rearing/Migration*

- Lack of suitable migratory cues – DO
- Lack of suitable over-summering habitat – DO, turbidity

### Monitoring to Ensure No Action is Warranted:

*Adult Migration*

- Negative sub-lethal effects (indirect; e.g., reduced fecundity or mortality via disease) – Passable physical barriers (including low water)

*Adult Spawning*

- Inadequate availability of high-quality habitat – DO

*Egg Development*

- Inadequate development conditions – Flow fluctuation, redd dewatering

### Monitoring to Track Magnitude:

*Egg Development*

- Inadequate development conditions – Contaminants/toxins, DO

*Juvenile Rearing/Migration*

- Lack of suitable over-summering habitat – Temperature
- Lack of suitable rearing habitat – Temperature

**Figure 29**

***O. mykiss* – Stressor Response Prioritization (Near Term/Fine Scale)**

While the stressor response prioritization figures and tables prioritize stresses (by life history stage), this is not meant to imply that stressor responses need to be conducted in the presented sequence in order to be effective. Stressor responses of different priorities can be addressed simultaneously. Additionally, the potential suite of actions necessary to resolve a single stressor may partially or completely resolve other stressors. There may also be a number of non-biological considerations (e.g., physical, political, and financial) that influence the timing and sequence with which conservation measures are implemented as stressor responses. However, the stressor response prioritization figures and tables are designed to provide guidance for the following:

- Which stressors are of greatest biological impact to the species
- How conservation measures should be optimally sequenced for the greatest biological benefit when not all stressors can be addressed simultaneously
- What the complete suite of stressor responses necessary to achieve Biological Objectives looks like

The coarse scale stressor figures (Figures 24 through 26) and tables in Appendix D are designed to provide a high-level sense of the critical issues facing each species and the broad categories of responses necessary to achieve Biological and Environmental Objectives. The fine scale stressor figures (Figures 27 through 29) and tables in Appendix D detail the specific attributes of environmental conditions where objectives are not being met to help guide targeted remediation actions. Both the stress and stressor prioritization and response figures and tables are further subdivided based on near-term responses (current and recovering population; Figures 24 through 29) and long-term responses (target population; Appendix D). Changes in stressor magnitude from the near term to the long term are principally driven by higher fish population size, long-term forcing factors (e.g., climate change), or the hypothesized effect of current trends carried out over time (e.g., climate-driven warming). To highlight what is most immediately relevant for the development of conservation measures, the stressor prioritization discussion in Sections 8.7.2 through 8.7.4 focuses on near-term priorities for each of the three species.

## *8.7.2 Priority Stressors and Responses – Fall-run Chinook Salmon*

### 8.7.2.1 Actions

For fall-run Chinook salmon in the Stanislaus River, the stressor analysis indicates that the juvenile life history stage is stressed to the greatest extent. At the coarse scale, stresses to juveniles necessitating high priority actions in the short term include lack of suitable rearing habitat, lack of suitable migratory conditions, compressions of the rearing and migration window, and lack of suitable migratory cues (Figure 24). Fine scale stressors for juveniles driving coarse scale stress include compression of the migration window in response to unsuitable temperatures and temperature for migration (in both the main channel and off-channel/floodplain). The availability of high-quality rearing habitat is limited by contaminants and toxins present in the Stanislaus River during the rearing and migration windows; suitable migratory cues are limited by low velocity; and coarse sediment input is impacting rearing and migration conditions. A lack of fitness/genetic maladaptation is limited by hatchery introgression. Though to a lesser degree than the presence of contaminants and toxins, the availability of high-quality rearing habitat is also limited by suitable depth, cover, and temperature, and the availability of high-quality migratory conditions is limited by suitable depth (Figure 27).

High priority actions in the near term are necessary to address stresses for spawning adults; to reduce interactions and introgression from hatchery stocks; and for eggs to improve development conditions in the area of temperature as well as a number of other parameters for which the extent of limitation is still not well understood (Section 8.7.2.2). Negative sub-lethal effects on migrating adults from unsuitable temperatures require near-term action, albeit at a slightly lower priority.

#### 8.7.2.2 Research and Monitoring

Stressors for fall-run Chinook salmon that are the highest priority for research to inform actions relate to delay and the effects of potentially late access to spawning grounds for migrating adults. Of particular concern for migrating adults are the effects of reduced attraction flow, low DO levels, high contaminant levels, and unsuitable temperatures during the migration and spawning windows. Additional stressors that are a high priority for research are rearing habitat distribution, cover, and velocity as they relate to the in-channel migratory conditions for juveniles and juvenile migratory cues related to temperature and turbidity (Figures 24 and 27).

