Appendix D - Attachment 1

Appendix D1 Components for the Reinitiation of Consultation on Long-Term Operations

D1.1 Introduction

This appendix contains the components used for alternative formulation along with supporting performance analysis. Monitoring and the organization structure to accomplish reporting and adaptive management are described independent of the potential actions in a specific component. The implementation aspects are organized by:

- Watershed
  - Central Valley Wide
  - Upper Sacramento (Shasta and Sacramento Divisions)
  - Trinity River
  - Feather River
  - American River
  - Bay-Delta
  - Stanislaus River
  - San Joaquin River
  - Friant Division
- Category
  - Water Operation
  - Temperature Facility Improvements
  - Habitat
  - Flow Routing
  - Salvage Efficiency
  - Conservation Hatchery
  - Production Hatchery
  - Passage and Reintroduction
  - Diversion Screening

Component documentation includes:

- Title
- Summary

- Description
- Objectives
- Conceptual Model (CM) (Each Species and Life Stage)
- Current Condition
- Background
- Current Science
- Justification
- References

D1.2 Site-Specific Proposed Action

D1.2.1 Central Valley Wide

D1.2.1.1 *Water Operations*

D1.2.1.1.1 Coordinated Operation Agreement

Summary

United States Department of the Interior, Bureau of Reclamation and California Department of Water Resources (DWR) have agreed to revisions to the 1986 Coordinated Operations Agreement (COA) (Reclamation and DWR 1986), which establishes the mechanisms for coordinating operations of the Central Valley Project (CVP) and State Water Project (SWP). The California State Water Resources Control Board (SWRCB) conditioned Reclamation's and DWR's water rights individually to protect the beneficial uses of water within the CVP and SWP and jointly for the protection of beneficial uses in the Sacramento Valley and the Sacramento-San Joaquin Delta Estuary. Reclamation and DWR coordinate and operate the CVP and SWP to meet these requirements.

Description

The COA was signed by both Reclamation and DWR and authorized by Congress in 1986. It defines the project facilities and their water supplies, sets forth procedures for coordination of operations, and identifies formulas for sharing joint responsibilities for meeting Delta standards and other legal uses of water. It also identifies how unstored flow will be shared, sets up a framework for exchange of water and services between CVP and SWP, and provides for periodic review of the agreement.

Through the COA, Reclamation and DWR share the obligation for meeting in-basin uses. In-basin uses are defined in the COA as legal uses of water in the Sacramento Basin, including the water required for SWRCB Delta standards. Each project is obligated to ensure water is available for these uses. The respective degree of obligation depends on whether the Delta is in balanced or excess conditions.

Balanced water conditions are defined in the COA as periods when it is mutually agreed that releases from upstream reservoirs plus unregulated flows approximately equal the water supply needed to meet Sacramento Valley in-basin uses plus exports. During excess water conditions, sufficient water is available to meet all beneficial needs, and the CVP and SWP are not required to supplement the supply with water from reservoir storage. Under COA Article 6(g), Reclamation and DWR have the responsibility (during excess water conditions) to store and export as much water as possible within physical, legal, and contractual limits. In excess water conditions, water accounting is not required. However, during balanced water conditions, CVP and SWP share the responsibility in meeting in-basin uses.

Reclamation and DWR have agreed to modify four key elements of the COA to address changes since COA was originally signed: (1) in-basin uses; (2) export restrictions; (3) CVP's use of Harvey O Banks Pumping Plant (Banks Pumping Plant); and (4) periodic review. These elements are proposed to be updated as follows:

- In-basin use (COA Article 6(c)) – Sharing of Responsibility for Meeting Sacramento Valley In-basin Use with Storage Withdrawals During Balanced Water Conditions

  Each party's responsibility for making available storage withdrawals to meet Sacramento Valley in-basin use of storage withdrawals must be determined by multiplying the total Sacramento Valley in-basin use of storage withdrawals by the percentages in Table D1.2-1, Sharing of Requirements for Storage Withdrawals for In-basin Use, (changed from 75% United States and 25% State of California).

  Table D1.2-1. Sharing of Requirements for Storage Withdrawals for In-basin Use

Water Year Type[1]	United States	State of California
Wet	80%	20%
Above Normal	80%	20%
Below Normal	75%	25%
Dry	65%	35%
Critical	60%	40%

  [1] Water year types will be determined by the Sacramento Valley 40-30-30 index.

  The water year classifications described in Article 6(c) must be based on the Sacramento Valley 40-30-30 index as most recently published through DWR Bulletin 120. In a dry or critical year following two dry or critical years, the United States and the State will meet to discuss additional changes to the percentage sharing of responsibility to meet in-basin use.

- Sharing of Applicable Export Capacity When Exports Are Constrained

  During periods when exports are constrained by nondiscretionary requirements imposed on the CVP and SWP South Delta exports by any federal or state agency and the Delta is in balanced water conditions, CVP and SWP will share the total export capacity with Reclamation pumping up to 65% of the allowable total exports and DWR pumping the remaining capacity, no less than 35%.

  When restrictions are in place and the Delta has excess water conditions, CVP and SWP will share the available capacity with Reclamation pumping 60% and DWR pumping 40% of available water.

- CVP Use of Banks Pumping Plant

  DWR will transport up to 195,000 acre-feet (AF) of CVP water through the California Aqueduct Reaches 1, 2A, and 2B no later than November 30 of each year by direct diversion or by rediversion of stored CVP water at times those diversions do not adversely affect SWP purposes or do not conflict with SWP contract provisions. The State will provide available capacity to the CVP from the Banks Pumping Plant to divert or redivert 195,000 AF when the diversion capacity at the South Delta intake to Clifton Court Forebay exceeds 7,180 cubic feet per second (cfs) during July 1 through September 30. When the Delta has excess water conditions during July 1 through September 30, the diversion capacity at the South Delta intake to Clifton Court Forebay that exceeds 7,180 cfs will be shared equally by the State and the United States. Article 6(c) does not alter the Cross-Valley Canal contractors' priority to pump at the Banks Pumping Plant, as stated in Revised Water Rights Decision 1641 (March 15, 2000).

- Periodic Review (Article 14(b)(2): 24)

  Prior to December 31 of the fifth full year following execution of the revised COA and before December 31 of each fifth year thereafter or within 365 days of the implementation of new or revised requirements imposed jointly on CVP and SWP operations by any federal or state agency or prior to initiation of operation of a new or significantly modified facility of the United States or the State or more frequently if so requested by either party, the United States and the State jointly will review the operations of both the CVP and the SWP. The parties will (1) compare the relative success with which each party has had in meeting its objectives; (2) review operation studies supporting this agreement, including the assumptions contained therein; and (3) assess the influence of the factors and procedures of Article 6 in meeting each party's future objectives.

Objectives

Fisheries: juveniles at Chipps Island per Adult Return, Abundance

Conceptual Model (Each Species and Life stage)

Increased water in storage in Shasta reservoir could be used for multiple purposes to benefit fish. It could remain in storage as part of the cold water pool or be released at times that downstream flows would help fish. The Salmon and Sturgeon Assessment of Indicators by Life Stage (SAIL) CM indicated "Water temperature affects the rate of development of embryos and alevins" for Winter-Run Chinook Salmon. Increased flows could also help eggs survive by reducing stranding and dewatering. Regarding fry survival, the SAIL CM found "The foremost factor affecting migration, growth, and survival of SRWRC fry is habitat…" and "[i]ncreased instream flow affects many of these factors through dilution (e.g., toxicity and contaminants), reduction in water temperatures (which also affects DO, food availability, predation, pathogens, and disease) and entrainment and stranding risk." While this CM is specific to Winter-Run Chinook Salmon, the benefits of increased flow and decreased temperatures are similar for Spring-Run Chinook Salmon.

Flexibility on the American River system could help CV Steelhead and Fall-Run Chinook Salmon that reside in the Lower American River. There is no CM specific to Steelhead and salmon on the American River, but the stressors are generally similar to Winter-Run Chinook Salmon. Decreased temperatures during the Steelhead spawning and incubation period (roughly March and April) could extend the period with suitable conditions and benefit fish (Hannon and Deason 2005). Additionally, increased flows could reduce stranding or dewatering of redds.

Current Condition

Water is released from Shasta and Folsom Reservoirs to meet in-delta standards. Reclamation provides 75% of the water needed to meet these standards, and DWR provides 25% from Oroville Reservoir releases.

Background

Reclamation and DWR agreed to COA in 1986, when regulations governing operations were different. As water quality and flow requirements have increased, the agreement has become less applicable to current conditions.

Current Science

For Shasta Reservoir, Reclamation submits a Sacramento River Temperature Management Plan each spring to the SWRCB to comply with Water Rights Order 90-5. In 2014 and 2015, drought conditions resulted in limited supplies available to meet flow targets and to maintain temperatures within the Sacramento River. Warmer fall water temperatures resulted in Winter-Run Chinook Salmon mortality, but these effects were reduced in 2016 (NMFS 2018).

Drought conditions for the American River were similarly hard on Steelhead and Fall-Run Chinook Salmon during 2014 and 2015. Monitoring in 2014 found that populations of both fish decreased substantially compared to 2013 (PSMFC 2014). Temperatures in 2014 and 2015 were warm enough that the Nimbus Fish Hatchery had to be evacuated (CDFW 2015).

Justification

Different sharing agreements between the CVP and SWP could result in more operational flexibility for fish and water supply.

References

California Department of Fish and Wildlife (CDFW). 2015. Drought Prompts Fish Evacuation at American River and Nimbus Hatcheries. Available: https://cdfgnews.wordpress.com/2015/06/25/drought-prompts-fish-evacuation-at-american-river-and-nimbus-hatcheries/. Accessed: October 26, 2018.

Hannon, J. and Deason, B. 2005. American River Steelhead (*Oncorhynchus mykiss*) Spawning 2001–2005. Available: http://cahatcheryreview.com/wp-content/uploads/2012/08/Hannon-and-Deason-2005-LAR-steelhead-spawning-2001-2005.pdf. Accessed: October 26, 2018.

National Marine Fisheries Service (NMFS). 2018. Letter from Maria Rea, NMFS, to Jeff Rieker, Reclamation. Subject: Winter-Run Chinook Salmon Juvenile Production Estimate for Brood Year 2017. Available: https://www.westcoast.fisheries.noaa.gov/publications/Central_Valley/Water%20Operations/Delta%20Operations%20for%20Salmonids%20and%20Sturgeon/DOSS%20WY%202018/winter-run_juvenile_production_estimate__jpe__for_brood_year_2017_-_january_29__2018__1_.pdf. Accessed: October 26, 2018.

Pacific States Marine Fisheries Commission (PSMFC). 2014. Juvenile Salmonid Emigration Monitoring in the Lower American River, California January – May 2014. Unpublished report prepared for the U.S. Fish and Wildlife Service and California Department of Fish and Wildlife, Sacramento, California. Available: https://www.fws.gov/cno/fisheries/CAMP/Documents-Reports/Documents/2014_American_River_rotary_screw_trap_report.pdf. Accessed: October 26, 2018.

D1.2.2 Upper Sacramento River Basin (Shasta and Sacramento Divisions)

D1.2.2.1 *Water Operations*

D1.2.2.1.1 Shasta Temperature Management

Summary

Starting at a biologically relevant date in the spring, Reclamation would manage the available volume of cold water in Shasta Reservoir to meet or exceed a minimum level of Winter-Run Chinook Salmon egg incubation and emergence requirements for redds on the Sacramento River above Clear Creek (CCR). In years when Reclamation determines that temperature criteria would restrict water supply operations, Reclamation would optimize use of cold water by varying water temperatures based on stage-specific temperature-dependent mortality models, e.g., Anderson (2017) at CCR. In years when Reclamation determines that insufficient cold water is available to meet stage-specific requirements, Reclamation would manage release temperature at Keswick Dam to maximize Winter-Run Chinook Salmon survival based on available cold water and real-time monitoring of redd location.

Description

Spring Pulse Flows

In spring, Keswick Dam releases are gradually increased as flows are needed to support instream demands on the mainstem Sacramento River and Delta requirements. As a standard practice, Reclamation operates Shasta Reservoir in the spring to have storage in the reservoir high enough to use the Shasta Dam temperature control device (TCD) upper shutters by the end of May to maximize the cold water pool potential for Winter-Run Chinook Salmon egg incubation management.

Under the Core Water Operation, Reclamation would not release spring pulse flows unless the projected May 1 Shasta Reservoir storage is greater than 4 million acre-feet (MAF). If Shasta Reservoir total storage on May 1 is projected to be greater than 4 MAF, Reclamation would make a spring pulse release as long as the release would not cause Reclamation to drop into a lower tier of the Shasta Reservoir summer temperature management.

Spring Management of Spawning Locations

Reclamation and NMFS may agree as part of the Adaptive Management Implementation Plan to run experiments in individual years to determine if keeping water colder earlier induces earlier spawning or if keeping April and May Sacramento River temperatures warmer induces later spawning.

Temperature Management

The closer Shasta Reservoir is to full by the end of May, the greater the likelihood of being able to meet the Winter-Run Chinook Salmon temperature control criteria throughout the entire temperature control season. If Shasta Reservoir storage is high enough to use the Shasta Dam TCD upper shutters by the end of May, Reclamation can maximize the cold water pool potential. Storage of 3.66 MAF allows water to pass through the upper gates of the Shasta Dam TCD, but historical relationships suggest that a storage of 4 MAF on May 1 generally provides enough storage to continue operating through the upper gates and develop a sufficient cold water pool to meet 53.5 degrees Fahrenheit (°F) on the Sacramento River above Clear Creek (at the CCR gaging station) for Winter-Run Chinook Salmon. Figure D1.2-1, Relationship between Temperature, Shasta Storage, and Cold Water Pool, provides an approximate rule of thumb for the relationship between temperature compliance, total storage in Shasta Reservoir, and cold water pool in Shasta Reservoir.

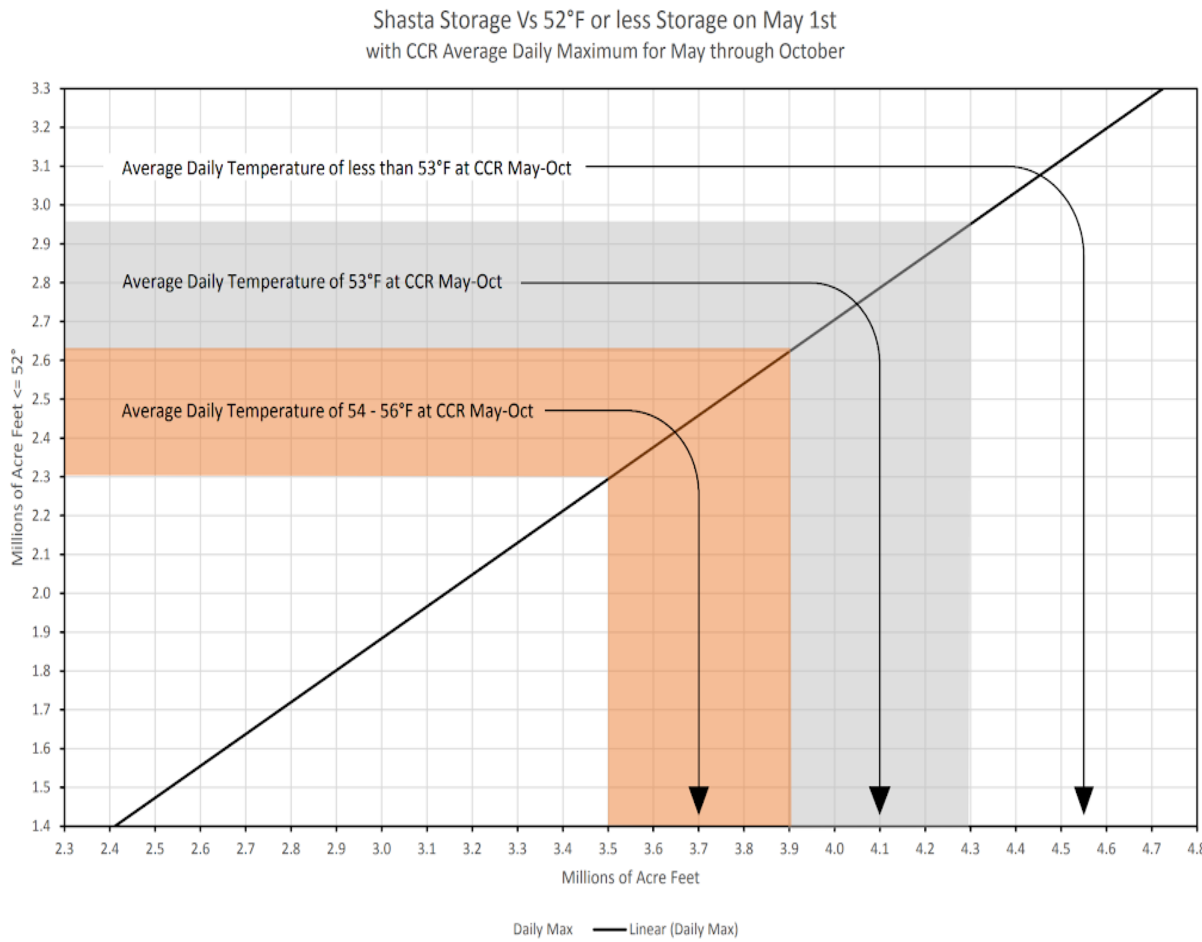

Figure D1.2-1. Relationship between Temperature, Shasta Storage, and Cold Water Pool

Summer Temperature Management

Reclamation proposes to operate the TCD at Shasta Dam to continue providing temperature management in accordance with the Central Valley Project Improvement Act (CVPIA) 3406(b)(6) while minimizing impacts to power generation. Reclamation proposes to address cold water management using a tiered strategy that allows for strategically selected temperature objectives based on projected total storage and cold water pool, meteorology, Delta conditions, and habitat suitability for incoming fish population size and location. The proposed tiers (Tiers 1 through 4) are described below.