### *8.7.3 Priority Stressors and Responses – Spring-run Chinook Salmon*

#### 8.7.3.1 Actions

For spring-run Chinook salmon in the Stanislaus River, the stressor analysis indicates that high priority stressors affect almost all life history stages. Coarse scale stresses to juvenile spring-run Chinook salmon necessitating high priority actions in the near term include lack of suitable rearing habitat and lack of suitable migratory conditions (Figure 25). Fine scale stressors driving these coarse scale stresses that need near-term remediation include lack of coarse sediment and substrate, temperature and velocity conditions throughout the migratory corridor (in both the main channel and off-channel), contaminant levels and velocity in rearing habitat, and lack of sufficient velocity to cue and support juvenile migration (Figure 28).

High priority actions in the near term are necessary to alleviate stressors for spawning adults, including interactions with hatchery fish and habitat segregation for salmon runs. Lack of suitable holding habitat for adults is also a high priority for action at the coarse scale level, with unsuitable temperatures being the primary issue. Conditions for developing eggs are also a high priority for spring-run Chinook salmon, with temperature being the primary factor in need of remediation through action (Figure 28).

#### 8.7.3.2 Research and Monitoring

Based on the stressor analysis, the stresses for spring-run Chinook salmon that are the highest priority for research are related to negative sub-lethal effects during adult migration, loss of fecundity in holding fish, and compressions of the spawning window. Specific concerns related to adult migration, holding, and spawning life history stages are principally related to lack of attraction flow (migration), unsuitable temperatures (migration and spawning), unsuitable DO levels (migration), and high contaminant levels (holding). Additional stressors that are a high priority for research include compression of the juvenile rearing and migration window as a result of unsuitable temperatures, suitable migratory conditions related to cover and habitat distribution for juveniles, and suitable migratory cues related to turbidity. Lower priority stressors that are important for research in the near term include the following (Figures 25 and 28):

- Inadequate egg development conditions as a function of contaminants and pesticides, redd scour due to flow fluctuation, and fine sediment impacts on egg survival
- Impact of disease on adult holding and migrating and rearing juveniles
- Contaminants present in adult holding and spawning areas
- Loss of fecundity due to temperature conditions in holding areas
- Predator density-driven predation in holding areas and on juvenile outmigrants
- Lack of suitable rearing habitat relative to turbidity

### *8.7.4 Priority Stressors and Responses – O. mykiss*

#### 8.7.4.1 Actions

For *O. mykiss* in the Stanislaus River, high priority stressors affect almost all life history stages. The lack of suitable rearing conditions, migratory conditions, and migratory cues are the highest priority stresses for juveniles (Figure 26). The lack of suitable holding habitat conditions for adults and inadequate development conditions for eggs and embryos also rank among the highest priority. Fine scale stressors driving the high priority for juvenile rearing include a lack of coarse substrate, unsuitable (low) velocity (in channel), and high levels of contaminants and pesticides. For juvenile migration and migratory cues (Figure 29), a lack of sufficient velocity and velocity variability are the most acute, specific stressors in need of near-term remediation. Though slightly lower in priority, suitability of depth and cover for in-channel habitat, temperature in the migratory corridor, and contaminants in over-summering habitat are also in need of action to improve juvenile rearing and migration. For adult holding conditions and egg development conditions, temperature is the primary stressor driving the high priority for near-term action and, to a lesser extent, a lack of coarse sediment in holding areas (Figure 29).

#### 8.7.4.2 Research and Monitoring

Stressors for steelhead that are the highest priority for research include the following (Figure 29):

- Lack of suitable temperature conditions as migratory cues for juveniles or variable or unsuitable temperatures (to promote migration), especially during the summer months
- Lack of turbidity and cover as a component of migratory conditions for juveniles
- Lack of suitable over-summering habitat relative to depth
- Predator density-driven predation rates on juvenile outmigrants

Also among the highest research priorities are the effects of contaminants and pesticides on adult holding conditions as well as the influence of hatchery introgression on adult spawning and reproductive success.

Additional stressors in need of research, though at a lower level of priority, include the following:

- Negative sub-lethal effects from a lack of attraction flow, unsuitable temperatures, and contaminants and pesticide levels for migratory adults
- Impacts to spawning habitat from temperature, predator density, and presence of contaminants
- Effects of disease, lack of cover, poaching, and predator density on adult holding conditions
- Redd scour due to flow fluctuations and pesticide levels relative to egg development
- Limitations to juvenile rearing habitat quality resulting from low turbidity, low prey density, disease, lack of fitness from hatchery genetics, and temperature and DO effects on compressing the rearing and migration window

### *8.7.5 Application of Stressors to Conservation Measure Development and Adaptive Management*

When combined with the Biological and Environmental Objectives, the stressor analysis provides the basis for the following:

- Prioritizing conservation measures (including habitat enhancement actions and research) for maximum biological benefit
- Understanding the full range and extent of conservation measures necessary to support population recovery
- Setting expectations related to the extent of conservation measures required to alleviate stress to see progress towards the Biological Objectives for a given life history

Stressors are the obstacles to achieving the desired conditions identified through the Environmental Objectives process and removing them are necessary for the species to attain the target population conditions quantified in the Biological Objectives. For any given life history stage, progress towards the Biological Objectives can only be expected once the high priority stressors have been addressed and Environmental Objectives are largely achieved. The efficacy of conservation measures designed to reduce stressors should therefore be measured based on the extent to which those measures advance or achieve Environmental Objectives. Once Environmental Objectives have been significantly advanced—or achieved via the resolution of priority stressors—Biological Objectives become the following:

- Metrics to measure species response to the actions
- Triggers for adaptive management in the case where Environmental Objectives do not result in the predicted biological response

Although Environmental Objectives and stressors do not have a one-to-one relationship with Biological Objectives, there are several core relationships among them that, for a given life history stage, can serve to guide expectations around biological response to the attainment of Environmental Objectives.

**Habitat Quality → Survival**

Given the carrying capacity associated with a given spatial area of habitat, fish condition and survival are largely linked with habitat quality as defined by Environmental Objectives and stressors for a given life history stage. Attainment of Environmental Objectives for habitat quality via resolution of high priority stressors for a given life history stage should therefore trigger a response in biological metrics (and make progress towards objectives) related to the survival rate for individuals of that life history stage, given the limits to carrying capacity. For example, attainment of the habitat quality objectives for egg development should be measurable in terms of progress towards Biological Objectives for egg survival.

**Habitat Spatial Extent → Abundance**

Given habitat quality and suitability (as quantified by the Environmental Objectives) and associated survival rates, increased spatial extent of suitable habitat increases carrying capacity for that life history stage. Increases in habitat spatial extent should therefore be measurable in biological metrics (and make progress towards objectives) related to abundance for that life history stage to the extent that abundance is constrained by carrying capacity. For example, attainment of the habitat quantity objectives for adult holding and spawning habitat should be measurable in terms of progress towards Biological Objectives for adult in-river and spawner abundance.

**Habitat Temporal Extent → Diversity and Resilience**

Given sufficient habitat quality and spatial extent, the temporal extent and availability of habitat increases the potential for a given life history stage to express diversity. The range of diversity expressions for each life history stage, across life history stages, comprise the resilience of the cohort. Similarly, the resilience of the individual cohorts, across multiple cohorts, comprise the resilience of the population. Attainment of Environmental Objectives for habitat temporal availability for a given life history stage should trigger a response in biological metrics (and make progress towards objectives) related to diversity in that life history stage or, across life history stages, resilience in the cohort and population. For example, attainment of the temporal extent objectives for juvenile rearing and migration should be measurable in terms of progress towards Biological Objectives for juvenile diversity.

Even when the primary stressors for a given life history stage have been addressed, certain Biological Objectives (e.g., population growth and abundance) require success across multiple or all life history stages. Therefore, it becomes necessary for the high priority stressors to be addressed and the Environmental Objectives to be achieved for all life story stages in order to see meaningful progress towards the full suite of Biological Objectives.

# 9 Moving Forward: Design and Implementation of a Conservation Strategy, Monitoring, and Adaptive Management

Good decisions are defined by the process in which they were generated and how the decision framework incorporates new information in order to reduce uncertainty and improve decision outcomes (Williams et al. 2009). The process of developing the SEP's objectives and stressor evaluations represents a significant advance in the application of science to improve understanding of conservation needs and challenges in the Stanislaus River and throughout the San Joaquin River basin. When the SEP began, participating organizations and agencies often had very different definitions of conservation success for the Stanislaus River, and those desired outcomes were often not clearly articulated. Similarly, many of the participating scientists entered the SEP with an internal (but unarticulated) conceptual model of the key problems and limits that prevented attainment of desired biological outcomes. The goals, objectives, and stressor rankings emerging from this process represent a new scientific consensus around a vision of what the Stanislaus River can be expected to attain with regard to salmon restoration, how this vision fits into the requirements of existing policy for the Central Valley as a whole, and a shared conceptual model regarding the numerous barriers to attainment of the vision generated by the current landscape and water management practices in the Stanislaus River.