In any given year, cold water pool and storage could result in Reclamation switching between tiers within the year if needed to optimally use the cold water pool. Cold water pool is defined as the volume of water in Shasta Lake that is less than 52°F, which Reclamation would determine based on monthly (or more frequently) reservoir temperature profiles. Reclamation will use the most recent reservoir temperature profile to develop the May temperature management plan and any necessary updates. The Sacramento River at CCR is a surrogate for the downstream most redd. Temperature management would start after May 15 or when the Winter-Run Chinook Salmon monitoring team determines, based on real-time monitoring, that Winter-Run Chinook Salmon have spawned, whichever is later. Temperature management ends October 31 or when the Winter-Run Chinook Salmon monitoring team determines, based on real-time monitoring, that 95% of Winter-Run Chinook Salmon redds' eggs have emerged, whichever is earlier.

Tier 1

Temperature management would start after May 15 or when the Winter-Run Chinook Salmon monitoring team determines, based on real-time monitoring, that Winter-Run Chinook Salmon have spawned, whichever is later. In years when Reclamation determines that cold water pool is sufficient (more than 2.8 MAF of cold water pool in Shasta Reservoir at the beginning of May or modeling suggests that a daily average temperature of 53.5°F at CCR can be maintained from May 15 to October 31), Reclamation proposes to operate to a daily average temperature of 53.5°F at the Sacramento River above CCR to avoid temperature-dependent mortality based on the latest egg mortality models. Reclamation proposes to operate to this temperature until the Winter-Run Chinook Salmon monitoring team determines, based on real-time monitoring, that 95% of the Winter-Run Chinook Salmon redds' eggs have emerged or October 31, whichever is earlier.

Tier 2

In years when cold water pool is insufficient to allow Tier 1 or above (less than 2.8 MAF of cold water pool in Shasta Reservoir at the beginning of May or modeling suggests the 53.5°F at CCR cannot be maintained from May 15 to October 31), Reclamation would optimize use of cold water for Winter-Run Chinook Salmon eggs based on life stage specific requirements, reducing the duration of time that ideal water temperature targets are met. Water temperatures at CCR would vary based on real-time monitoring of redd timing and life stage-specific temperature-dependent mortality models, e.g., Anderson et al. (2017). The period of 53.5°F at CCR would be centered around the projected period when the Winter-Run Chinook Salmon eggs have the highest dissolved oxygen requirement (37 to 67 days post-fertilization). At 2.79 MAF of cold water pool, Reclamation would operate to 53.5°F from 37 days after the first observed redd to 67 days after the last observed redd, as long as it is earlier than October 31. The duration of the 53.5°F protection will decrease in proportion to the available cold water pool on May 1. Reclamation will determine this period by running different temperature scenarios through the latest egg mortality model(s) and real-time monitoring of redds. Daily average temperatures at CCR during the temperature management season outside of the stage-specific critical window would not exceed 56°F without prior coordination with NMFS and U.S. Fish and Wildlife Service (USFWS).

Tier 3

When Reclamation determines that life stage-specific temperature targets cannot be met per Tier 2 above (less than 2.3 MAF of cold water pool in Shasta Reservoir at the beginning of May), Reclamation proposes to use cold water pool releases to maximize Winter-Run Chinook Salmon redd survival by increasing the coldest water temperature target (see Figure D1.2-2, Tiers for Shasta Temperature Management). At the highest storage levels in Tier 3, the targeted temperature at CCR will be a daily average of 53.5°F and, as storage decreases, would warm in the life stage-specific critical period up to 56°F. Reclamation would increase the temperature while minimizing adverse effects to the greatest extent possible, as determined by the latest egg mortality models, real-time monitoring, and expected and current water availability. This tier would be in effect until Reclamation could no longer meet 56°F at CCR.

Tier 4

If there is less than 2.5 MAF of total storage (note the use of "total" storage as opposed to the "cold water pool" used in the previous criteria) in Shasta Reservoir at the beginning of May, Reclamation will attempt to operate to a less than optimal temperature target and period that is determined in real-time with technical assistance from NMFS and USFWS. Reclamation proposes to implement intervention measures (such as increasing hatchery intake, as described below).

Figure D1.2-2 shows potential examples of the four different methods.

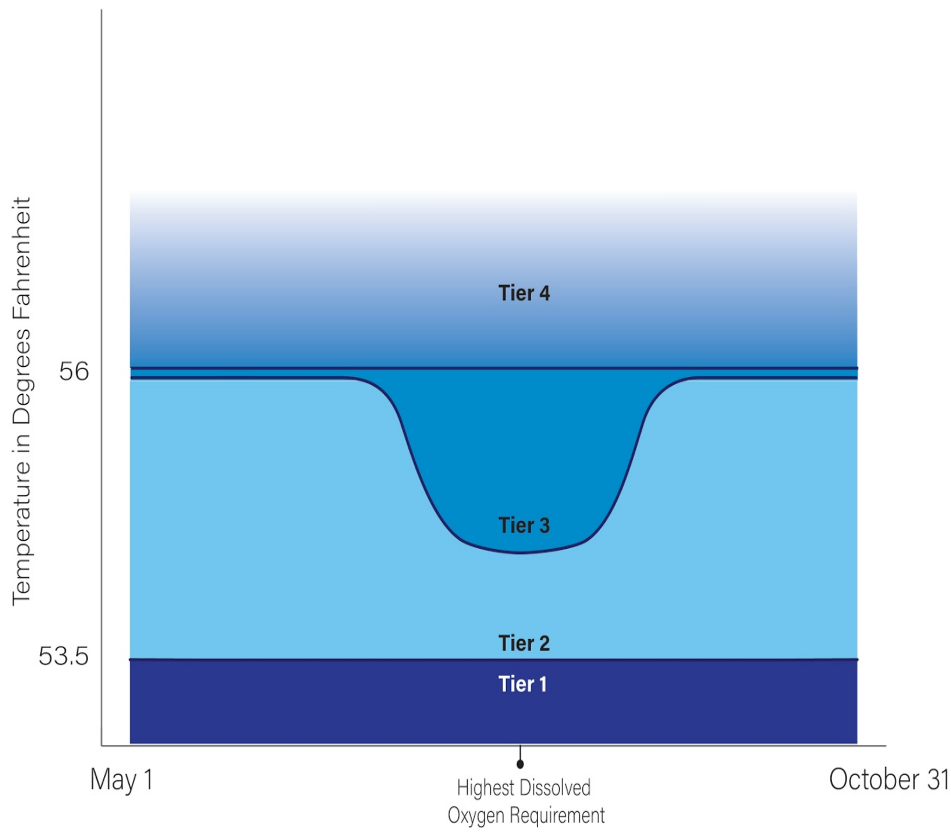

Figure D1.2-2. Tiers for Shasta Temperature Management

Figure D1.2-3, Shasta Temperature Management Decision Tree, provides a decision tree explaining the decision points for Shasta Reservoir temperature management.

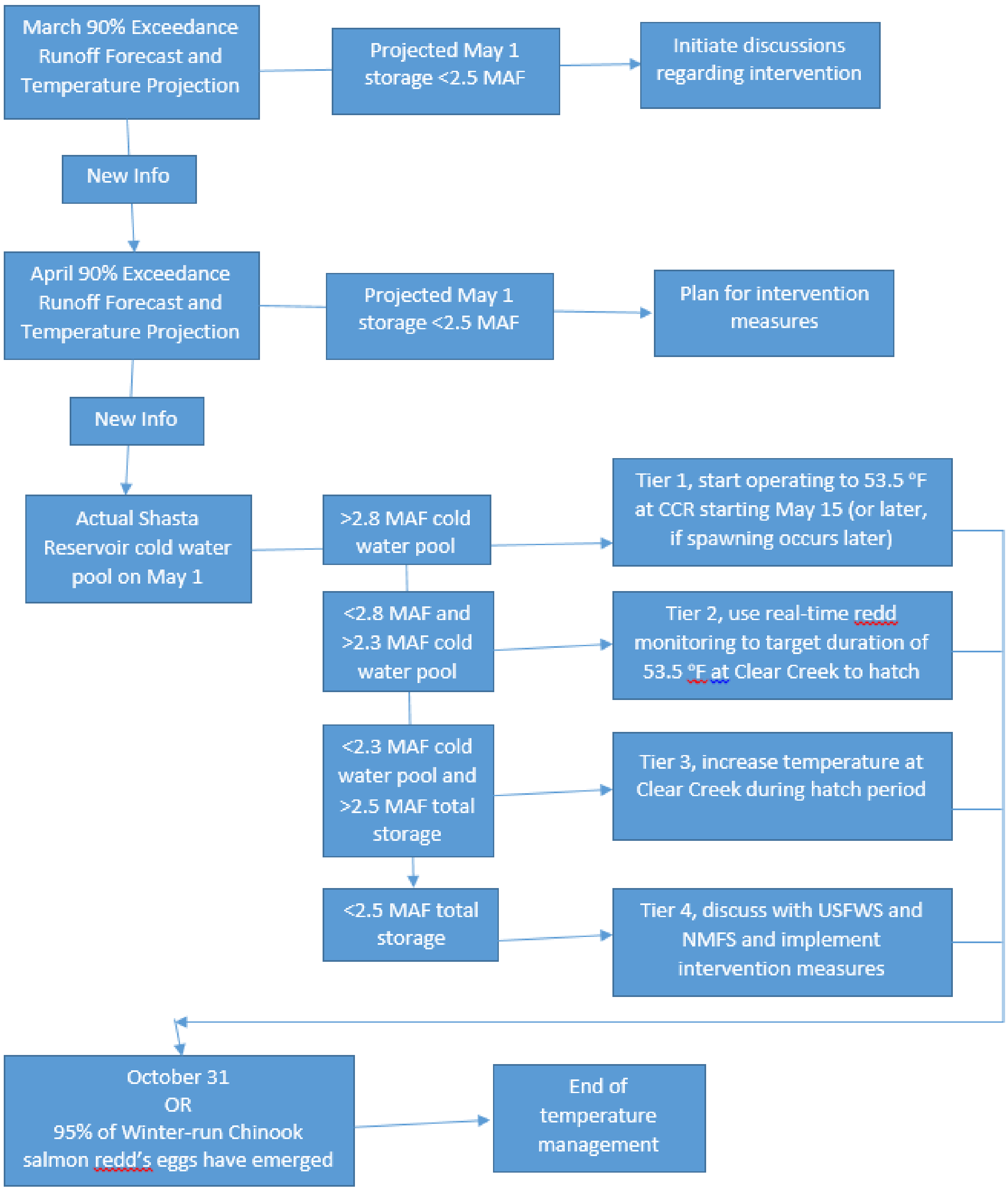

Figure D1.2-3. Shasta Temperature Management Decision Tree

At the March forecast (mid-March), if the forecasted Shasta Lake total storage is projected to be below 2.5 MAF at the end of May, Reclamation would initiate discussions with USFWS and NMFS on potential intervention measures, if the low storage condition continues into April and May, as described in Tier 4.

Reclamation proposes to perform the first temperature model run in April after DWR Bulletin 120 has been received and the operations forecast completed. This is the first month that a temperature model run is feasible based on temperature profiles. Prior to April, there is insufficient stratification in Shasta Lake to allow a temperature model to provide meaningful results. The April temperature model scenario is used to develop an initial temperature plan for submittal to the SWRCB under WRO 90-5. This temperature plan may be updated as Reclamation has improved data on reservoir storage and cold water pool via the reservoir profiles at the end of May and throughout the temperature control season.

Reclamation intends to provide temperature profile measurements for Shasta, Whiskeytown, and Trinity Reservoirs in Water Year 2019 as shown in Table D1.2-2, Temperature Profile Measurements for Shasta, Whiskeytown, and Trinity Reservoirs.

Table D1.2-2. Temperature Profile Measurements for Shasta, Whiskeytown, and Trinity Reservoirs

Reservoir	Every Month	Every Two Weeks	Every Week	Comment
Shasta	01/01–03/01 12/1–12/31	03/01–05/01 11/15–12/01	05/01–11/15	25-foot intervals for “every month,” otherwise 5-foot intervals
Whiskeytown	01/01–12/31			25-foot intervals
Trinity	01/01–12/31			25-foot intervals

Reclamation proposes to provide a draft temperature management plan to the Sacramento River Temperature Task Group in April for its review and comment per WRO 90-5. Reclamation’s proposed April temperature management plan will describe the four tiers below Reclamation projects for that year’s summer temperature management season along with a temperature modeling scenario and operations forecast. SWRCB has overall authority to determine if the plan is sufficient to meet water right permit requirements.

Reclamation proposes to incorporate drought protection into water supply allocations and to implement CVPIA 3406(b)(19).

<u>Fall and Winter Refill and Redd Dewatering</u>

Reclamation proposes to rebuild storage and the cold water pool for the subsequent year. Maintaining releases to keep late spawning Winter-Run Chinook Salmon redds underwater may decrease storage necessary for temperature management in a subsequent year. Reclamation will minimize effects with a risk analysis of the remaining Winter-Run Chinook Salmon redds, the probability of sufficient cold water in the subsequent year, and conservative distribution and timing of subsequent Winter-Run Chinook Salmon redds. If maintaining flows puts the subsequent Winter-Run Chinook Salmon year class at a 10% temperature-dependent egg mortality risk, Reclamation will reduce releases to rebuild storage.

Demands by the national wildlife refuges, upstream CVP contractors, and Sacramento River Settlement Contractors in October result in Keswick releases that are generally not maintained throughout the winter due to needs to store water for beneficial uses the following year. These releases result in some early fall Chinook redds being dewatered at winter base flows.

Following the emergence of Winter-Run Chinook Salmon and prior to the majority of Fall-Run Chinook Salmon spawning, upstream Sacramento Valley CVP contractors and Sacramento River Settlement Contractors propose to work to synchronize their diversions to lower peak rice decomposition demand. With lower late October and early November flows, Fall-Run Chinook Salmon are less likely to spawn in shallow areas that would be subject to dewatering during winter base flows. Reductions would balance the potential for dewatering late spawning Winter-Run Chinook Salmon redds.

Targets for winter base flows (December 1 through end of February) from Keswick would be set in October and would be based on Shasta Reservoir end-of-September storage. These targets would be set based on end-of-September storage and current hydrology. These base flows would be set based on historical performance to accomplish improved refill capabilities for Shasta Reservoir to build cold water pool for the following year.

Table D1.2-3, Keswick Release Schedule for End-of-September Storage, shows examples of possible Keswick releases based on Shasta storage condition; these would be refined through modeling efforts.

Table D1.2-3. Keswick Release Schedule for End-of-September Storage

Keswick Release (cfs)	Shasta End-of-September Storage
3,250 cfs	< 2.2 MAF
4,000 cfs	< 2.8 MAF
5,000 cfs	> 3.2 MAF

cfs = cubic feet per second

Objectives

- Fundamental objectives: Increase juveniles at Chipps Island per adult return.
- Means objectives: Productivity.

Conceptual Model

The SAIL report for Winter-Run Chinook Salmon states:

> Water temperature affects the rate of development of embryos and alevins (H7; Beachum and Murray 1990; Rombough 1988). It is recommended that temperature does not exceed 56°F to avoid egg mortality (Slater 1963; Myrick and Cech 2004). The amount of cold water available to achieve optimal temperature for this life stage varies as a function of the amount of cumulative precipitation, reservoir stratification, and previous water operations. Water temperature also affects the saturation concentration of dissolved oxygen within the stream. Dissolved oxygen has been positively correlated with Chinook larval growth up to a concentration of ~ 11 mg O2/L, however the concentration within the Central Valley is typically less, resulting in embryo and alevin development to potentially be stunted (H5; Mesick 2001). Pathogens, disease, and contaminants affect the survival of eggs and the condition of emerging fry and can be exacerbated by increased water temperature and reductions in flow (H9, H2; McCullough 1999; Scholz et al. 2000). Water temperature can also impact the predation rate on eggs, embryos, and fry as predator metabolic demands increase with temperature (H9).

For fry the SAIL report states, “[a]ll historical SRWRC rearing habitat has been blocked since the construction of Shasta Dam, confining fry to the low elevation habitats on the Sacramento River. Remaining rearing areas are dependent on cold water releases from Shasta Dam in order to sustain the remnant population (H7).”

Current Condition

The 2009 NMFS Biological Opinion (BO) Reasonable and Prudent Alternative (RPA) Action I.2.4 requires, in part:

> daily average water temperatures not in excess of 56 degrees Fahrenheit at compliance locations between Balls Ferry and Bend Bridge from May 15 through September 30 for protection of winter-run, and the same requirement in the same area through October 31 for protection of mainstem spring-run.

Background

Prior to the passage of the CVPIA in 1992, Reclamation was able to function as a multiyear project. This means that end of year reservoir storages were higher to allow for carryover storage into the next year to help protect against a drought. However, since the passage of CVPIA, the projects have come under increasing pressure to provide water for environmental protections, which has resulted in decreased ability to allocate water to CVP contractors that then has resulted in additional pressure being applied to Reclamation from contractors to allocate additional water. As a result, the reservoirs are drawn down lower more frequently to meet the additional demands. The combined effect of these actions is that the CVP now operates primarily as an annual project. Only in the wettest years is Reclamation able to carry over supplies into the following year for drought protection.