There is no silver bullet for restoring populations of fall-run Chinook salmon, spring-run Chinook salmon, or *O. mykiss* on the Stanislaus River. The stressor evaluation presented in Section 8—which is based on comparisons of current conditions to the best available science regarding desired environmental conditions for salmonids—reveals that a comprehensive conservation strategy is needed, and it must include a variety of actions to address a wide range of high priority barriers that occur throughout the freshwater life cycle of target salmonid populations. Some actions may require engineered solutions; however, some conservation actions may require the implementation of habitat-forming processes (i.e., restore the natural processes that created the desired environmental conditions) to ensure the long-term maintenance of desired environmental conditions in the river (Beechie and Bolton 1999).

The SEP Group's products provide the essential framework for designing an effective and efficient conservation strategy that can produce desired outcomes on the Stanislaus River (Watershed-Specific Goals) and ensure that this watershed is contributing to attainment of larger laws and policies regarding salmonid restoration throughout the Central Valley (i.e., Central Valley Goals and Objectives). These products will support the prioritization of conservation actions by helping planners to make good decisions based on the best available science and to avoid the misallocation of limited resources to actions or monitoring that are not part of the critical path to successful outcomes.

## 9.1 Using SEP Products in Adaptive Management

Adaptive management is a systematic approach for improving resource management by learning and adapting from management outcomes through partnerships of managers, scientists, and other stakeholders who learn together how to create and maintain sustainable resource systems (Sexton et al. 1999). Throughout this report, the SEP Group has described how the products developed in this report can serve in managing towards its vision of conservation success in an adaptive fashion. Specific opportunities for adaptive management are identified in Section 8.

Three elements are necessary for a program to follow the USDOI adaptive management protocol (Williams et al. 2009). First, decisions must be recurrent to allow opportunities for learning to influence future decision making. Second, decisions must be based on predictions that incorporate structural uncertainty; often this will be represented by two or more alternative models or hypotheses about system functionality. Third, there must be an objective-driven monitoring program. Where these three elements are present, adaptive management is a critical component of resource management that allows implementation and improvement of conservation strategies in the face of uncertainty. These three elements either are described or are implicit in the framework, approach, and results presented in this report.

Each component of the SEP framework is essential to adaptively managing a comprehensive salmonid conservation strategy. The Biological Objectives represent the minimum conditions necessary to achieve Watershed-Specific Goals for the Stanislaus River and its contribution to Central Valley Goals and Objectives for anadromous fish restoration. All management activities must be oriented toward attainment of the Biological Objectives and may be modified over time, as necessary, to achieve those objectives. In other words, prior to selection and implementation of conservation actions, proposed actions must be evaluated based on their ability to support the Biological Objectives, and, following implementation, monitoring will be needed to assess whether the actions' expected benefits materialize. Because it is difficult to measure the direct effect of individual actions on phenomena described in the Biological Objectives, the Environmental Objectives provide the physical design criteria against which conservation actions (individually and collectively) can be evaluated. Environmental Objectives represent hypotheses of the environmental conditions needed to achieve the Biological Objectives. Stressors, and their relative magnitude and certainty scores, represent hypotheses regarding existing and expected future barriers to attainment of Environmental and/or Biological Objectives. Finally, conservation actions will represent hypotheses about the best way to ameliorate stressors and attain Environmental and Biological Objectives.

## 9.2 Next Steps for the Stanislaus River: Designing, Evaluating, Implementing, and Monitoring Conservation Actions

The next steps in developing a comprehensive conservation strategy for salmonids in the Stanislaus River will be the design of a suite of specific conservation actions, including the monitoring elements needed to evaluate the performance of actions individually and collectively. Such actions can and should be evaluated based on their ability to alleviate the priority stressors identified in Section 8 and to produce the Biological and Environmental Objectives described in Sections 6 and 7, respectively. Taken together, stressors and Environmental Objectives display, in practical terms, the scale of the problems that need to be solved. For instance, many off-channel habitat restoration projects will be required to fully alleviate the stress generated by "Lack of suitable rearing habitat" for juvenile Chinook salmon and steelhead (Section 8 and Figures 24, 25, and 26). Without explicitly defined objectives and prioritization of stressors, those who develop and/or evaluate conservation actions would not have an appropriate biological basis for comparing competing sets of habitat restoration proposals. In addition, they would have no benchmark to determine how the need for this kind of action changes as more projects are implemented (i.e., no way to know when habitat restoration actions are approaching a level where "lack of suitable rearing habitat" is no longer the highest priority stressor).