If releases are reduced during some time frames to maintain higher storage levels in reservoirs, they have a corresponding effect in reducing inflows to the Delta, which then reduces Delta outflows. Reduced Delta outflows may have a negative impact on Delta fisheries. The benefit of increased reservoir storage has to be weighed against the potential negative downstream impacts to fisheries. In addition, maintaining a higher carryover storage increases the risk of having to make flood control releases early in the season to draw down to the required maximum flood conservation space. Making flood control releases in October and November to draw down to the required maximum storage conflicts with Winter-Run Chinook Salmon needs, for which Reclamation reduces flows rapidly during the fall to encourage development of the cold water pool for the following year.

Inflow to Shasta Reservoir, while not absent during summer, is mostly from winter rain and spring snowmelt between November and May. By April the reservoir has received almost all expected inflows. Therefore, Shasta Reservoir operations for the Sacramento River between April and October are working with a mostly known volume of water. April and May is when the reservoir begins to warm, stratify, and form a warm pool layer. Between May and October is when the Winter-Run Chinook Salmon spawn; with the majority spawning in June and July (WRC 2018). Between May and October is the only time when temperature management occurs because it is the only time that has a warm pool and that Winter-Run Chinook Salmon eggs are temperature sensitive. Temperature management during this period includes the concept of "hedging," a small certain loss now to reduce larger future risks. Hedging for temperature starts in May at the beginning of the temperature planning season. Between May and October the system must meet specific downstream temperature targets, which require optimal combinations of warm and cold pool storage during the stratified May through October period and optimal volumes of cold storage during the mixed November through April time. When operating with full delivery allocations and temperature requirements, the reservoir always empties by the second year, independently of whether hedging or a static Sacramento River temperature target is used.

On January 19, 2017, NMFS transmitted a proposed amendment to the 2011 amended RPA for Shasta Reservoir operations (RPA Action Suite I.2). The amendment included minimum storage targets between April 1 and May 31 between 3.5 MAF and 4.2 MAF, depending on water year type, and end of season storage between 1.9 MAF and 3.2 MAF, depending on water year type. Reclamation implemented a pilot program in 2017 for the draft amendment and modeled the draft amendment. The amendment's storage targets resulted in hundreds of thousands of acre-feet reduction in CVP water user deliveries.

Described below are water years, which showcase the difficulty of meeting temperature targets with a limited cold water pool and conflicting objectives during period of drought and the resulting redd counts from those years.

During water year 2013, 23 redds were counted in July near Keswick Dam in temperatures between 54 to 55°F. The weighted average mortality was 14% overall. On March 8, Keswick Dam releases were increased to support D-1641 flow requirements. By April 12, Keswick Dam releases increased to 5,700 cfs and as high as 13,00 cfs by mid-May due to Wilkins Slough flow objectives and Delta requirements. By June, depletions in the Sacramento River were the highest on record. Due to low storage and elevation in the Shasta Reservoir, the middle shutters on the TCD were required to be open sooner than desired to meet hydraulic operational criteria. Opening the middle shutters sooner than projected depleted the cold water pool earlier than expected. Reclamation continued to meet temperature compliance at Airport Road from May to August.

During water year 2014, 20 redds were surveyed in temperatures of at least 54°F to 55°F with half of those surveyed in 55°F to 56°F between June to late July. The weighted average observed mortality of all the redds for water year 2014 was 79.1%. Water year 2014 was a critically dry year and initial carryover storage in Shasta Reservoir was 1.9 MAF. In late April, the temperature target at CCR was changed to 56°F based on late April temperature analysis. Due to a calibration error, the temperature modeling showed trending Keswick Dam temperature to be 1°F lower than the actual trend. This likely further depleted the cold water pool sooner than necessary.

During water year 2015, 27 redds were surveyed. Nineteen redds were surveyed in temperatures between 56°F to 57°F, seven were surveyed in temperatures of 55 to 56°F,and one was surveyed in temperatures of 54°F to 55°F. For all redds surveyed during water year 2015, there was a weighted average observed mortality of 88.9%. Water year 2015 was a critically dry year and initial carryover storage in Shasta Reservoir was 1.15 MAF. A target of 57°F, not to exceed 58°F, was conducted for CCR compliance location in mid-April and this extended the cold water pool.

Current Science

According to a recent paper, approximately 53.6°F) is the critical temperature for Winter-Run Chinook Salmon egg incubation (Martin et al. 2017).

> Hatching is an important transition in the incubation because eggs obtain oxygen by diffusive flux across the egg membrane while alevin obtain oxygen by pumping water through their gills (Wells and Pinder 1996. This switch from diffusive to pump transport, greatly increases the fish's ability to tolerate low oxygen after hatching. The critical oxygen level below which routine metabolism becomes dependent on the ambient oxygen rises steadily during egg development and then drops about 50% after hatching (Rombough 2007). Additionally, the post-hatching oxygen sensitivity is essentially independent of incubation temperature (Rombough 1986). Thus, sensitivity to low oxygen increases steadily during egg development and then drops rapidly and stabilizes in the alevin stage. (Anderson 2018, pre-print)

Anderson (2018, pre-print) compared the Martin egg mortality model (Martin et al. 2017), which is the NMFS-SWFSC temperature-dependent mortality model, with several expanded models. Model I, developed by Martin et al. (2017), expresses thermal mortality independent of the stage or age of incubation and background mortality independent of redd location. Model II extends Model I with age-dependent thermal mortality and Model III adds river reach-specific background mortality. According to Anderson, the models with the finer spatial and temporal resolution (Models II and III) predict reservoir operations that require less flow and better protect fish. Thus, there could be benefits to Reclamation to use Model II and/or III instead of the Martin model for Sacramento River temperature management.

Reclamation's proposed action incorporates the concept of risk management, or what some refer to as "hedging": a small certain loss now to reduce larger future risks. Examples of this include intentionally releasing small floods to avoid large ones, or conserving some storage and causing some immediate shortage to avoid deeper drought. For reservoirs for which cold water limits meeting downstream temperature and flow goals, there is a set of months, seasons and years for which expected and available water supply render meeting downstream targets unachievable, another set for which meeting temperature targets requires careful planning, and another set for which incoming fish population size is too small to warrant water use for temperature management under extreme drought conditions (Adams 2017).

Justification

The proposed action includes operating to 53.5°F at Clear Creek (Tier 1) when May 1 Shasta cold water pool is more than 2.8 MAF, which occurs 47% of the time. In a Tier 1 year, Reclamation would operate to a temperature which is colder than recommended by the CM and operate to this temperature from May 15 to October 31 (or a shorter window, based on real-time monitoring of the Winter-Run Chinook Salmon). Tier 1 should have limited if any mortality of Winter-Run Chinook Salmon eggs, as it provides colder than the ideal temperature of 53.7°F per Martin, 2017. Occasional redds emerge downstream of Clear Creek, and these redds (depending on the distance downstream and the warming) could experience warmer temperatures than ideal, and should be the only sources of mortality in Tier 1.

In Tier 2, Reclamation operates to 53.5°F at Clear Creek for the critical period based on Anderson et al., 2017, which is tied to the maximum dissolved oxygen requirement right before hatch. Under the Jim Anderson Model (II / III), the duration of temperature control would be shorter. In essence, incorporating age and reach-specific dissolved oxygen requirements might provide the same thermal protection as the current RPA or NMFS' amendment, but use less water in normal years. It may also provide better protection of Winter-Run Chinook Salmon eggs in dry and critical dry years (Anderson 2018).

The strategy proposed by NMFS in the draft Shasta RPA amendment process maintains the duration and raises the compliance temperature in drier years. Reclamation takes a similar approach in Tier 3 of the Shasta temperature action, keeping the duration of the critical dissolved oxygen requirement cold water temperature time period, but increasing the temperature due to drier hydrology with a smaller cold water pool.

Between 2003 and 2018, Winter-Run Chinook Salmon fish count surveys only found an expected three spawning fish in April below Shasta Dam (WRC 2018). Thus, Reclamation's proposed action starts temperature management on May 15 or later, depending on Winter-Run Chinook Salmon spawning. However, statistical analysis indicates a correlation between warmer April temperatures and later Winter-Run Chinook Salmon spawning (Hendrix et al 2017).

Movement of the compliance location to the CCR gaging station provides for targeting consistent temperatures closer to the location of actual anticipated spawning. Table D1.2-4, Percentage of Aerial Redds between Airport Road Bridge and Keswick Dam on the Sacramento River, shows the percentage of aerial redds located between Airport Road Bridge and Keswick Dam on the Sacramento River for all salmonid runs from 2001 to 2018. The area between Airport Road Bridge and Keswick Dam is located upstream from the current compliance location. High percentages of redds from Winter-Run and Late-Fall-Run Chinook Salmon are consistently spawned in this area. Focusing on the location of anticipated spawning area may benefit cold water pool storage in the fall months.

Table D1.2-4. Percentage of Aerial Redds between Airport Road Bridge and Keswick Dam on the Sacramento River

Year	Late-Fall	Winter	Spring	Fall
2001	68.1%	94.8%	24.1%	22.4%
2002	66.8%	98.2%	45.7%	25.7%
2003	85.3%	99.3%	59.1%	12.6%
2004	93.4%	99.7%	95.5%	19.9%
2005	52.1%	99.8%	69.5%	39.3%
2006	38.0%	99.7%	83.9%	30.7%
2007	61.9%	94.1%	63.3%	36.6%
2008	66.5%	99.8%	78.3%	25.6%
2009	85.4%	100%	N/S	42.0%
2010	73.1%	100%	33.3%	40.0%
2011	97.6%	100%	N/A	36.7%
2012	86.1%	100%	N/A	43.9%
2013	N/A	99.8%	100%	42.4%
2014	67.0%	100%	N/A	38.5%
2015	N/A	100%	N/A	32.9%
2016	100%	100%	100%	62.3%
2017	89.7%	100%	100%	70.6%
2018	87.8%	100%	N/S	N/S

N/S indicates not surveyed
N/A indicates no redds observed

As discussed above, Reclamation has incorporated “hedging” into its proposed action. Reclamation is willing to accept a certain reduction in this year’s juvenile outmigration (lack of spring pulse flows) if the anticipated impacts of reduced cold water pool on next year’s eggs are greater. If Shasta total storage on May 1 is projected to be greater than 4 MAF, Reclamation would make a Spring pulse release as long as the release would not cause Reclamation to drop into a lower Tier of the Shasta summer temperature management. 4 MAF of storage on May 1 is a Tier 1 year. Dropping from Tier 1 to 2 or especially from Tier 2 to 3, is anticipated to have a larger effect on next year’s temperature-dependent egg mortality than the benefit of spring pulses on this year’s juvenile outmigration. The March and April time period during juvenile outmigration is critical due to the in-progress stratification of Shasta Reservoir, and therefore uncertain volume of cold water pool.

Similarly, Reclamation has incorporated hedging into fall baseflow releases. Reclamation will minimize effects with a risk analysis of the remaining Winter-Run Chinook Salmon redds, the probability of sufficient cold water in the subsequent year, and conservative distribution and timing of subsequent Winter-Run Chinook Salmon redds. If maintaining fall / winter baseflows flows puts the subsequent Winter-Run Chinook Salmon year class at a 10% temperature-dependent egg mortality risk, Reclamation will reduce releases to rebuild storage. The certain risk of dewatering a small percentage (<10%) of this year's Winter-Run Chinook Salmon redds is less than the uncertain risk of impacting 10% of next year's Winter-Run Chinook Salmon eggs.

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D1.2.2.2 *Habitat*

D1.2.2.2.1 <u>Spawning Habitat</u>

Summary

Reclamation proposes to place 40–55 tons of gravel in the upper Sacramento River to enhance spawning opportunities.

Description

Reclamation proposes to place gravel in the Sacramento River between Keswick Dam and Red Bluff Diversion Dam (RBDD) to increase spawning habitat for salmonids and sturgeon. In addition, The gravel placements would benefit egg and larval salmonids and sturgeon, as well as invertebrate prey species of rearing juveniles. Restoration actions would occur through the year 2030. A total of 40–55 tons of gravel would be placed to create spawning habitat at the project sites listed below.

The following are spawning project sites that are to be completed in the future;

- Salt Creek Gravel Injection Site (River Mile [RM] 300.7)
- Keswick Dam Gravel Injection Site (RM 302)
- South Shea Levee (RM 289)
- Shea Levee (RM 290)
- Tobiasson Island Side Channel (RM 292)

Spawning projects could include these sites or other sites, but would include at least three sites upstream of Bonnyview Bridge.

The gravel placed would be uncrushed, rounded “natural river rock” with no sharp edges. The gravel would be free of oils, clay, debris, and organic materials. Three different gravel augmentation methods could be applied:

- Lateral Berm: A recruitment pile of gravel is placed as a steeply sloping bar parallel to the channel to provide a long-term supply of spawning gravel and is mobilized into the river channel during high flows
- Riffle Supplementation: Gravel is placed, contoured within the channel (partial or entire channel width), and graded to appropriate depths to provide immediate spawning habitat
- End Dump Talus Cone: A large pile of gravel is placed on the riverbank for recruitment into the river during high flows

Current plans indicate that Salt Creek would be a lateral berm placement; Keswick would be an end dump talus cone, and South Shea Levee, Shea Levee, and Tobiasson Island would be a riffle supplementation (Reclamation 2015).

Objectives

- Fundamental objective: Increase juveniles at Chipps Island per adult return
- Means objective: Abundance

Conceptual Model (Each Species and Life Stage)

The salmonid life stages most affected by spawning habitat enhancements are the eggs and alevins in the spawning redds and the spawning adults. These life stages are addressed by the SAIL CM1 and CM7 for Winter-Run Chinook Salmon (Windell et al. 2017). CM1 conceptualizes upper Sacramento River the life stage periods from egg spawning and incubation to fry emergence from the redds, which can be used to conceptualize potential effects of spawning gravel augmentation on these life stages of Winter-Run Chinook Salmon, as well as on spawning success in the upper Sacramento River for Spring-Run, Fall-Run, and Late Fall-Run Chinook Salmon and Steelhead. Per the CM1 framework diagram (Windell et al. 2017, Figure D1.2-3), erodible sediment supply, which includes gravel augmentation, is linked to substrate size and related to hypothesis $\mathbf{H_8}$, “sedimentation and gravel quantity.” Per the narrative (page 7), “Since 1997, a total of 213,000 tons of gravel have been placed from 300 yards to 1.5 miles downstream of Keswick Dam to increase the availability of suitable spawning habitat ($\mathbf{H_8}$).”

The SAIL CM7 conceptualizes the adult life stage period from holding in the upper Sacramento River to spawning. Per the CM7 framework diagram (Windell et al. 2017, Figure 34), erodible sediment supply, including gravel augmentation, is linked to the environmental driver, gravel quality and distribution/augmentation, which in turn is linked to the habitat attribute, spawning habitat.

Green Sturgeon spawn in gravel substrates, so gravel augmentation in the upper Sacramento River would potentially enhance habitat for Green Sturgeon egg incubation and larval development (Heublein et al. 2017). The potential importance of spawning habitat for Green Sturgeon is addressed in hypothesis H_4 of the CM for Green and White Sturgeon in the San Francisco Estuary watershed produced by the Southwest Fishery Science Center (Heublein et al. 2017), which proposes that incubation habitat availability and quality influences relative embryo abundance and distribution. The egg sub-model (page 15) links the environmental driver, Channel Morphology & Substrate, to the habitat attribute, Incubation Habitat. The larvae sub-model (page 18) similarly links the environmental driver, Channel Morphology & Substrate, to the habitat attribute, Rearing Habitat. In the case of the larvae, the gravel substrate provides rearing habitat for only the first part of the larval life stage because the larvae leave the hatching area well before they metamorphose into the juvenile stage.

Current Condition

Coarse sediment from the upper watershed is prevented from being transported downstream by Shasta and Keswick dams, resulting in an alluvial sediment deficit and reduction in fish habitat quality within the upper Sacramento River. From 1964 to 1980, there appears to have been a significant loss in spawning area in portions of the upper Sacramento River (Stillwater 2007). By 2005, extensive new spawning areas had developed upstream of the Anderson Cottonwood Irrigation District Dam, presumably in response to gravel injections at Keswick Dam and Salt Creek that helped locally offset losses due to the deficit in coarse sediment supply occurring as a result of blockage by Shasta Dam (Stillwater 2007).

Significant efforts have been made to increase the quantity and quality of spawning habitats below the dams. Many habitat restoration projects have been recently implemented in the upper Sacramento River. The following are spawning and rearing habitat projects that were recently completed but will require annual maintenance: Kutras Lake Rearing Structures (RM 296), North Cypress (RM 295), North Tobiasson Side Rearing Structures (RM 292), Kapusta 1-A Side Channel (RM 288), and Lake California Side Channel (RM 270).

Between 2002 and 2013, gravel was placed on two sites in the upper Sacramento River. The Keswick and Salt Creek gravel placement sites listed above have received approximately 220,000 tons of gravel since 1997. CDFW aerial redd surveys and instream gravel locations show that Chinook Salmon are preferentially using gravel that was placed at the Keswick Dam and Salt Creek sites (Reclamation 2016).

Background

CVPIA Section 3406 (b)(13) directs Reclamation to develop and implement a continuing program for the purpose of restoring and replenishing, as needed, salmonid spawning gravel lost due to the construction and operation of CVP dams and other actions that have reduced the availability of spawning gravel and rearing habitat in the Sacramento River from Keswick Dam to RBDD. The CVPIA Programmatic Environmental Impact Statement included habitat restoration projects between Keswick Dam and RBDD (Reclamation 2016).

In 2014, NMFS released the *Central Valley Salmon and Steelhead Recovery Plan*, which identifies two salmonid conservation principles: (1) recovery cannot be achieved without sufficient habitat and (2) species with restricted spatial distribution are at a higher risk of extinction from catastrophic environmental events. The plan identifies lack of spawning gravel as one of the key threats below Keswick Dam and outlines a recovery action to develop a long-term gravel augmentation plan to increase and maintain spawning habitat.

Current Science

Recent research using physical modeling experiments to guide river restoration projects yielded three restoration manuals (Stillwater Sciences et al. 2008). The purpose of the research project was to build state-of-the-art flumes and conduct a series of physical modeling experiments to address some of the fundamental and unresolved scientific questions underlying the river restoration strategies of gravel augmentation, dam removal, and channel-floodplain redesign. Three manuals (one for each of the three restoration practices) integrate results from laboratory experiments from this study with theoretical analysis, numerical modeling, and field case studies to produce scientifically based guidelines for assessing, implementing, and predicting the in-channel response of these common restoration strategies. The manuals are intended for use by restoration practitioners and managers.

A research effort entailing over a decade of river restoration field research on the Sacramento River has yielded new understanding of many river processes and new numerical models and decision analysis tools (TNC et al. 2008).

Justification

Gravel augmentation provides a source of appropriately sized gravels to restore spawning habitats once gravels are mobilized and redeposited downstream by high flows. Riffle supplementation will create instantly available spawning habitat up to 15 acres per year (NMFS 2015).

The need for the action derives from the declines of naturally spawned salmonid stocks due in part to loss of spawning habitat through curtailment of gravel recruitment due to blockage of the river channel by dams and the alteration in flow patterns.

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D1.2.2.3 *Passage and Reintroduction*

D1.2.2.3.1 Adult Rescue

Summary

Reclamation proposes to trap and haul adult salmonids and sturgeon from Yolo and Sutter bypasses during droughts and after periods of bypass flooding, when flows from the bypasses are most likely to attract upstream migrating adults, and move them up the Sacramento River to spawning grounds. This would improve survival of the adults, leading to increased juvenile production in the following year and, therefore, corresponding flexibility at salvage.

Description

This action requires Reclamation to provide rescues of adult salmonids and sturgeon trapped at barriers in the Yolo and Sutter bypasses. Fish rescues are often needed when Sacramento River flows overtop the Fremont and/or Tisdale Weirs. At such times, flows within the bypasses are typically much greater than flows within the Sacramento River, attracting adult salmonids and sturgeon migrating up the Sacramento River into the Yolo Bypass at the Cache Slough complex and into the Sutter Bypass at the Feather River confluence. Adult fish may also by attracted into the bypasses during drought periods, when flow exiting the bypasses may be higher relative to Sacramento River flow than during other periods. For the Yolo Bypass, west side tributary and drainage canal flows can attract anadromous fish into the bypass at the Cache Slough complex, particularly during periods of high tides and low Sacramento River flows. Fish attracted by west side stream and drainage canal flows migrate upstream through the Toe Drain, Tule Canal, Knights Landing Ridge Cut, and Colusa Basin Drain Canal. Similar to fish stranded during weir spill events, fish attracted into the Yolo Bypass by west side tributary and drainage canal flows are unable to return to the Sacramento River. CDFW initiated fish trapping and rescue efforts in the Colusa Basin Drain in 2013 and at the Wallace Weir in the Knights Landing Ridge Cut in 2014 to return anadromous fish to the Sacramento River (CDFW 2016).

Fish rescue efforts should be viewed as a last resort in terms of fisheries conservation measures within the Yolo and Sutter bypasses, but some level of fish rescue will likely always be needed. Many improvements for fish passage in the Yolo Bypass are currently under construction or in planning (DWR and Reclamation 2017). Plans include actions to improve passage at road crossings and other barriers, fish rescue at the Knights Landing Ridge Cut (to prevent fish from migrating upstream into the Colusa Basin Drain), and a new fish passage structure at Fremont Weir. The new Fremont Weir structure, scheduled for completion in 2019, is designed to allow passage of adult salmonids and sturgeon from the weir to the Sacramento River during periods when Sacramento River flow overtops the weir and for a period afterwards as the floodwater recedes (DWR and Reclamation 2017). It is expected that this structure will greatly reduce the number of adult salmonids and sturgeon that become trapped behind the weir. The old fish passage structure at Fremont Weir did not perform well, but the new structure is expected to correct most of the problems identified with the old structure (DWR and Reclamation 2017). DWR and Reclamation are planning to construct a new gated notch in Fremont Weir to increase inundation of the

Yolo Bypass for floodplain rearing habitat, and this gated structure would further improve fish passage. Nonetheless, some continued stranding of fish should be expected, and fish rescues will continue to be needed.

Following periods of Yolo Bypass flooding, some of the fish attracted into the bypass are stranded in the western section of Fremont Weir, which currently has no access to the fish passage structure, and at road crossings, ponds, canals and weirs. The many improvements for fish passage in the Yolo Bypass are expected to reduce these strandings, but not to eliminate them. As noted above, the potential to strand fish may also be high during drought periods, when water levels in the bypass are relatively low, but the number of adult fish attracted into the bypass are also likely to be lower than during period of bypass flooding. There are numerous isolation and stranding areas within the Sutter Bypass, and until fish passage improvements are implemented in the Sutter Bypass, fish rescue operations will continue to be needed to prevent the loss of threatened and endangered fish species in this bypass (CDFW 2017; DWR and Reclamation 2017).

Fish rescues are currently conducted primarily by the CDFW. The timing of fish rescue operations is dependent on factors such as water depth temperature, inundation area, species composition, and potential safety issues. All fish captured are identified to species, enumerated, assessed for condition, and measured. Adult salmonids and sturgeon are tagged before release and subsequently monitored to determine post-release survival, spawning success, and behavior (CDFW 2016). These procedures would be continued under this proposed fish rescue component, but rather than returning the fish to a nearby portion of the Sacramento River, as is currently done, the rescued fish would be transported upriver, if feasible, to suitable spawning areas of the fish.

Objectives

- Fundamental objective: Increase juveniles at Chipps Island per adult return
- Means objective: Abundance

Conceptual Model (Each Species and Life stage)

The SAIL CM included for the Winter-Run Chinook Salmon addresses stranding and rescue of adult salmonids is CM6, Adult Migration from Ocean to Upper Sacramento River (Windell et al. 2017). Per the CM6 framework diagram (Windell et al. 2017, Figure 8), the landscape attribute, Flood Bypass Weirs, is linked to the habitat attribute, Stranding Risk, and the environmental driver, Colusa Basin Releases, is also linked to Stranding Risk. Per the narrative (page 30):

> Water operations can influence the routing of Upper Sacramento River-origin water through agricultural fields into drainage canals and can create false attraction cues that cause salmon to deviate from the mainstem Sacramento River migration corridor and become stranded in agricultural fields behind flood bypass weirs (H3).

The CM6 narrative also discusses several linkages addressed in the model hypotheses and other effects of stranding:

> … stranding in bypasses can expose SRWRC [Sacramento River Winter-Run Chinook Salmon] to elevated and lethal water temperatures (H6) and poor water quality factors such as low DO (H4), which can compromise fish condition and the ultimate success of fish rescues into the mainstem Sacramento River. Stranding also increases the exposure of adults to poaching (H2).

The potential importance of passage impediments for Green Sturgeon is addressed in hypothesis H_{33} (Table 1, page 5) of the CM for Green and White Sturgeon in the San Francisco Estuary watershed produced by the Southwest Fishery Science Center (Heublein et al. 2017), which proposes that run-size and distribution are influenced by migration barriers. The spawning adult sub-model (page 27) links the environmental driver, Proximity to Barriers & Diversions, to the habitat attributes, Barriers and Harvest.

Current Condition

The Yolo Bypass and Fremont Weir and the Sutter Bypass and Tisdale Weir are sources of migratory delay and loss of adult Chinook Salmon, Steelhead, and sturgeon (NMFS 2009). The Yolo Bypass conveys up to 80% of the system's floodwaters for a distance of approximately 31 miles before discharging back into the Sacramento River upstream of Rio Vista. Yolo Bypass flows attract upstream migrating fish from the Sacramento River into the Yolo Bypass at the mouth of the Cache Slough complex. Among these are several Federal- and State-listed species, including Winter-Run Chinook Salmon, Spring-Run Chinook Salmon, Central Valley Steelhead, and Green Sturgeon. These fish continue migrating up the Yolo Bypass and may be able to return to the Sacramento River via the Fremont Weir (or the Tisdale Weir in the Sutter Bypass) as long as a sufficient volume of water flows over the weirs. However, when floodwaters recede, fish can be trapped in the weir splash basins and downstream scour ponds, pools, and swales. The original fish passage structure at Fremont Weir was inadequate to allow fish passage at most flows. As a result, adult salmonids and sturgeon migrating upstream through the Yolo Bypass were unable to reach upstream spawning habitat in the Sacramento River and its tributaries (https://www.calfish.org/ProgramsData/ConservationandManagement/CentralValleyMonitoring/SacramentoValleyTributaryMonitoring/YoloandSutterBypasses-Monitoring.aspx).

Even when floodwaters do not overtop flood control weirs, flows entering the Yolo Bypass from the west side (streams and agricultural drains) are oftentimes sufficient to attract fish. These fish continue their upstream migration through a series of perennial flowing agricultural drains such as Toe Drain, Tule Canal, and Knights Landing Ridge Cut. However, greater numbers of adult fish, particularly salmonids and sturgeon enter the Yolo Bypass during overtopping of the Fremont Weir and subsequent inundation of the Yolo Bypass (https://www.calfish.org/ProgramsData/ConservationandManagement/CentralValleyMonitoring/SacramentoValleyTributaryMonitoring/YoloandSutterBypasses-Monitoring.aspx).

Flow conditions in the bypass often allow adult salmonids and sturgeon to enter the Colusa Basin Drain, where they become stranded. There are three routes to enter the Colusa Basin Drain: (1) Yolo Bypass via the Knights Landing Ridge Cut, (2) Knights Landing Outfall Gates, and 3) hydrologic connection between the Colusa Basin and the Sacramento River (Windell et al. 2017). To hold back drainage water, an earthen Wallace Weir was manually constructed annually at the terminus of Knights Landing Ridge Cut in the Yolo Bypass for many years. Winter storms often broke the weir, allowing adult salmonids to stray into the Colusa Basin where they cannot reenter the Sacramento River. A permanent structure, including a fish rescue facility, was recently completed that remains operational under all flows (DWR and Reclamation 2017).

Stranding of adult salmonids and sturgeon in the Yolo Bypass has been well-documented in recent years. Since 1955, CDFW has conducted 28 fish rescues at Fremont Weir and inundated features within the Fremont Weir Wildlife Area (CDFW 2016). Over 10,000 fish, comprising 19 species, including four listed species (Winter-Run and Spring-Run Chinook Salmon, Central Valley Steelhead, and Green Southern Sturgeon DPS), have been captured and relocated during these rescue efforts. Without these efforts, many of these fish would die from poor water quality, predation, or poaching. (DWR and

Reclamation 2017). The ultimate reproductive success of fish intercepted at the bypass weirs and returned to the Sacramento River is unknown (Windell et al. 2017).

The Sutter Bypass has not been studied as extensively as the Yolo Bypass, but also contains impediments and barriers to adult fish upstream migration. Although the Sacramento River overflows Tisdale Weir during most years, it is unlikely that upstream passage at the weir occurs during flood events due to the dimensions of the weir and prohibitive hydraulic conditions below and above the weir. Adult salmon, Steelhead, and White Sturgeon have been found in Tisdale Weir's stilling basin after flood recessions. CDFW conducts rescue efforts at Tisdale Weir to relocate stranded individuals. Rescued fish that have been tagged have been observed migrating to spawning grounds and have been found in carcass surveys in the Sacramento River and Butte Creek. Various ponds, scour pools, drainages, and swales within the Tisdale and Sutter bypasses also can strand fish. Efforts to improve fish passage at Fremont Weir will be used to inform potential future efforts to provide for fish passage at Tisdale Weir (DWR and Reclamation 2017). Butte Creek also drains through the Sutter Bypass prior to its confluence with the Sacramento River, which can result in salmonids returning to Butte Creek or emigrating from Butte Creek to the Sacramento River becoming isolated in the Sutter or Tisdale bypasses (CDFW 2016).

Background

CDFW staff has conducted numerous fish rescues at the Fremont and Tisdale weirs for over 60 years, saving tens of thousands of fish, including listed species. The *Draft Environmental Impact Statement/Environmental Impact Report for the Yolo Bypass Salmonid Habitat Restoration and Fish Passage Project* addresses alternatives to modify the Fremont Weir to increase volitional fish passage back to the Sacramento River. However, the project is not scheduled for construction until 2021. Although project completion is expected to enhance fish passage and reduce stranding in the Yolo Bypass, CDFW will continue to monitor the Yolo Bypass for fish stranding and conduct rescues as necessary. Plans to modify the Tisdale Weir for structural improvements and fish passage are moving forward, but some fish rescue will still be necessary at this facility. https://www.calfish.org/ProgramsData/ConservationandManagement/CentralValleyMonitoring/SacramentoValleyTributaryMonitoring/YoloandSutterBypasses-Monitoring.aspx

Current Science

A number of modeling and research tools have recently been developed to assist in creating facilities to reduce stranding of fish in the bypasses. These include the following (DWR and Reclamation 2017; DWR 2017):

- Yolo Bypass Passage for Adult Salmonid and Sturgeon (YBPASS) tool combined with and U.S. Army Corps of Engineers Hydrologic Engineering Center River Analysis System (HEC-RAS) modeling to compare modeled water depths and velocities in the alternative-specific intake structures and transport channels to against adult Chinook Salmon and sturgeon fish passage criteria.
- Sedimentation and river hydraulics two-dimensional (SRH-2D) modeling along the Fremont Weir section of the Sacramento River to predict the hydrodynamics under the influence of various Fremont Weir notch configurations.
- Daily hydrodynamic two-dimensional unsteady flow (TUFLOW) modeling in the Yolo Bypass and Sacramento River downstream of Fremont Weir to evaluate hydraulic conditions in the Yolo Bypass and Sacramento River associated with changes in Sacramento River flows entering the Yolo Bypass at Fremont Weir.

Justification

The need to modify existing flood bypass weirs to reduce migration delays, mortality, and stranding risks has been identified by several agency efforts (CALFED 2000; USFWS 2001; Reclamation and DWR 2012, cited in Windell et al. 2017). In some years, flows through the bypasses likely result in false migration cues and large numbers of adult salmonids and sturgeon swim upstream in the bypasses and associated drains before being blocked at weirs and other impediments preventing successful migration. It is not possible to monitor and rescue all adults that become stranded and therefore the loss of adults prior to spawning can be demographically costly to the population (Windell et al. 2017).

Design and construction of fish passage improvement measures at the Fremont Weir and within the Yolo Bypass have begun and are scheduled to continue through 2021. While some of the proposed fish passage designs will likely increase fish passage through the Yolo and Sutter bypasses and back to the Sacramento River, sturgeon in particular may still be susceptible to isolation and stranding due to increased duration of flows through the bypass, as some planned modifications are intended to increase floodplain inundation for salmonid rearing (CDFW 2016). Monitoring for isolation and stranding of fish within the Yolo and Sutter bypasses should continue even after completion of fish passage improvement measures to determine if the measures are successful. Fish rescue efforts should be conducted as necessary to reduce lethal take of listed species (CDFW 2016)

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D1.2.3 Trinity Division

D1.2.3.1 *Water Operations*

D1.2.3.1.1 Clear Creek

Summary

Reclamation would release pulse flows from Whiskeytown Reservoir for habitat needs and channel maintenance on Clear Creek.

Description

Reclamation proposes to create pulse flows for channel maintenance by releasing up to 7,000 AF through the regular outlet once every three years to increase the flood magnitudes in Clear Creek. In addition, Reclamation will continue to release 7,000 AF for attraction flows in the spring. For the channel maintenance flows, Reclamation will release flows up to 900 cfs timed to coincide with high flows downstream of Whiskeytown Dam. This revised action will include mechanical side channel restoration when flow actions have not adequately addressed the rearing habitat needs. In addition, other mechanical methods may be used to improve habitat quantity and quality downstream of Whiskeytown Dam. If flows are sufficient downstream of the dam, the channel maintenance flows could reactivate fluvial geomorphic processes to recreate and maintain diverse instream and floodplain habitat required to support and recover aquatic and riparian habitat.

Objectives

- Fundamental objective: Increase juveniles at Chipps Island per adult return
- Means objectives: Spatial structure, productivity, diversity

Conceptual Model (Each Species and Life stage)

Increased flow releases would improve Spring-Run Chinook Salmon spawning habitat quantity and quality and rearing habitat diversity in Clear Creek by increasing the frequency and magnitude of flows sufficient to transport gravel and erode the banks. In combination with gravel augmentation, the high flows would allow for regular gravel transport and floodplain inundation throughout the river, and limit sand deposition on the bed. This component addresses SAIL CM upper river hypothesis sedimentation and gravel quantity (H8) and redd quality (H3) (Windell et al. 2017). Alluvial bank erosion and bar construction associated with the high flows would increase juvenile rearing habitat in Clear Creek.

Current Condition

Currently, flow in Clear Creek is primarily controlled through releases from Whiskeytown Dam, which is located 17 miles upstream from the confluence with the Sacramento River. The reservoir can release flows up to 1,200 cfs for a reservoir elevation of 1,209 feet (just below the Glory Hole elevation). Under current conditions, flood flows can be released through the Glory Hole Spillway, but the magnitude of these flows cannot be controlled, which may lead to safety issues and potentially fish stranding as the reservoir elevation drops below the lip of the Glory Hole.

Background

Restoration projects on Clear Creek include the removal of Saeltzer Dam, spawning gravel augmentation, riparian habitat restoration, and channel reconstruction. Minimum flow releases from the reservoir are 50 cfs from January to October and 100 cfs from November to December. In addition, flows are released through the existing infrastructure from June 1 to October 31 to maintain sufficiently low temperatures for incubating eggs in summer. The flows to maintain temperature can be much higher than the minimum flows. For example, for October 1 through October 15, 2018, 200 cfs were released from Whiskeytown to Clear Creek (Reclamation 2018), 150 cfs more than the required minimum flow.