By articulating Watershed-Specific Goals; expressing those goals in S.M.A.R.T. terms in the Biological and Environmental Objectives; and identifying, describing, evaluating, and prioritizing stressors, this report provides a clear vision of desired biological outcomes and makes transparent the linkage between that vision and subsequent conservation actions. Prior to selection and implementation of conservation actions, stakeholders, resource managers, and decision makers can evaluate the specific contributions of different conservation actions (alone and together) to the Biological and Environmental Objectives. Following implementation of conservation actions, information developed through monitoring can be synthesized to allow measurement of an action's effects in terms of the environmental conditions (Stressors and Environmental Objectives) it was intended to modify. This comparison enables efficient adjustment of conservation actions and adaptation of the conservation strategy, as needed. If monitoring indicates that conservation actions are not performing as intended, changes to the actions or additional actions will be implemented to ensure that Environmental Objectives and Biological Objectives are reached. Conversely, if Biological Objectives are attained prior to implementing the full suite of conservation actions, then the conservation strategy can be modified.

Implementation of the conservation actions will require various levels of monitoring, including site-specific monitoring to document compliance and performance of specific measures and system-wide monitoring to evaluate overall effectiveness. Monitoring activities will need to produce data that is relevant to assessing progress at all levels of the "logic chain" structure (Figure 3).

Monitoring results should inform managers whether progress is being made towards the following four outcomes:

1. Intended performance of individual conservation actions
2. Stressor reduction/elimination
3. Environmental Objectives
4. Biological Objectives

Monitoring needed to assess the performance of conservation actions can only be determined after the conservation strategy is described in detail. However, the monitoring needed to evaluate progress towards larger desired outcomes (items 2 through 4 in the list above) has been defined by the performance metrics presented in this report.

Measurability of Biological and Environmental Objectives was a key consideration in their design and expression. Indeed, established monitoring programs already provide information to track changes in biological and environmental conditions that are described in the objectives (Tables 66 and 67). These monitoring efforts may need to be refined or expanded in order to fully evaluate progress, but the long data series already established by these programs makes them particularly valuable in evaluating changes in environmental conditions and biological responses to those conditions. For example, the duration and frequency of operation of RSTs and the salmon counting weir may need to be expanded and juvenile sampling at Mossdale may need to be refined. Where current monitoring in the Stanislaus and lower San Joaquin rivers does not directly address Biological Objectives, the SEP Group considered whether monitoring was possible (i.e., that all objectives are measurable) with currently available technology. Several new elements of a monitoring and assessment plan needed to track objectives and stressors developed by the SEP Group are identified in Tables 66 and 67, though the information in these tables is not comprehensive.

**Table 66**
**Current and Potential Monitoring that Could be Used to Measure Progress Towards SEP Biological Objectives**