Current Science

Modeling and monitoring of sediment transport on Clear Creek suggest that gravel transport initiates between 3,000 and 3,500 cfs (McBain and Trush 2001; Pittman and Matthews 2004). Daily average flow at the United States Geological Survey (USGS) gage at Igo exceeded 3,000 cfs on only 5 days (in 2 years) from WY 1998 to 2018, although annual peak flows exceeded 3,000 cfs 9 out of 20 years from 1998 to 2017. This suggests that peaks have a short duration that limits their geomorphic effectiveness.

In 2018, the Carr Fire burned much of the Clear Creek watershed below Whiskeytown Dam. This fire is likely to increase the sediment supply to Clear Creek in the near-term, and its potential effects will need to be assessed in tandem with flow release investigations.

Justification

Maintaining high spawning gravel quality and quantity requires relatively frequent sediment transport, a common attribute of alluvial rivers (e.g., Trush et al. 2000). Monitoring of sediment mobility in Clear Creek has shown that sediment transport thresholds differ throughout the river length. In general, sediment transport thresholds appear to occur between 3,000 and 3,500 cfs for most of the river (McBain and Trush 2001).

Over 190,000 tons of gravel have been augmented in Clear Creek (TNC 2017), but Pittman and Matthews (2007) estimated that 560,000 tons of sediment may be required to resupply gravel to the entire length of

Clear Creek below Whiskeytown Dam. As of 2007, this sediment was slowly moving downstream (Pittman and Matthews 2007). Maintaining spawning habitats requires relatively frequent gravel transport (every 1 to 3 years) to limit gravel embeddedness. The flows will provide some bank erosion in alluvial sections of the river and remove fine sediment from the bed (and deposit in the floodplain). All the responses to increased flows will increase spawning and rearing habitat quality and quantity in Clear Creek. Increases in flow will likely require an increase in the volume of augmented spawning gravel to match the increased sediment transport rate associated with higher flows. Moreover, these flow increases will require additional monitoring to ensure that gravel supply is similar to gravel transport.

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D1.2.3.1.2 Grass Valley Creek Flows

Summary

Reclamation would increase flow from the Buckhorn Dam outlet works to Grass Valley Creek for maintenance of the outlet channel and improve juvenile and adult migration.

Description

Reclamation proposes to release flow from Buckhorn Dam to Grass Valley Creek in accordance with requirements published in the Buckhorn dam and reservoir standard operating procedures manual for water rights permit 18879 issued to the California Department of Water Resources, which establishes the timing and magnitude of minimum flows and flushing flows from the dam.

In addition, Reclamation proposes to increase flow from the dam outlet works for maintenance of the outlet channel and to cue juvenile salmonids in the reach to begin their downstream migration to the Trinity River. Pulse flows will occur when the reservoir water elevation exceeds 2,803.13 feet above sea level between March 1 and April 15. Pulse discharge magnitudes will be up to 100 cfs, sufficient to mobilize gravel in the outlet channel upstream of where the spillway outlet. The pulse discharge may occur in a discrete event or by accumulation of multiple events lasting 5 to 7 days.

Reclamation also proposes to increase flow in the outlet channel when necessary in October and November to provide adult Coho Salmon sufficient flow for upstream migration and spawning. For this purpose, flow released from the outlet works will be increased to provide flow depths that are ≥0.60 feet on riffle crests within a downstream distance of 600 feet from the upstream extent of the run-of-river channel and increases discharge at the USGS stream gage near Lewiston to ≥10 cfs.

Objectives

- Fundamental objective: Increase juveniles at Chipps Island per adult return
- Means objectives: Spatial structure, productivity, diversity

Conceptual Model (Each Species and Life stage)

Increased flow releases would improve spawning habitat quantity and quality and rearing habitat diversity in Grass Valley Creek by increasing the frequency and magnitude of flows sufficient to transport gravel. This component addresses SAIL CM upper river hypothesis sedimentation and gravel quantity (H8) and redd quality (H3) (Windell et al. 2017).

The juvenile life stage for Coho Salmon is the most limited and quality summer and winter rearing habitat is lacking for the population. NMFS 2014 states the current high stressors for juvenile Coho Salmon to include:

- Rearing opportunities and capacity are low due to a reduced and dampened flow regime. Loss of flow variability and reduced rearing habitat during the fall and winter months as a result of water storage and regulation is expected to reduce the ability of the habitat in the Upper Trinity River to support winter rearing of juvenile Coho Salmon.
- Trinity River Hatchery plays a role in limiting the productivity (recruits produced per spawner) of the Upper Trinity River population through negative genetic and ecological interactions. Competition with hatchery fish released from Trinity River Hatchery limits rearing and spawning capacity in the Upper Trinity River. Hatchery-produced adult Coho Salmon estimates range from 590 to 17,448 fish during the period from 2008 through 2017 (Kier et al. 2018)
- Floodplain and channel structure is a high stress for the population and particularly affects fry, juveniles, and adults. Poor floodplain and channel structure is attributed to changes in the hydrology of the sub-basin. Changes in sediment supply, storage, and transport, in combination with altered mainstem flow following construction of the Trinity River Division, altered the channel geomorphology.

Current Condition

Gauge records at the mouth of Grass Valley Creek indicate a variable hydrology with a mean average flow of approximately 20 cfs. Discharge fluctuations range from the low end of 6 cfs which is controlled by the Buckhorn Dam outlet works and winter-spring runoff events that can reach up to 1,000 cfs for a short multiple hour duration. Approximately 600 feet downstream of the outlet works there is an exposed bedrock outcrop that is causing a natural hydraulic control resulting in raised surface water elevations.

Construction of Buckhorn Debris Dam and the operation of the Hamilton sediment ponds have prevented a considerable amount of fine sediment from entering the mainstem via Grass Valley Creek. Since 2005, Reclamation has constructed lowered floodplains, side channels, off channel habitat, and improved channel morphology at 33 locations in the Trinity River Restoration Program (TRRP), including in the Grass Valley Creek area. Reclamation works with partners to fund sediment reduction projects in the tributaries which have substantially reduced fine sediment inputs. Reclamation also carries out a program of annual gravel augmentation of the reach immediately below Lewiston Dam to offset the deficit of gravel that is trapped behind the dams.

Most recently in 2018, the TRRP continued to advance channel rehabilitation designs, reviews, and environmental permitting at 34 of the 47 sites within the TRRP Focal Reach (on the Trinity River between Lewiston Dam and the confluence of the North Fork Trinity River) as described in 1999 Trinity River Flow Evaluation Final Report; coordinated and scheduled the release of 369 TAF from Lewiston Dam allowed under the Trinity River ROD in a critically dry water year and conducted studies to monitor the results of the release; scheduled daily flows during the spring restoration flow releases to more closely match the daily pattern on natural river systems; and re-organized the Riparian and Aquatic Ecology Workgroup to better reflect the workgroup’s riparian wildfire and vegetation efforts related to Trinity River restoration (TRRP 2019).

Background

For 1.2 miles above the reservoir and from the dam to the mouth, Grass Valley Creek is a fish bearing Class I waterbody, supporting Chinook and Coho Salmon, Steelhead, rainbow and brown trout, Klamath small-scale sucker, and Lamprey. Steelhead trout are found as far as the dam and Chinook Salmon are found 7.5 miles up from the mouth of the dam. Surveys conducted by TRRP and NMFS on June 23, 2011 observed Coho Salmon in the outlet channel, although no Coho Salmon were observed above an exposed bedrock outcrop located approximately 600 feet downstream of the outlet works (Reclamation 2012). Grass Valley Creek is being used by Coho Salmon throughout most its 10.8 miles of stream length between the dam and confluence with the Trinity River.

NMFS 2014 states for Coho Salmon population: “The Upper Trinity River population is at moderate risk of extinction because NMFS estimates the ratio of the three consecutive years of lowest abundance within the last twelve years to the amount of IP-km in a watershed is greater than one, but the ratio is less than the minimum required spawner density.”

Buckhorn Dam was built to trap fine sediment eroding from the upper Grass Valley Creek watershed in order to reduce fine sediment input into the Trinity River. It has an uncontrolled/un-gated “run of the river” concrete spillway on the north end of the dam that spills during the winter-spring runoff period or storm events. The dam also has a buried 800-foot long gated-conduit system as the main outlet works. Buckhorn Dam completely blocks upstream fish migration.

Current Science

As part of an ongoing study for the TRRP, Reclamation conducts bedload and suspended sediment sampling at four monitoring locations on the mainstem Trinity River: at Lewiston (TRAL), near Grass Valley Creek (TRGV), at Limekiln Gulch (TRLG), and near Douglas City (TRDC). TRLG is downstream of the mouth of Grass Valley Creek. Other components of the TRRP include monitoring of habitat, habitat use, juvenile populations, and adult populations. TRRP’s restoration strategy involves a combination of Spring Flow Releases, fine and coarse sediment management, and mechanical channel rehabilitation. Annual studies are conducted as part a sediment budget approach to understanding sediment-related habitat issues. The sediment load estimates inform gravel injection strategies (locations and volumes) and hydrograph development for Spring Flow Releases.

The *Final Southern Oregon/Northern California Coast Coho Recovery Plan* (NMFS 2014) lists recovery actions for the Upper Trinity River Coho Salmon population. The following are applicable to Grass Valley Creek.

- Improve flow timing or volume: Increase instream flows.
- Improve flow timing or volume: Secure and maintain sufficient instream flows.
- Increase channel complexity: Increase large woody debris, boulders, and other stream structures.
- Reduce water temperature, increase dissolved oxygen: Increase flow.
- Reconnect the channel to the floodplain: Increase beaver abundance.

Justification

Maintaining high spawning gravel quality and quantity requires relatively frequent sediment transport, a common attribute of alluvial rivers (e.g., Trush et al. 2000). NMFS 2014 states: "Recovery activities in the watershed should promote increased spatial distribution as well as increased productivity and abundance. Curtailing the effects of hatchery fish on this population is of utmost importance. Activities that increase streamflows, reduce summertime stream temperatures, increase fish distribution through barrier removal, promote increased floodplain and channel structure and improve long-term prospects for large woody debris recruitment, should be a priority in the watershed."

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D1.2.4 Feather River Basin

D1.2.4.1 *Water Operations*

D1.2.4.1.1 Core Water Operations

Summary

DWR would adjust Lake Oroville releases to result in more favorable flow and temperature conditions for salmonids.

Description

DWR would adjust river flow and temperature in the Feather River, as provided under the Federal Energy Regulatory Commission (FERC) Settlement Agreement for the Licensing of Oroville Facilities, to create additional spawning and rearing habitat by increasing useable area for adult and juvenile salmonids. Table D1.2-6, Feather River Flow and Temperature Adjustments, shows the new flow and temperature targets. These targets are within the Feather River Low Flow Channel (LFC), which is the reach between the fish barrier dam and the Thermalito Afterbay Outlet (where the flows through the powerplant are discharged).

Table D1.2-6. Feather River Flow and Temperature Adjustments

Flow	
Flow Velocity (cfs)	*Implementation Date*
700	April 1–September 8
800	September 9–March 31
Temperature	
Target (°F, mean daily)	*Compliance Point*
56–63	Robinson Riffle

cfs = cubic feet per second
°F = degrees Fahrenheit

The temperature target would be 56°F from October through April, then have a transition period through May 15. The temperature target would shift to 63 degrees through August, with a transition period to September 8. For the rest of the month of September, the temperature target would be 58°F.

DWR would also provide for re-operation of the Oroville facilities to maximize spawning and rearing in the Feather River for salmonids. Instead of routing flows through Thermalito Forebay and the power generation facilities at Oroville, a pulse flow would instead be routed directly through the low-flow channel to create optimal conditions for fish in the upper Feather River. This pulse flow would be 2,000 cfs for 14 or more continuous days between January 1 and April 15. DWR would make this release in dry, below normal, or above normal years, and it would result in a release of 43 TAF on an average annual basis.

Objectives

- Fundamental objective: Increase juveniles at Chipps Island per adult return
- Means objectives: Abundance and productivity

Conceptual Model (Each Species and Life stage)

Increased flows and decreased temperatures in the LFC would benefit Spring-Run and Fall-Run Chinook Salmon in the Lower Feather River, particularly the spawning and rearing periods. The biggest stressor is high water temperature during the spawning periods, when the air temperature is warm.

Aspects of the SAIL CM for Winter-Run Chinook Salmon on the Sacramento River can be linked to Spring-Run and Fall-Run Chinook Salmon on the Feather River. The SAIL CM identifies the impacts of high water temperatures as a stressor for spawning and rearing for salmonids. The SAIL CM states:

> In recent years, water temperatures suitable for critical SRWRC life stages (spawning, egg incubation, and fry emergence) appear to have confined successful reproduction to the upper 10 to 15 river miles below Keswick Dam. Adult Chinook Salmon held at temperatures greater than 60°F have exhibited poor survival and reduced egg viability (DWR 1988). Laboratory and field studies have shown that when adult fish are exposed to constant or average temperatures above 55.4°F–60°F (13°C–15.6°C) during holding prior to spawning, there is a detrimental effect on the size, number, or fertility of eggs held in vivo (EPA 2001). Thus, adult holding and spawning distribution may be limited by the temperature controlled stretch of the Sacramento River.

For rearing to outmigrating juveniles, the SAIL CM states:

> The foremost factor affecting migration, growth, and survival of SRWRC fry is habitat (e.g., substrate, water quality, water temperature, water velocity, shelter, and food; Williams 2006, Williams 2010). Additional factors include disease, predation, and climate variability (NMFS 1997, Williams 2010). Increased instream flow affects many of these factors through dilution (e.g., toxicity and contaminants), reduction in water temperatures (which also affects DO, food availability, predation, pathogens, and disease) and entrainment and stranding risk, and potentially increases in cues to stimulate outmigration.

Current Condition

The Thermalito Diversion Dam and Powerplant is four miles downstream from the Oroville Dam/Hyatt Powerplant. The dam diverts water to the Thermalito Power Canal, which bypasses water from the Feather River into the Thermalito Forebay, Thermalito Pumping-Generating Plant, and Thermalito Afterbay. This water re-enters the Feather River at the Thermalito Afterbay Outlet.

Just downstream from the Thermalito Diversion Dam is the Fish Barrier Dam, which is impassible to fish that diverts fish into the ladder into the Feather River Fish Hatchery. The Feather River LFC is the reach from the Fish Barrier Dam downstream to the Thermalito Afterbay Outlet. Currently, DWR releases 600 cfs into this reach to maintain conditions for fish (NMFS 2016).

Background

The lower Feather River (downstream of Oroville Dam) supports Spring-Run and Fall-Run Chinook Salmon. Adult Fall-Run Chinook Salmon typically migrate upstream to spawn from September through December, and Spring-Run typically move upstream from March through June to spawn the following fall. Before development of water and power facilities on the Feather River system, Fall-Run Chinook Salmon spawned in the mainsteam river downstream of the current Oroville Dam site. Spring-Run Chinook spawned upstream of the current Oroville Dam site in the three branches of the Feather River (Sommer et al. 2001).

Construction of the Oroville water and power facilities has changed the flows and temperatures within the LFC. Mean monthly flows through the LFC are now 5% to 38% of pre-dam levels. Mean monthly temperatures are 2 to 14 degrees cooler during May through October and 2 to 7 degrees warmer during November through April (Sommer et al. 2001).

Current Science

Currently, the Feather River LFC presents the primary area of interest for salmon spawning (Sommer, et al. 2001). There is little or no spawning downstream of Honcut Creek (downstream from the LFC).

In support of the FERC relicensing effort, DWR studied water temperatures and the relationships to Spring-Run Chinook salmon immigration and holding in the lower Feather River. The study established index values to indicate suitable temperatures, and found that these index values were exceeded in some pools during the holding period. The conclusion indicated that "increased incidence of disease, developmental abnormalities, increased in-vivo egg mortality, and temporary cessation of migration could occur due to elevated water temperatures in some areas of the lower Feather River" (DWR 2004).

Justification

The flow and temperature targets would maintain suitable conditions for Spring-Run and Fall-Run Chinook Salmon during the periods that they are migrating upstream, holding, spawning, and rearing in the Lower Feather River.

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D1.2.5 American River Basin

D1.2.5.1 *Water Operations*

D1.2.5.1.1 2017 Flow Management Standard Releases and "Planning Minimum"

Summary

Reclamation proposes to implement a version of the Flow Management Standard (FMS) proposed by the Water Forum in 2017 that incorporates a multiyear sustainable management approach.

Description

Reclamation proposes to meet water rights, contracts and agreements that are both specific to the American River Division as well as those that apply to the entire CVP, including the Delta Division. For lower American River flows (below Nimbus Dam), Reclamation proposes to adopt the minimum flow schedule and approach proposed by the Water Forum in 2017. Flows range from 500 to 2000 cfs based on time of year and annual hydrology. The flow schedule is intended to improve cold-water pool and habitat conditions for Steelhead and Fall-Run Chinook Salmon. Minimum releases into the lower American River are determined based on multiple formulas established through a cooperative effort with stakeholders (American River Water Agencies 2017).

Reclamation proposes to work together with the American River Stakeholders (CDFW and DWR, American River Water Agencies) to define an appropriate amount of storage in Folsom Reservoir that represents the lower bound for typical forecasting processes at the end of calendar year (the "planning minimum") (DWR and CDFW 2018). The objective of the planning minimum is to preserve storage to protect against future drought conditions and to facilitate the development of the cold water pool when possible. This planning minimum will be a single value (or potentially a series of values for different hydrologic year types) to be used for each year's forecasting process into the future. The objective of incorporating the planning minimum into the forecasting process is to provide releases of salmonid-suitable temperatures to the lower American River and reliable deliveries (using the existing water supply intakes and conveyance systems) to American River water agencies that are dependent on deliveries or releases from Folsom Reservoir. To meet this objective, Reclamation proposes to work together with the American River parties to determine the draft value(s) that are appropriate. If there is a change circumstances that may necessitate adjustments to the value(s) for the planning minimum, any American River Stakeholder may request that the technical group reconvene and that Reclamation re-evaluate its preferred value(s) based on the changed circumstances.

Reclamation would then determine preferred value(s) for use in its forecasting process for guiding seasonal operations, however, the forecasted storage may fall below the "planning minimum" due to a variety of circumstances and causes. In those instances, Reclamation and the American River stakeholders will develop a list of potential off-ramp actions that may be taken to either improve forecasted storage or decrease demand on Folsom. In its forecasting process for guiding seasonal operations, Reclamation will plan to maintain or exceed the planning minimum at the end of the calendar year. When Reclamation estimates, using the forecasting process, that it would not be able to maintain Folsom Reservoir storage at the end-of-December "planning minimum" for that year type (such as in extreme hydrologic conditions) or unexpected events cause the storage level to be at risk, American River Division contractors would coordinate with Reclamation to identify and implement appropriate actions to improve forecasted storage conditions, and the American River stakeholders would work together to educate the public on the actions that have been agreed upon and implemented and the reasons and basis for them. If potential changes to Folsom operations would have impacts on other divisions of the

CVP/SWP or the entire integrated system, Reclamation will meet and discuss with Water Contractors. Reclamation would ramp down to the revised minimum flows from Folsom Reservoir as soon as possible in the fall and maintain these flows, where possible.

Objectives

- Fundamental objective: maintain minimum fish population during drought
- Means objective: spatial structure

Conceptual Model (Each Species and Life stage)

The FMS would benefit Steelhead and Fall-Run Chinook Salmon in the Lower American River, particularly the spawning and rearing periods. Steelhead spawn during winter, and juvenile Steelhead generally rear over summer before emigrating to the ocean following winter or spring. Therefore, their biggest stressor is high water temperature during the summer, when the air temperature is hot. Fall-Run Chinook Salmon spawn during the fall, and the juveniles emigrate from the river before summer. Their biggest stressor is warm water temperatures and inadequate spawning flows during October and November.

Aspects of the SAIL CM for Winter-Run Chinook Salmon on the Sacramento River can be linked to Fall-Run Chinook Salmon and Steelhead on the American River (Windell et al. 2017). The SAIL CM identifies the impacts of high water temperatures as a stressor for spawning and rearing for salmonids. The SAIL CM states:

> In recent years, water temperatures suitable for critical SRWRC life stages (spawning, egg incubation, and fry emergence) appear to have confined successful reproduction to the upper 10 to 15 river miles below Keswick Dam. Adult Chinook Salmon held at temperatures greater than 60°F have exhibited poor survival and reduced egg viability (DWR 1988). Laboratory and field studies have shown that when adult fish are exposed to constant or average temperatures above 55.4–60°F (13–15.6°C) during holding prior to spawning, there is a detrimental effect on the size, number, or fertility of eggs held in vivo (EPA 2001). Thus, adult holding and spawning distribution may be limited by the temperature controlled stretch of the Sacramento River.

For rearing to outmigrating juveniles, the SAIL CM states:

> The foremost factor affecting migration, growth, and survival of SRWRC fry is habitat (e.g., substrate, water quality, water temperature, water velocity, shelter, and food; Williams 2006, Williams 2010). Additional factors include disease, predation, and climate variability (NMFS 1997, Williams 2010). Increased instream flow affects many of these factors through dilution (e.g., toxicity and contaminants), reduction in water temperatures (which also affects DO, food availability, predation, pathogens, and disease) and entrainment and stranding risk, and potentially increases in cues to stimulate outmigration.

Current Condition

The current operations at Folsom Dam are guided by the NMFS BO RPA Action II.1, Lower American River Flow Management, which requires Reclamation to implement the flow schedule specified by the 2006 FMS. Folsom Dam is operated to meet the State Water Rights permits and requirements adopted by the State Water Resources Control Board (SWRCB) in 1958 though Decision 893.

Background

The 2006 FMS is a set of measures that includes minimum release requirements and water temperature objectives, oversight by an interagency workgroup (American River Group), and monitoring and evaluation. The 2006 FMS uses a sliding scale for minimum flow releases, and water temperature targets that balance available water supplies with achievable objectives to preserve wildlife and biological functions within the river.

Current Science

The Sacramento Water Forum has been working on options to modify the FMS, and the process is ongoing.

Justification

Recent drought conditions have demonstrated the need for reliable water storage in Folsom Reservoir and a modification to the current flow requirements of the lower American River. Modification of the FMS could allow Reclamation to maintain reliable water supplies within the Folsom Reservoir and improve habitat conditions for Steelhead and Fall-Run Chinook Salmon in the lower American River.

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D1.2.5.2 *Habitat*

D1.2.5.2.1 Spawning and Rearing Named Projects

Summary

This component includes spawning and rearing projects to improve conditions for Chinook Salmon in the Lower American River system.

Description

These projects would increase spawning and rearing opportunities in the Lower American River (Reclamation 2016):

- Paradise Beach: The site includes a large floodplain area along the left bank of the river upstream of Paradise Beach. Side channel habitat would be created and the floodplain habitat modified so that it becomes inundated over a range of flows. Woody material would be included in the side channel habitat.
- Howe to Watt: The site includes the low elevation area along the south side of the river between the Watt and Howe boat ramps. It includes existing side channel and backwater habitat that becomes disconnected from the river at lower flow levels. Work at this site would increase the connectivity between the backwater habitat and the river channel so that juvenile rearing can occur at most flows.
- Upper River Bend: The site includes a one mile reach of the river between the upstream part of River Bend Park and the downstream end of Ancil Hoffman golf course. The reach includes floodplain area along both sides of the channel. The riffles in this area include low density spawning. Much of the existing habitat is armored with material too large for spawning. Side channel habitat would be created and floodplain habitat modified in the low elevation areas on both sides of the river.
- Ancil Hoffman: The site includes floodplain area along the right bank of the river. The main channel includes riffle habitat where spawning occurs, mostly along the left bank and adjacent to the island at the upstream end of the site. The project would include side channel creation and floodplain modification along the right bank and gravel placement in the main river channel. The short side channel at the upstream end of the site includes good depths and velocities for spawning but the substrate is mostly too large. The oversized material would be pushed to deeper water or onto the island and replaced with spawning sized material from the floodplain area. The finished side channel would be slightly deeper than the existing channel which is dry at low flows. Woody material would be added to the side channel areas.
- Sacramento Bar – North and South: The site includes Sacramento Bar and the reach of river adjacent to Sacramento Bar. Sacramento Bar is a slightly perched floodplain where both gravel mining and dredging occurred in the past. The mining left a pond disconnected from the river at all times except for high flows. The river channel at the upstream end of the site receives spawning use, predominantly along the edges of the channel. The spawning habitat consists of predominantly oversized material with most usable sized material along the banks. The project would create side channel and modify floodplain habitat on Sacramento Bar. Gravel from the bar would be sorted and placed in the river channel along the east side of the bar to improve the size distribution of the spawning habitat.
- El Manto: The site includes low elevation floodplain habitat along the left bank of the river and the main channel of the river upstream and downstream of San Juan Rapids. Spawning occurs on the riffles through this reach. The habitat in the center of the channel is armored with material too large for spawning. The project would include side channel creation and floodplain modification along the left bank of the river.
- Sunrise: The site includes the reach of the river between the Sunrise Boulevard Bridge and the old Fair Oaks Bridge. The area consists of a riffle where heavy salmonid spawning occurs, pool habitat upstream of the riffle, and some low elevation floodplain on the south side of the river. However, a juvenile isolation area is currently within the floodplain. Work at this site would

include side channel creation, floodplain modification, and woody material placement along the south side of the river.

- Upper Sunrise (Lower Sailor Bar): This site includes a 0.75-mile reach of the river between the upper Sunrise side channel and the 2012 gravel placement and side channel creation project and includes the adjacent floodplain along the south side of the river. Previous projects occurred in this reach in 2010–2012. The past work included riffle and island creation midway through the reach, side channel reconnection at the downstream end of the reach and gravel placement and side channel creation at the upstream end of the reach. Woody material was placed in the main channel adjacent to the created islands and within the created side channel at the upstream end of the reach. The reach includes a low elevation area along the south side of the river where additional side channel and floodplain habitat could be created. Additional gravel placement could occur at the 2010–2011 placement sites to enlarge the site to create a channel spanning riffle.

Objectives

- Fundamental objective: Increase juveniles at Chipps Island per adult return
- Means objective: Abundance and productivity

Conceptual Model (Each Species and Life stage)

Spawning habitat restoration is primarily focused on gravel augmentation, which can benefit multiple Chinook Salmon life stages. Provided that gravel augmentation creates suitable depth, velocity, and substrate conditions, these rehabilitation actions can increase adult spawning activity (Merz and Setka 2004; Zeug et al. 2013) and provide high quality incubation habitat for embryos and yolk sac fry (Merz et al. 2004). Gravel augmentation can also improve juvenile rearing habitat by increasing local water surface elevation, resulting in more frequent and extensive inundation of edge habitat and floodplains (Sellheim et al. 2015). However, if spawning substrate is too large, it may not be used by smaller-bodied species or individuals within a species (Zeug et al. 2013); in contrast, if substrate is too small it may result in poor embryo survival, even if spawning occurs (Merz et al., in press). The projects also include rearing habitat improvements by increasing the opportunities to activate floodplains, creation of secondary channels to access floodplain, and improvement of floodplain rearing habitat quality.

Current Condition

Historic gold and gravel mining have greatly altered geomorphic and hydraulic conditions of the American River, with adverse impacts to salmonid populations (Williams 2001; Yoshiyama et al. 2001). Extensive alterations to the American River streambeds deeply incised the main channel, disconnected side channels and floodplains, and altered riparian vegetation (James 1997). Regulated flows compounded incision, further eroded beds and banks, coarsened bed material, and inhibited the flushing of fine particles from the gravel (Kondolf 1997; Kondolf et al. 2001).

Background

Gravel augmentation is a widely accepted technique for rehabilitating anadromous salmonid spawning habitats within regulated streams of the California Central Valley (Wheaton et al. 2004a, 2004b). Several studies have demonstrated that gravel augmentation can increase Chinook Salmon spawning activity (Merz and Setka 2004; Palm et al. 2007; Zeug et al. 2013). Physical and biological effects of gravel augmentation projects are influenced by a suite of intermediate mechanisms and external factors related to hydrodynamics, geomorphology, and ecology (Downs and Kondolf 2002). Therefore, the overall effects of restoration projects on river ecosystems and specified life stages of target species, and secondary influences on non-target organisms, are highly variable both within and among ecosystems. In addition, because even heavily regulated rivers are dynamic and both flow and physical engineering of spawning beds by salmon cause downstream sediment transport, a gravel augmentation project is not expected to function indefinitely and will be reduced as sediment is carried downstream (Merz et al. 2006; Humphries et al. 2012).

In the past two decades, several rehabilitation efforts have been undertaken on the American River to improve the quality and quantity of salmonid spawning habitat. Table D1.2-7, CVPIA Gravel Augmentation in the American River from 1999 to Present, summarizes the amounts of gravel added to the river during each year in which a gravel augmentation project was implemented.

Table D1.2-7. CVPIA Gravel Augmentation in the American River from 1999 to Present

Year	Gravel augmentation (tons)
1999	6,000
2008	7,000
2009	10,600
2010	16,000
2011	20,770
2012	24,510
2013	6,000
2014	10,000
2016	30,000
TOTAL	130,880

Current Science

Multiple effectiveness monitoring studies have been implemented on the American River to test the effects of gravel augmentation on salmon adults, embryos, and juveniles. Zeug et al. (2012) found that gravel augmentation increased site utilization, but the degree to which a particular augmentation action was effective depended upon the species (Chinook Salmon or Steelhead) and substrate size. Cramer Fish Sciences (2017a) found that substrate size impacts benthic invertebrate prey production, with lower prey density in smaller gravels. Merz et al. (in press) also observed conflicting optimal gravel sizes between adult spawners and salmon embryos, with higher spawning activity in small gravel and higher embryo survival in large gravel. Sellheim et al. (2015) found that gravel augmentation improved juvenile rearing habitat by reconnecting remnant floodplains under lower streamflow conditions. Cramer Fish Sciences (2017b) assessed gravel augmentation site longevity and that the positive effects of gravel augmentation (i.e., increased habitat utilization) declined to pre-project levels within 5 to 6 years after implementation.

Justification

In response to continued anadromous salmonid stock declines, Public Law 102-575 was passed by Congress in 1992 and, under Title 34, established the CVPIA (1992). With the goal of protecting, restoring, and enhancing fish, wildlife, and associated habitats in the Central Valley, this legislation granted authority to Reclamation and USFWS to co-lead anadromous fish restoration efforts for the United States Department of the Interior (Interior). The resulting CVPIA Fisheries Program was directed to make "…all reasonable efforts…" to double natural production of anadromous fish [Section 3406(b)(1)]. Section 3406(b)(1)(A) gives "…first priority to measures which protect and restore natural channel and riparian habitat values through habitat restoration actions" (CVPIA 1992). Additionally, to compensate for actions that reduced the availability of spawning and rearing habitat, CVPIA Section

3406(b)(13) authorizes and directs Reclamation and USFWS, along with other Federal and State agencies, to create a program to continue restoration and replenishment of spawning gravel in Central Valley rivers, including the American River below Nimbus Dam (hereafter referred to as the lower American River).

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D1.2.6 Bay-Delta

D1.2.6.1 *Water Operations*

D1.2.6.1.1 <u>OMR Management</u>

Summary

OMR reverse flow provides a surrogate indicator for how export pumping, inflow and the spring-neap tidal cycle influence hydrodynamics in the south Delta. Reverse OMR flow (negative values of OMR) indicates a net flow from the Sacramento River toward the export pumps. The RPAs in 2008/2009 BOs added OMR reverse flow criteria to protect listed fish species in the Delta from entrainment into channels that lead to the export pumps. Reclamation would propose Real-Time OMR Protections for Delta Smelt and salmonids, including modifications to USFWS BO Actions 2 and 3 along with NMFS BO IV.2.3 to incorporate real-time monitoring of fish distribution, hydrodynamic models, and entrainment models into the decision support for the management of OMR, as follows:

The Smelt Working Group (SWG) and Delta Operations for Salmon and Sturgeon (DOSS) would inform Reclamation when fish species have entered the portion of the Delta that is within the influence of the Pumping Plants.

1. At that time, Reclamation would conduct a risk assessment based on hydrodynamic models, entrainment models, and the monitoring of fish distribution to determine whether the pumps were at risk of entraining fish over the incidental take limit.
2. If Reclamation's risk assessment indicates low risk to the species, pumping would continue. If the risk assessment indicates high risk of exceeding the take limit, pumping would be reduced until the risk lowers.
3. Once 50% loss has been reached in a given year/season, Reclamation would begin operating to the density dependent triggers as identified in the 2009 NMFS BO, as amended.

Storm event OMR management during storm-related events, consistent with the Water Infrastructure Improvements for the Nation Act (WIIN) Act, Section 4003, to continue to occur through the duration of the BO. Reclamation would propose to operate to the Index Based OMR that utilizes an equation for measuring compliance.

Description

Reclamation and DWR propose to operate the CVP and SWP in a manner that maximizes exports while minimizing entrainment of fish and protecting critical habitat. OMR reverse flows provide a surrogate indicator for how export pumping, inflow, and the spring-neap tidal cycle influence hydrodynamics in the south Delta. The management of OMR, in combination with other environmental variables, can minimize or avoid the entrainment of fish in the South Delta and at CVP and SWP salvage facilities. Reclamation and DWR propose to maximize exports by incorporating real-time monitoring of fish distribution, turbidity, temperature, hydrodynamic models, and entrainment models into the decision support for the management of OMR to focus protections for fish when necessary and provide flexibility where possible, consistent with the WIIN Act Sections 4002 and 4003, as described below. Estimates of species distribution will be described by multi-agency Delta-focused technical teams. Reclamation and DWR will make a change to exports within 3 days when monitoring, modeling, and criteria indicate protection for fish is necessary.

- Reclamation and DWR propose to operate to an index equation for OMR. An OMR index allows for short-term operational planning and real-time adjustments.
- OMR Management: From the onset of OMR management to the end, Reclamation and DWR will operate to an OMR index no more negative than a 14-day moving average of −5,000 cfs unless a storm event occurs. Grimaldo et al. (2017) indicate that negative 5,000 cfs is a key OMR threshold for fish entrainment. OMR could be more positive than negative 5,000 cfs if additional real-time OMR restrictions are triggered as described below.
- Onset of OMR Management: Reclamation and DWR shall start OMR management when one or more of the following conditions have occurred:
    - Integrated Early Winter Pulse Protection – After December 1, when the 3-day average turbidity is 12 Nephelometric Turbidity Units (NTU) or greater at Old River at Bacon Island (OBI), Prisoner's Point (PPT), and Victoria Canal (VCU) in December, Reclamation and DWR propose to operate to -2,000 cfs of the 14-day average OMR index for 14 days.
    - Salmonids – After January 1, if more than 5% of any one or more salmonid species (wild young-of-year Winter-Run Chinook Salmon, wild young-of-year Spring-Run Chinook Salmon, or Steelhead) are estimated to be present in the Delta as determined by their

appropriate Monitoring Team based on available real-time data, historical information and modeling.