| Biological Objective Type | Species | Life History Stage | Specific Objective | Relevant Current Monitoring (Monitoring Agency) | Relevant Monitoring Needed |
|---|---|---|---|---|---|
| Productivity | All | Egg | Egg-emergence to Oakdale RST survival | Adult escapement at counting weir (USFWS weir – Tri-Dam funds);<br>life history investigations (e.g., escapement and carcass surveys; CDFW);<br>Oakdale RST catch (Tri-Dam – currently not shared) | To be determined |
| Productivity | All | Egg | Viability | None | Requires incubation chamber (in hatchery or on site) measured by surrogates (e.g., egg trays) and/or as projected by monitoring of temperature, flow, sediment deposition, and scour |
| Productivity | All | Egg | Development success | None | Spawning surveys, redd mapping (superimposition), redd capping |
| Life History Diversity | Chinook salmon fall-run (FR) and spring-run (SR) | Adult migration | Migration timing | Adult Escapement at counting weir (USFWS weir – Tri-Dam funds);<br>Life history investigations (e.g., escapement and carcass surveys; CDFW) | To be determined |
| Productivity | Chinook salmon FR and SR | Adult migration and spawning | Abundance | Adult Escapement at counting weir (USFWS weir – Tri-Dam funds);<br>Life history investigations (e.g., escapement and carcass surveys; CDFW) | To be determined |
| Productivity | Chinook salmon FR and SR | Adult migration and holding | Survival | Adult Escapement at counting weir (USFWS weir – Tri-Dam funds);<br>Life history investigations (e.g., escapement and carcass surveys; CDFW) | Include surveys for SR |
| Life History Diversity | Chinook salmon FR-SR | Adult migration and spawning | Spawning timing | Adult Escapement at counting weir (USFWS weir – Tri-Dam funds);<br>Life history investigations (e.g., escapement and carcass surveys; CDFW) | Include surveys for SR |
| Productivity | Chinook salmon FR and SR | Adult migration and spawning | Prespawn mortality | Adult Escapement at counting weir (USFWS weir – Tri-Dam funds);<br>Life history investigations (e.g., escapement and carcass surveys; CDFW) | Include surveys for SR |
| Productivity | Chinook salmon FR and SR | Juvenile emigration | in river (egg to delta) survival | Adult Escapement at counting weir (USFWS weir – Tri-Dam funds);<br>Life history investigations (e.g., escapement and carcass surveys; CDFW);<br>Caswell RST catch (USFWS);<br>Mossdale trawl (CDFW) | Include surveys for SR;<br>Add or modify surveys at Mossdale to more accurately/frequently survey migrating salmonids, and smaller fish in particular;<br>Otolith microchemistry to distinguish juveniles from different natal streams in the lower San Joaquin |
| Genetic | Chinook salmon FR and SR | Adult migration and spawning | Percentage of hatchery-origin spawners | Adult Escapement at counting weir (USFWS weir – Tri-Dam funds);<br>Life history investigations (e.g., escapement and carcass surveys; CDFW) | Include surveys for SR |
| Genetic | Chinook salmon FR and SR | Juvenile emigration | Percent introgression (SR-FR) | None | Genetic testing of outmigrating juveniles |
| Life History Diversity | Chinook salmon FR and SR | Juvenile emigration | Size, timing, and proportion of migrants; number of yearlings | Caswell RST catch (USFWS) | Include surveys for SR;<br>Add or modify surveys at Mossdale to more accurately/frequently survey migrating salmonids, and smaller fish in particular;<br>Otolith microchemistry to distinguish juveniles from different natal streams in the lower San Joaquin |
| Productivity | *O. mykiss* (steelhead) | Juvenile emigration | Smolt survival down the river and size and proportion of smolt migrants | None | Inclined-screen traps and video cameras, Didson cameras (imaging sonar system), or mark-resight estimates based on PIT tagging (some data from RST) |
| Productivity | *O. mykiss* (steelhead) | Juvenile emigration | Number of smolts (> 150 mm) per female spawner and total number of smolts per female spawner | Adult escapement at counting weir (USFWS weir – Tri-Dam funds);<br>Life history investigations (e.g., escapement and carcass surveys; CDFW); Caswell RST catch (USFWS) | Inclined-screen traps and video cameras, Didson cameras (imaging sonar system), or mark-resight estimates based on PIT tagging (some data from RST) |
| Productivity | *O. mykiss* | Juvenile rearing | Parr density | Snorkel surveys (USBR) | Electrofishing or other appropriate sampling |
| Productivity | *O. mykiss* (steelhead) | Juvenile rearing | Number of smolts (> 150 mm) per female spawner and total number of smolts per female spawner | Adult escapement at counting weir (USFWS weir – Tri-Dam funds);<br>Life history investigations (e.g., escapement and carcass surveys; CDFW);<br>Caswell RST catch (USFWS) | Inclined-screen traps and video cameras, Didson cameras (ARIS), or mark-resight estimates based on PIT tagging (some data from RST) |

| Biological Objective Type | Species | Life History Stage | Specific Objective | Relevant Current Monitoring (Monitoring Agency) | Relevant Monitoring Needed |
|---|---|---|---|---|---|
| Productivity | *O. mykiss* | Juvenile rearing | Parr growth rates | None | Growth rates could either be measured by capturing, PIT tagging, and recaptured juvenile *O. mykiss* in the river or estimated by back calculating lengths at age from scales |
| Life History diversity | *O. mykiss* | Adults | Percentage of anadromous and resident adults | None | Resident: adult snorkel surveys or masks and recapture;<br>Anadromous: weir counts, snorkel surveys, or redd surveys, otolith microchemistry |
| Life History diversity | *O. mykiss* | Juvenile rearing | Proportion of anadromous mothers | None | Otolith microchemistry |
| Life History diversity | *O. mykiss* (rainbow trout) | Adults | Minimum abundance of resident adults | None | Resident: adult snorkel surveys, mark and recapture, or electrofishing |
| Life History diversity | *O. mykiss* (steelhead) | Juvenile emigration | Detection of emigrating smolts | Caswell RST catch (USFWS);<br>Oakdale RST catch (Tri-Dam – not currently shared);<br>Mossdale trawl (CDFW) | Modifications to Mossdale trawl (CDFW) to detect juvenile-size ranges |