- Additional Real-Time OMR Restrictions: Reclamation and DWR shall manage to a more positive OMR based on the following conditions:
  - Turbidity Bridge Avoidance: Reclamation and DWR propose to operate to avoid a turbidity bridge (defined as 3-day average turbidity of 12 NTU at OBI). If a turbidity bridge occurs (3-day average turbidity is 12 NTU or greater at OBI and VCU and/or other predictors of a turbidity bridge), Reclamation and DWR propose to operate to a 5-day average OMR index of -2000 cfs for at least 5 days until 24 hours after the turbidity bridge dissipates (drops below 12 NTU at any of the southernmost stations). If turbidity is triggered by a wind event in Franks Tract and the channels immediately adjacent to Franks Tract, Reclamation would not modify the controlling OMR. When water temperature reaches 12 degrees Celsius based on a three station daily mean at Mossdale, Antioch, and Rio Vista, or when Delta Smelt spawning starts (indicated by spent females in the Spring Kodiak Trawl (SKT), Enhanced Delta Smelt Monitoring (EDSM) Program, or at Jones or Banks), this action terminates.
  - Wild Central Valley Steelhead Protection: Reclamation and DWR would operate to OMR of -2,500 cfs for 5 days whenever natural-origin Steelhead loss trigger between the onset of OMR management for Steelhead and May 31 exceeds 10 Steelhead per TAF. The timing of this action is intended to provide protections to San Joaquin origin Central Valley Steelhead, but the loss-density trigger is based on loss of all Steelhead since there is currently no protocol to distinguish San Joaquin-basin and Sacramento-basin Steelhead in salvage. Reclamation would use the current loss equation for Steelhead or surrogate.
  - Salvage or Loss Thresholds: To backstop real-time operations, Reclamation and DWR propose a cumulative loss threshold of 90% of the take limit for Chinook Salmon, a cumulative loss threshold of 90% of the take limit for Steelhead, a cumulative expanded salvage threshold of 90% of the take limit for Green Sturgeon, 1% of the abundance estimate based on EDSM for adult Delta Smelt, and 5% of the abundance estimate based on EDSM for juvenile Delta Smelt. Reclamation and DWR propose to operate as follows:
    - Reclamation and DWR may operate to a more positive OMR when the daily salvage loss indicates that continued OMR of negative 5,000 cfs may exceed cumulative salvage loss thresholds.
    - When Q-West is negative and larval or juvenile smelt are within the entrainment zone of the pumps based on real-time sampling, Reclamation and/or DWR propose to run hydrodynamic models informed by the EDSM, 20 mm or other relevant survey data to estimate the percentage of larval and juvenile smelt that could be entrained, and operate to avoid no greater than 10% loss of modeled larval and juvenile cohort Delta Smelt. (Typically, this would come into effect no earlier than the middle of March.)
    - Restrict OMR to a 14-day moving average OMR index of –3,500 cfs when a species-specific cumulative salvage or loss threshold exceeds 50% of the threshold. The OMR restriction to –3,500 cfs will persist until the species-specific off ramp is met.
    - Restrict OMR to a 14-day moving average OMR index of –2,500 cfs (or more positive if determined by Reclamation) when cumulative salvage or loss threshold for any of the above species exceeds 75% of the threshold. The OMR restriction to –2,500 cfs will persist until the species-specific off ramp is met.

- Species-specific off ramp: Species-specific OMR restrictions will end when the individual species-specific “End of OMR management criteria” are met. For instance, if a Winter-Run Chinook Salmon cumulative salvage loss exceed 50% of the criteria during the season, operations would be limit to –3,500 OMR until it is estimated 95% of Winter-Run Chinook Salmon have migrated past Chipps Island.

The Secretaries of Interior and Commerce will comply with Section 4002 of the WIIN Act while the WIIN Act is in effect for OMR more positive than negative 5,000 cfs.

If Reclamation determines that a more negative OMR than the thresholds is warranted, Reclamation shall seek technical assistance from USFWS and NMFS, and support DWR in seeking California Endangered Species Act compliance.

- Storm-Related OMR Flexibility: If Reclamation and DWR are not implementing additional real-time OMR restrictions, consistent with other applicable legal requirements, Reclamation and DWR may operate to a more negative OMR up to a maximum (otherwise-permitted) export rate of 14,900 cfs (which could result in a range of OMR values) to capture peak flows during storm-related events. Reclamation and DWR will continue to monitor fish in real-time and will operate in accordance with “Additional Real-time OMR Restrictions,” above.
- End of OMR Management: OMR criteria may control operations until June 30, or when both of the following have occurred, whichever is earlier:
    - Delta Smelt – when the daily mean water temperature at Clifton Court Forebay reaches 25°C for 3 consecutive days.
    - Salmonids – When more than 95 percent of salmonids have migrated past Chipps Island, as determined by their Monitoring Team, OR after daily average water temperatures at Mossdale exceed 72 degrees Fahrenheit for 7 days during June.

Figure D1.2-5, OMR Decision Tree, shows OMR management in a decision tree.

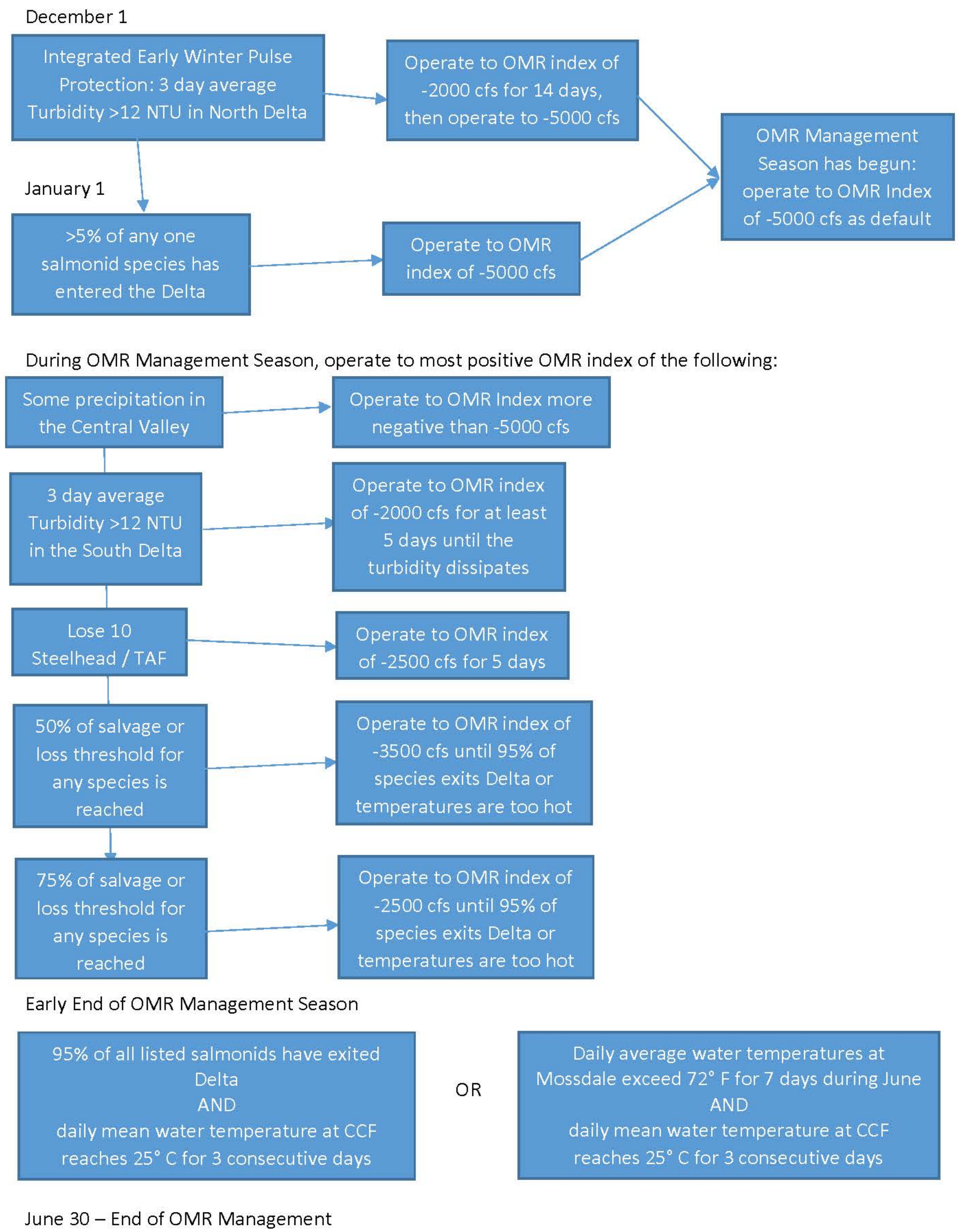


Figure D1.2-5. OMR Decision Tree

Objectives

- Fundamental objective: Increase juvenile salmon at Chipps Island per adult return
- Means objective: Adult Delta Smelt abundance

Conceptual Model (Each Species and Life stage)

This action affects CM4: Rearing to Migrating Juvenile in Tidal Delta, Estuary, and Bays for Winter-Run Chinook Salmon, and similar CMs for other salmonids. Habitat attribute H9 in this life stage is the effect of Jones and Banks Pumping Plants on entrainment risk for salmonids, which affects survival, timing and growth. The SAIL CM states:

> Migration corridors and rearing habitats near water diversions increase the risk of entrainment-related mortality (H9). Juvenile salmon arriving in the South Delta are at risk of entrainment in the CVP and SWP water intakes. Each of these pumping plants has a fish salvage facility, and recent research suggests that once juvenile salmon enter the South Delta survival can be higher for fish captured in the CVP salvage facility and re-released more seaward (Buchanan et al., 2013). This reflects the extremely poor survival rate in the south Delta, which is hypothesized to result from poor rearing conditions such as low refuge habitat and food availability, and high predation risk. In addition, juvenile salmon may experience a diminished ability to navigate out of the south Delta toward the ocean due to confusion of navigational cues such as altered hydrology, channel network configuration, water quality gradients, and further navigational impairments from contaminants.

It further states:

> In the interior Delta longer travel times and lower survival have been documented (Brandes and McLain 2001; Newman and Brandes 2010; Perry et al. 2010). In one study, survival probabilities were negatively associated with water exports, suggesting that water exports affect migration by increasing the risk of entrainment (Newman and Brandes 2010).

In the SAIL CM, water diversions also affect the fish assemblage, which affects predation and competition, which affects the survival, timing, and growth of salmonid juveniles.

For Delta Smelt, relevant linkages from the CM (IEP MAST 2015) are:

- Proximity to water diversion sites can affect entrainment risk for multiple life stages of Delta Smelt (H1 from adult to larvae CM, H4 from larvae to juvenile CM).
- Exports (Brown et al. 2016) can also affect autochthonous and allochthonous food production and retention, which affects food availability and visibility, which affects multiple life stages of Delta Smelt (H2 from larvae to juvenile CM, H3, H4b from juvenile to subadult CM, subadult to adult CM).

Current Condition

2008 USFWS Biological Opinion (2008 BO) – RPA Actions 1, 2, and 3

- Action 1 – To protect pre-spawning adult Delta Smelt from entrainment during the first flush and to provide advantageous hydrodynamic conditions early in the migration period. Action 1 Limits exports so that the average daily OMR flow is no more negative than −2000 cfs for a total duration of 14 days, with a 5-day running average no more negative than −2500 cfs (within 25 percent). From December 1 to December 20, the action may be required based upon an examination of turbidity data from PPT, Holland Cut, and VCU and salvage data from CVP and SWP, and other parameters for protection. After December 20th the action will begin if the 3-day average at all three stations exceeds 12 NTU or if three days of Delta Smelt salvage after December 20 at either facility or cumulative daily salvage count that is above a risk threshold based upon the daily salvage index greater than or equal to 0.5.

- Action 2 – To protect pre-spawning adults from entrainment and adverse hydrodynamic conditions. Action 2 limits the range of net daily OMR flows to no more negative than −1,250 to −5000 cfs. Action 2 will begin immediately after Action 1 or as recommended by the SWG if Action 1 Is not implemented.
- Action 3 – To minimize the number of larval Delta Smelt entrained at the facilities by managing the hydrodynamic in the Central Delta flow levels pumping rates spawning a time sufficient for protection of Delta Smelt. Action 3 limits OMR daily flow to no more negative than −1,250 to −5000 cfs, based on a 14-day running average with a simultaneous 5-day running average within the 25 percent of the applicable requirement for OMR. Action 3 is required when temperatures reaches 12C base on a three station average at Mossdale, Antioch and Rio Vista or at the onset of spawning (presence of spent females in SKT or at either facility.

2009 NMFS 2009 Biological Opinion (2009 BO) – RPA Action IV.2.3

The 2009 BO RPA Action IV.2.3 was intended to reduce the vulnerability of emigrating juvenile Winter-Run Chinook Salmon, Yearling Spring-Run Chinook Salmon, and CV Steelhead within the lower Sacramento and San Joaquin rivers to entrainment into the channels of the South Delta and at the pumps due to the diversion of water by the export facilities in the South Delta. This action is also intended to enhance the likelihood of salmonids successfully exiting the Delta at Chipps Island by creating more suitable hydraulic conditions in the mainstem of the San Joaquin River for emigrating fish, including greater net downstream flows. These actions require CVP and SWP to reduce exports, as necessary, to limit negative flows to negative 2,500 to negative 5,000 cfs in the OMR, depending on the presence of salmonids, from January 1 through June 15.

Background

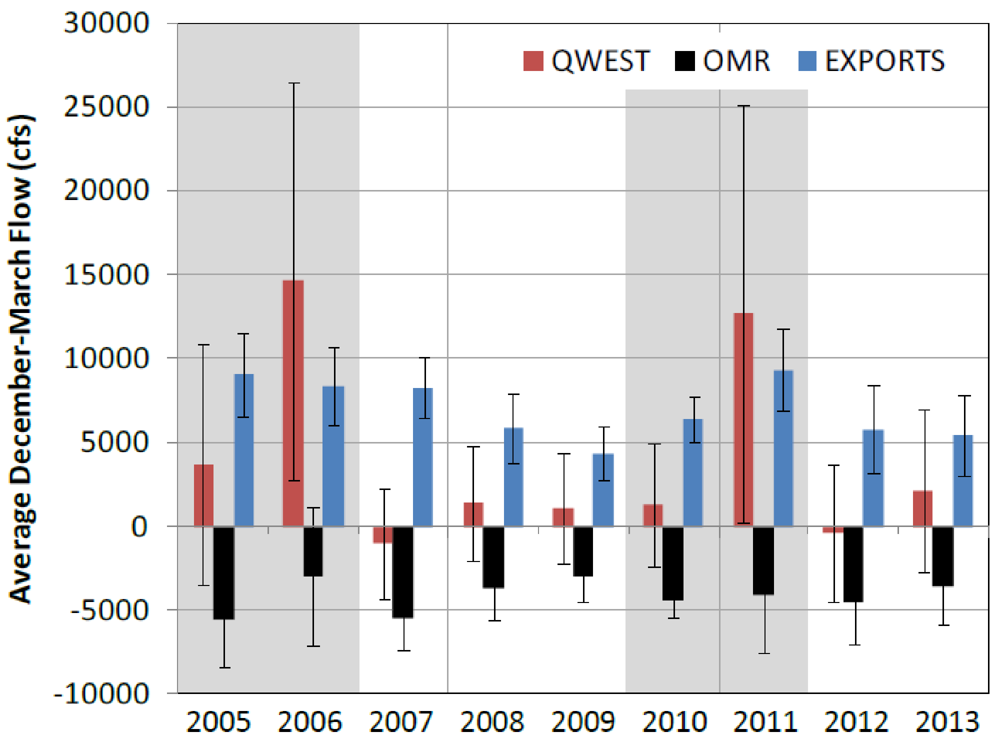
Historically, the OMR was part of the tidal distributary channel network of the San Joaquin River (Whipple et al. 2012). Today, they are a central component of the CVP and SWP water conveyance system through the Delta. Water from the Sacramento River in the north now flows through the northern Delta (down Georgiana Slough, through Three-Mile Slough and around Sherman Island) and eastern Delta (via the artificial "Delta cross-channel" and down the forks of the Mokelumne River) to OMR in the central Delta, then to the SWP and CVP. The SWP and CVP pumps are capable of pumping water at rates sufficient to cause the loss of ebb tide flows and to cause negative net flows through OMR toward the pumps (Grimaldo et al. 2009), thus greatly altering regional hydrodynamics and water quality (Monsen et al. 2007). Fish and other aquatic species in the Delta may be transported toward the pumps (Arthur et al. 1996; Brown et al. 1996; Moyle et al. 2010), may swim toward the pumps if they are behaviorally inclined to follow net flow (Grimaldo et al. 2009), or may move toward the pumps if they are employing tidal surfing behavior (Sommer et al. 2011).

The use of OMR management was introduced by the USFWS and the NMFS in their 2008/09 BOs on the LTO of the CVP and SWP. These BOs imposed additional constraints on the Projects' exports during December to June by requiring RPA OMR operation for protected fish species such as Delta Smelt, Steelhead, and Winter-Run Chinook Salmon. In general, Delta Smelt salvage increases with increasing net OMR flow reversal (i.e., more negative net OMR flows) and when turbidity exceeds 10–12 NTU (USFWS 2008; Grimaldo et al. 2009). OMR flows represent the direction and magnitude of flows in the South Delta between the Projects' export facilities and the lower San Joaquin River. The flows are dependent on factors such as flow into the Delta from tributaries and flows exported from the Delta by the Projects, but are also influenced by atmospheric pressure, spring-neap tidal cycles, diversions by local users of water, and the wind. Actual measurements on the OMR corridors are made through acoustic velocity meters maintained by the USGS and located near Bacon Island for both river corridors. Since 2014, Reclamation and DWR has managed OMR flows through an OMR Index Demonstration Project.