**Table 67**
**Current and Potential New Monitoring that Could be Used to Measure Progress Towards SEP Environmental Objectives**

| Environmental Objective Type | Species | Life History Stage | Specific Objective | Relevant Current Monitoring | Relevant Monitoring Needed |
|---|---|---|---|---|---|
| Temperature | All | All | Appropriate timing and ranges for all life history stages through the corresponding river reaches | Current CDEC and USGS stations include Goodwin Canyon, Knights Ferry, Orange Blossom Bridge, Oakdale, Ripon, Vernalis, and numerous Delta locations. | Special studies may be necessary to measure temperatures in currently unmeasured habitats (e.g., floodplains, intra-gravel, and coldwater refugia). |
| DO | All | All | Appropriate timing and ranges of DO in the mainstem river, floodplain habitat, and gravels (eggs) | CDEC stations at Ripon, Vernalis, and Delta locations | DO monitoring is needed in the main channel upstream of Ripon, in floodplain habitats, and in spawning gravels. |
| Pesticides | All | All | Maximum frequency of pesticide levels that will elicit detrimental conditions (e.g., direct and indirect) throughout the watershed | Some historical pesticide monitoring data are available for the Caswell area, and some pesticide modeling has provided baseline condition information. | Pesticide monitoring must continue in the future, and existing monitoring must be expanded to include the upstream mainstem and other aquatic habitats. Optionally, pesticide modeling may be able to provide better spatial and temporal resolution to estimate the pesticide impacts to the river. |
| Mercury and Selenium | All | All | Maximum concentrations of mercury and selenium in fish tissue | None | Adult tissue mercury and selenium monitoring every 5 to 10 years to ensure conditions have not degraded. Female spawner concentrations can be used to estimate mercury and selenium maternal transfer to eggs. Multi-year special study to verify that juvenile, yearling, and resident rainbow trout bioaccumulation of mercury and selenium is not at levels that will cause harm. Then, juvenile tissue mercury and selenium monitoring every 5 to 10 years to ensure conditions have not degraded. |
| Nutrients | All | All | Maximum average concentrations of ammonia, nitrate, and nitrite to prevent direct toxicity | No comprehensive, long-term monitoring of these constituents exists in the Stanislaus River; however, the limited recent and historical data suggest that nutrient concentrations are in the supportive range for toxicity impacts. | Nutrients should be monitored at a set of locations along the river corridor every 3 to 5 years to ensure conditions have not degraded over time |
| Nutrients | All | All | Nutrient levels (minimum and maximum) that support ecological use | A recent CDFW aerial assessment of rivering macrophytes was performed; however, there is no comprehensive long-term monitoring of macrophytes in place. DO levels are also an indicator of ecological use. | Nutrient concentrations, benthic and sestonic chlorophyll levels, and other environmental conditions (e.g., DO) should be evaluated to determine if nutrient or other biostimulatory factors are contributing to suboptimal conditions in the river. |
| Habitat | All | Adult migration | Minimum riffle depths | Routine river monitoring by CDFW and USFWS (e.g., float trips) could be used to identify when dramatic channel morphological changes might create conditions that could restrict migration. | To be determined |

| Environmental Objective Type | Species | Life History Stage | Specific Objective | Relevant Current Monitoring | Relevant Monitoring Needed |
|---|---|---|---|---|---|
| Habitat | Primarily Spring-run, but any holding species | Adult holding | Minimum water depth and maximum velocity | None | As the spring-run population approaches recovery, holding habitats should be identified and quantified to ensure adequate depths and velocities to fully support population recovery. |
| Habitat | All | Adult Spawning | Spawning habitat quantity and distribution | Spawning habitat quantity is an aggregate of multiple environmental objectives that define suitable spawning habitat. Many of these are already monitored (as listed in this table). | The monitoring for this objective requires the quantification of the acres of suitable spawning habitat. The required suitable habitat must be distributed spatially and temporally to prevent superimposition or introgression among species. This will require integration of monitoring for relevant objectives in a spatially explicit (GIS) format. |
| Habitat | All | Adult Spawning | Appropriate water depths and velocities for spawning | USBR and USFWS have a 2D habitat model and routinely conduct post-project mapping of gravel augmentation projects. | To be determined |
| Habitat | All | Adult Spawning | Appropriate sediment size distribution | Recent gravel augmentation projects actively monitor for appropriately sized gravel prior to/during augmentation activities. | To be determined |
| Habitat | All | Egg development | Maximum percentage of fine sediment (< 4.8 mm) | None | Fine sediment monitoring may be performed in conjunction with sediment size distribution surveys. However, additional monitoring may need to be conducted throughout the development period to ensure storm water inputs do not import large loads of fine sediment and degrade redd habitats. |
| Habitat | All | Juvenile rearing and migration | Spatial extent, distribution, and timing of rearing and migration habitat | Rearing and migration habitat quantity and distribution are aggregates of the environmental objectives that define the qualities of suitable habitat. Modeling of off-channel habitat inundation of various durations is available (FlowWest). | Field monitoring of timing, duration, annual frequency, quantity, and other physical characteristics of inundated habitat are needed to verify and calibrate model predictions under different flow regimes. Bioassessments may be necessary to ensure that primary and secondary production and export/transport is occurring as predicted in both shallow inundated and in-channel habitats. |
| Habitat | All | Juvenile rearing and migration | Appropriate water depths and velocities in floodplain habitats | Water depths and velocities, in part, define the quality and benefits of floodplain habitats for salmonids. Modeling of off-channel habitat inundation depths is available (FlowWest). | Site-specific modeling of water velocities in floodplain habitats will be needed (as part of project design) and field monitoring of both inundation depths and velocities will be needed to verify and calibrate models and ensure that an adequate area of suitable habitat is available under a range of flows. |
| Habitat | *O. mykiss* (steelhead) | Juvenile rearing and migration | In-channel flow variability | Unimpaired flow estimates are available from rim station dams (Department of Water Resources and other agencies) in order to mimic natural hydrograph variability that would contribute to the expression of anadromy in *O. mykiss*. | Additional temperature monitoring at rim station dams may be necessary in order to model/mimic temperature variability that would contribute to the expression of anadromy in *O. mykiss*. |
| Habitat | All | Juvenile rearing and migration | Minimum cover, structure, and substrate metrics in floodplain and in-channel habitats | USFWS and USBR incorporate these habitat measures in their 2D model. | To be determined |

The SEP's goals, objectives, and stressors also encourage targeted and efficient monitoring of individual conservation actions. When conservation actions are developed, their projected effect on relevant stressors must be described along with their expected contribution towards attainment of Environmental Objectives. Proposed conservation actions should also describe appropriate monitoring and assessment protocols to track performance of the action with respect to Stressors and Environmental Objectives; the monitoring proposed should be specific to the problems that the conservation actions are designed to address. In certain cases, the stressors addressed by a conservation action may transcend the effect of any particular physical or chemical environmental condition; actions that are designed to reduce predation pressure fall into this category. In such cases, monitoring plans that accompany the proposed action should be specific with regard to the way in which the action is expected to reduce the stress so that the effect of the action can be tracked by relevant monitoring.

## 9.3 Next Steps for the SEP Group

The SEP Group intends to move forward on two fronts. The first will be to develop goals and objectives and evaluate stressors for the San Joaquin River's other major tributaries (the Tuolumne River and Merced River) as well as for the lower mainstem San Joaquin River (downstream of its confluence with the Merced River). Restoring these waterways is critical to the attainment of Central Valley Goals and Objectives identified in this report. Additionally, several of the challenges identified in restoring salmonid populations to the Stanislaus River (e.g., hatchery influence, migration of juvenile and adult salmon through the lower San Joaquin River corridor) are problems that require a basin-wide perspective.

The second avenue for the SEP involves an evaluation of the proposed conservation actions in relation to the comprehensive conservation strategies for salmonid restoration throughout the San Joaquin River basin. Panels of scientists and managers that evaluate proposed conservation strategies will consist of SEP participants (excluding any individuals who were involved in developing the conservation actions that will be reviewed) and scientists with relevant experience who did not participate in the SEP Group. Scientific evaluations will rely on the SEP products developed in this report and will employ a structured assessment protocol similar to that developed for the DRERIP,[15] a multi-agency project to regulate salmonid restoration activities in the Central Valley Watershed.

[15] Available from http://www.dfg.ca.gov/erp/conceptual_models.asp

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# APPENDIX A
# STANISLAUS RIVER SURVIVAL MODEL

# APPENDIX B
# ENVIRONMENTAL OBJECTIVES FOR ACHIEVING THE STANISLAUS RIVER BIOLOGICAL OBJECTIVES

These matrices have been created to assist the SEP Group in evaluating conservation measures within a comprehensive framework documenting habitat needs (and stressors) of three runs of anadromous salmonids in the Stanislaus River.

# APPENDIX C
# ENVIRONMENTAL OBJECTIVES THAT APPLY ACROSS ALL SPECIES AND LIFE HISTORY STAGES

# APPENDIX D
# LONG-TERM STRESSOR PRIORITIES FOR FALL-RUN AND SPRING-RUN CHINOOK SALMON AND STEELHEAD