Management of OMR flow criteria through an index (estimate) using numerical model output or using data-based regression relationships, rather than actual USGS tidally filtered measurements. The index eliminated the 5-day running average requirement and allows operators to "ride out" daily OMR flow fluctuations without having to continuously adjust exports.

Past Implementation

Since 2009, net OMR flows during periods of increased fish entrainment risk can be less negative than they were in years prior to the BOs (see Figure D1.2-6). Prior to 2008, net OMR flows often reached −8,000 to −10,000 cfs (Kimmerer 2008; Grimaldo et al. 2009), when outflow was low. An exception to these strongly negative flows occurred during April−May export curtailments associated with the Vernalis Adaptive Management Program 2000–2012.



From: 2015 MAST Report

Figure D1.2-6. Annual average daily net flows for December through March in cfs in the OMR, past Jersey Point on the lower San Joaquin River (QWEST) and total exports in millions of acre-feet (MAR), 2005−2013. Error bars are 1 standard deviation

For complete more details concerning OMR implementation, see DOSS Technical Advisory Team annual reports from 2010 to 2018. These reports are available at: https://www.westcoast.fisheries.noaa.gov/central_valley/water_operations/doss.html.

Current Science

Salmonids

For salmon released in the Sacramento River, Perry et al. (2010) found, "survival of juvenile salmon migrating through the interior Delta, where water pumping stations are located, was consistently less than for fish that migrated via the Sacramento River." He also states that "survival is low when fish migrate via a route in which more water can flow inland than towards the ocean." Perry et al. (2010) noted that "travel times for fish migrating through the interior Delta were longer than alternative routes, possibly contributing to lower survival through the interior Delta." Reclamation infers from this study, as well as others, that Jones and Banks pumping plants do reduce juvenile salmon survival in an area around them, and that the export facilities do not just directly salvage fish but move them into areas where they may be more exposed to other mortality factors (e.g., predation, water quality). Releases of coded wire tag Fall-Run Chinook Salmon between 1993 and 2003 in the Sacramento and San Joaquin Rivers were analyzed by Zeug and Cavallo (2013). This study found that tributary conditions (temperature, water quality) and fish size may be more important than exports, and the authors state there "was little evidence that large-scale water exports or inflows influenced recovery rates in the ocean during this time period." The authors note that the use of ocean recovery data also may have influenced the lack of a detectable flow effect. The authors also state that "assumed relationships and CMs should be quantitatively evaluated before implementing management actions" (Zeug and Cavallo 2013). Reclamation infers from this study that tributary conditions may be more important than exports in affecting salmonid survival.

Michel et al. (2012) found that water velocity was negatively correlated with movement rates for Late Fall–Run yearling Chinook Salmon from the Sacramento River. Reclamation infers from this study that additional factors are at play in addition to water velocity (which exports affects in an area around the Jones and Banks Pumping Plants). Cavallo et al. (2015) found that both inflows and diversions had relatively small effects on the predicted routing of fish into the interior Delta at tidally dominated junctions. The authors concluded that the proportion of flow entering a distributary channel was selected as the best metric to explain route selection of juvenile Chinook Salmon at junctions in the Delta. The linear model explained a significant fraction of the total variation in observed routing; however, fish were less likely to enter distributary routes relative to total flow proportion. These results suggest that total flow proportion at each junction can be used in conjunction with the linear model to predict fish routing. This will be an effective tool for evaluating water management actions on fish routing; especially where little or no observed fish routing data are available. For example, if managers propose to keep more fish in the main stem by increasing inflows or reducing diversion, they can use the model to determine how much flow proportions would need to be altered to achieve a measurable effect on observed routing. However, because the authors did not examine the effects of flow and exports on fish that have already been entrained into the interior Delta these conclusions may not be applicable to proposed changes to OMR management or capable of assessing the impacts of exports on interior Delta entrainment and survival within the interior Delta. These results are in contrast to a multi-year analysis of flow-survival relationships in the North Delta which did use a substantially more robust set of observed fish routing data and revealed that flow effects were only significant in reaches that switch from bidirectional to unidirectional as flow increases (transitional reaches), whereas flow has no detectable effect where flow is always bidirectional (Perry et al. 2018). This emerging science indicates to Reclamation that exports do not affect the routing of salmon in the Delta once they reach its strongly tidal interior; specifically, once they pass Georgiana Slough on the Sacramento River or the head of Old River on the San Joaquin River.

On the San Joaquin River, Holbrook et al. (2009) found the highest survival of San Joaquin River Fall-Run Chinook Salmon through the San Joaquin River and stated that "once tagged fish entered Old River, only fish collected at two large water conveyance projects and transported through the Delta by truck were detected exiting the Delta, suggesting that this route was the only successful migration pathway for fish that entered Old River." San Joaquin River salmon survival has been declining over time, (https://www.fws.gov/lodi/juvenile_fish_monitoring_program/docs/PSP_CalFed_FWS_salmon_studies_final_033108.pdf), and thus research has found poor survival regardless of route. DWR's stipulation study found that for the "OMR flow treatments tested in this study, there appeared to be little influence of OMR flows tested on Steelhead tag travel times on the route-level and Steelhead tag movement at the junctions and routes examined in this study" (DWR 2014). The junctions and routes examined in the study were relatively far from Jones and Banks Pumping Plants. In addition, this was a one year study under which two OMR flows were evaluated –2500 and –5000. As such, it compares poor outmigration conditions to poor outmigration conditions for San Joaquin origin Steelhead and by proxy Chinook Salmon from both the Sacramento and San Joaquin River systems and is limited in its interpolation. In the San Joaquin Basin, habitat conditions may be so poor that even positive OMR flows do not have an effect on survival, which remains low (SJRGA 2011). Tag results from the six-year acoustic study suggest Vernalis flows accounted for more of the variation in Steelhead survival than: exports, inflow/export ratio, flow at the head of Old River, or OMR flows (Reclamation 2018a, 2018b, 2018c). "Exports did not appear to have an effect on route entrainment at the head of Old River, but flows, or rather, flow and stage did" (Reclamation 2018c).

The Salmonid Scoping Team (SST) issued a two-volume report in 2017 that looked at hydrodynamics, juvenile migration behavior of salmon and Steelhead, and survival of juvenile salmon and Steelhead in the San Joaquin River and central Delta. Neither coded wire tag nor acoustic tag data show a strong and consistent relationship between survival and exports (SST 2017). However, prior to this statement, the SST report identifies that the "basis of knowledge is considered to be low because information on the relationships between water project operations and South Delta hydrodynamics among different migration routes and drivers such as exports, barriers or Clifton Court radial gate operations, and migration route velocity is based primarily on non-peer-reviewed agency reports, and because of limitations of the models and lack of calibration and validation in the south Delta channels as presented in this report." The authors also state that "outside of the north Delta, it is not currently possible to predict how specific changes in flow and velocity impact migration rates. Acoustic tag studies have not shown strong relationships between exports and migration rate under the conditions tested, but few analyses have focused on the relationship between exports and migration rate. Also, exports, velocities, and flows may be linked in some locations such that determining relative effects among these variables will be difficult." For hydrodynamic effects, the Salmonid Scoping Team (2017) stated that "the effects of SWP and CVP exports on hydrodynamics is greatest in channels located in close proximity to the export facilities and decreases as a function of distance both upstream and downstream of the facilities." SST (2017) also stated that, "Water export operations contribute to salmonid mortality in the Delta via direct mortality at the facilities, but direct mortality does not account for the majority of the mortality experienced in the Delta; the mechanism and magnitude of indirect effects of water project operations on Delta mortality outside the facilities is uncertain." SST (2017) also recommends that further focused investigation into the links to water project operations underlying salmonid mortality due to hypothesized indirect mortality factors including, "increased metabolic rate of predatory fish such as striped bass and largemouth bass in the Delta, water project operations affecting the magnitude and timing of flow resulting in increased juvenile salmonid predation mortality, changes in Delta habitat, including expansion of non-native submerged aquatic vegetation, increased water clarity, potential exposure to contaminants, and other factors." "Further, there is also currently no broad scientific agreement on threshold changes in flows or velocities that influence salmonid migration behavior or survival within a channel or at a channel junction."

Some of the SST members felt that any change in velocity or flow resulting from water project operations could be biologically significant, while others felt that only changes above some threshold that has yet to be defined should be considered to have potential biological significance. For example, would a change in velocity at a specific location in the Delta as a result of a change in exports of 0.01 feet per second, 0.1 feet per second, or 1.0 feet per second be expected to affect route selection, migration rate, or survival?" (SST 2017). The SST 2017 also recommends conducting further focused investigation into the links between water project operations and salmonid mortality due to hypothesized indirect mortality factors including increased metabolic rate of predatory fish, water project operations affecting the magnitude and timing of flow resulting in increased juvenile salmonid predation and expansion of non-native submerged aquatic vegetation, increased water clarity, potential exposure to contaminants, and other factors

Independent review panels have found that "…simple flow metrics like OMR may have too much uncertainty to be an appropriate basis for setting standards," (Monismith et al. 2014) and "…the lack of relationships between OMR inflows/exports and smolt movement/survival suggest that these were insensitive indicators for evaluating effectiveness of Delta operations on salmonids" (Anderson et al. 2012, p. 31).

Appendix A – Juvenile Chinook Salmon Distribution and Timing draws upon data from the SacPAS website on the historical migration and timing of Winter-Run Chinook Salmon. As stated by Rosario et al. (2013), "Winter-run appear to be present in the Sacramento River system or Delta nearly year round—they are first detected emigrating from their natal grounds at Red Bluff in July, and last detected leaving the Delta at Chipps Island as smolts as late as May." The CM Reclamation presents in Appendix A shows that rearing fish are less vulnerable to the effects of exports as they are in slower moving or shallower areas less likely to be drawn toward the facilities. The presence of one of these rearing salmonids in the Jones or Banks Pumping Plants may not indicate a population level effect, as the rearing salmonids are at a different timing than migratory smolts and may be in smaller groups. However, significant numbers of Winter-Run Chinook Salmon passing Chipps Island may indicate that fish are beginning their emigration phase and may be vulnerable to adverse effects due to exports.

Delta Smelt

In evaluating historical data for the influence of OMR on Delta Smelt salvage Grimaldo et al. (2017) found that "during first flush periods, salvage at each facility was best explained by water exports (sampling effort), precipitation (recently linked to movement and vulnerability to offshore trawling gear), abundance and Yolo Bypass flow. During the entire adult salvage season, SWP salvage was best explained by SWP exports, Yolo Bypass flow, and abundance whereas CVP salvage was best explained by abundance, OMR flows, and turbidity. This study suggests that adult Delta Smelt salvage is influenced by hydrodynamics, water quality, and population abundance." The authors go on to state:

> CVP exports actually played a minor influence in directly affecting CVP salvage and that it had no detectable influence on SWP salvage. OMR flows had a higher influence on CVP salvage, more so than even CVP exports, suggesting an indirect influence of SWP and CVP exports as they both contribute to net reverse flows in the south Delta (Monsen et al. 2007). But the influence of OMR flow could also be related to San Joaquin River flow dynamics, especially for Delta Smelt that may take multiple routes to the salvage facilities.

Reclamation adds that SWP will export water for the CVP due to capacity constraints or other issues which would otherwise prevent the CVP from exporting all the water it possibly could. The authors state, "in some years, adult Delta Smelt move into the south Delta where they become more vulnerable to water exports because they become distributed within the hydrodynamic "footprint" of the Projects where the net movement of water is toward the pumping plants."

Grimaldo et al. (2017) further found:

> OMR flows have been used as metric for management of adult entrainment risk, because the magnitude of salvage observations was related to OMR in the US Fish and Wildlife's 2008 Biological Opinion (FWS 2008). Confirming those findings, BRT models of both CVP and SWP expected salvage increased at OMR < -5,000 cfs, when all other variables were held at their averages. While OMR flow was the second most important predictor of CVP salvage, more important than even CVP exports, the OMR threshold of -5,000 cfs was most notable in SWP salvage.

Based on this paper (among others), Reclamation infers that CVP and SWP exports affect the local hydrodynamics of the south Delta, creating negative OMR flows at times, which can entrain Delta Smelt. Reclamation also infers that OMR is a relevant physical parameter for protecting Delta Smelt, and specifically that an OMR of –5,000 cfs is a relevant threshold for predicting salvage.

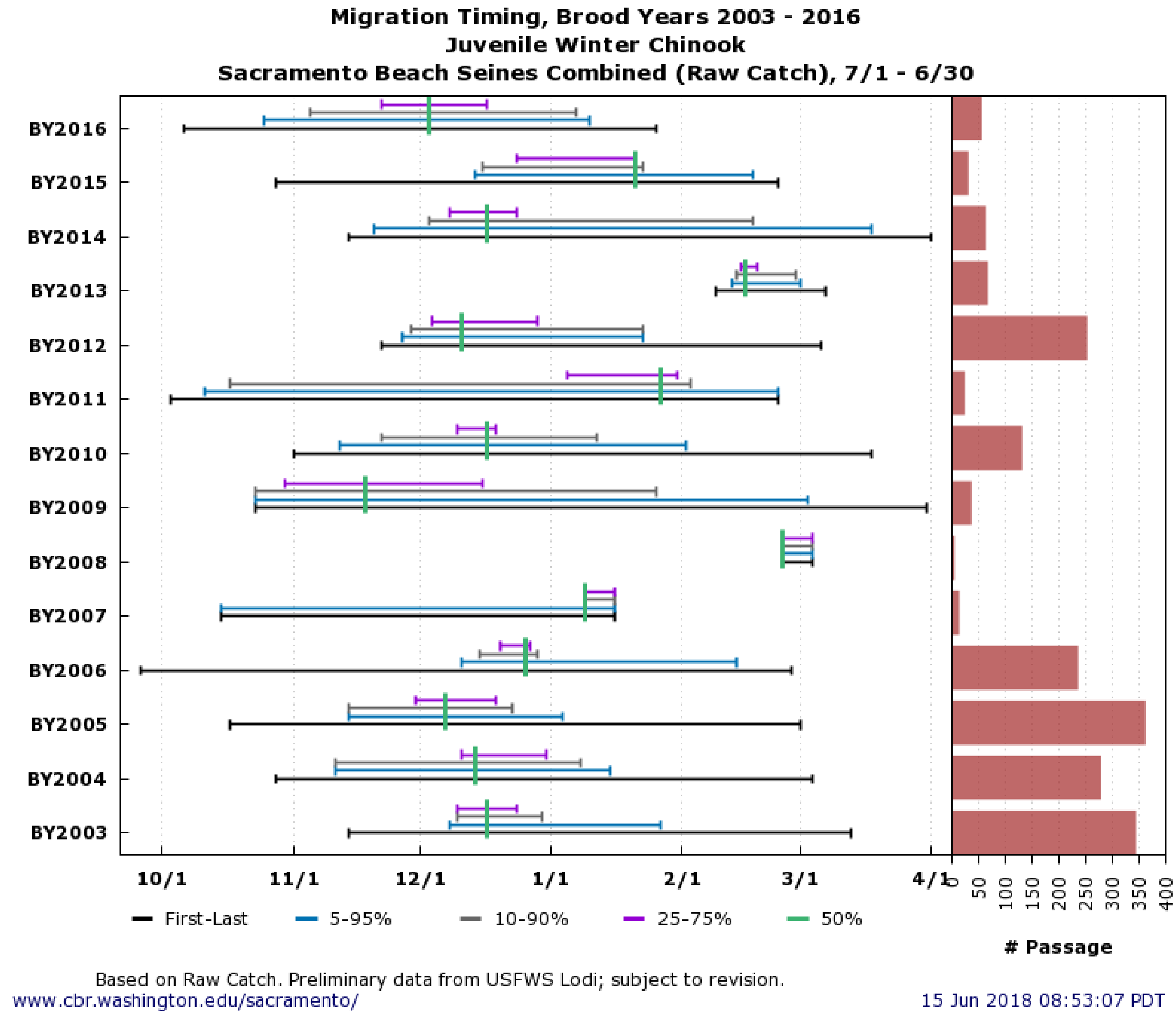
In addition to salvage, entrainment into the South Delta is an effect of CVP and SWP operations on Delta Smelt identified in the 2008 USFWS BO. Swanson et al. 1998 defined the critical swimming velocity (Ucrit) for Delta Smelt to be 24 to 32 centimeters per second. The paper states, “the relatively poor swimming ability of these Delta Smelt suggests that … this species would be at greater risk from entrainment.” From this paper, Reclamation infers that any Delta Smelt entering the south Delta will be unable to outswim strongly negative OMR flows irrespective of San Joaquin River flow dynamics.

In addition to the Fall Mid-Water Trawl (FMWT) and SKT, the EDSM Program provides information to inform entrainment risk by dynamic sampling of Delta sub-regions, improving the reliability estimates of distribution and abundance. However, it has been recognized that “abundances near the detection threshold of the sampling techniques makes it very difficult to draw reliable inferences about how many Delta Smelt there are, and where they are located” (2008 USFWS BO). Delta Smelt populations have reduced further since 2008. EDSM and all Delta Smelt monitoring programs are limited due to the low abundance of the species and therefore limited in their ability to support real-time decision making.

Justification

The justification for the action is to provide the maximum quantity of water supplies practicable to Central Valley Project contractors, and State Water Project contractors, through real-time OMR management while not jeopardizing federally listed fish species or adversely modifying their designated critical habitat. Reclamation would manage OMR flows for species protection while increasing water supply, by considering relevant factors such as the distribution of the listed species throughout the Delta, and the potential effects of high entrainment risk on subsequent species abundance, the water temperature and turbidity.

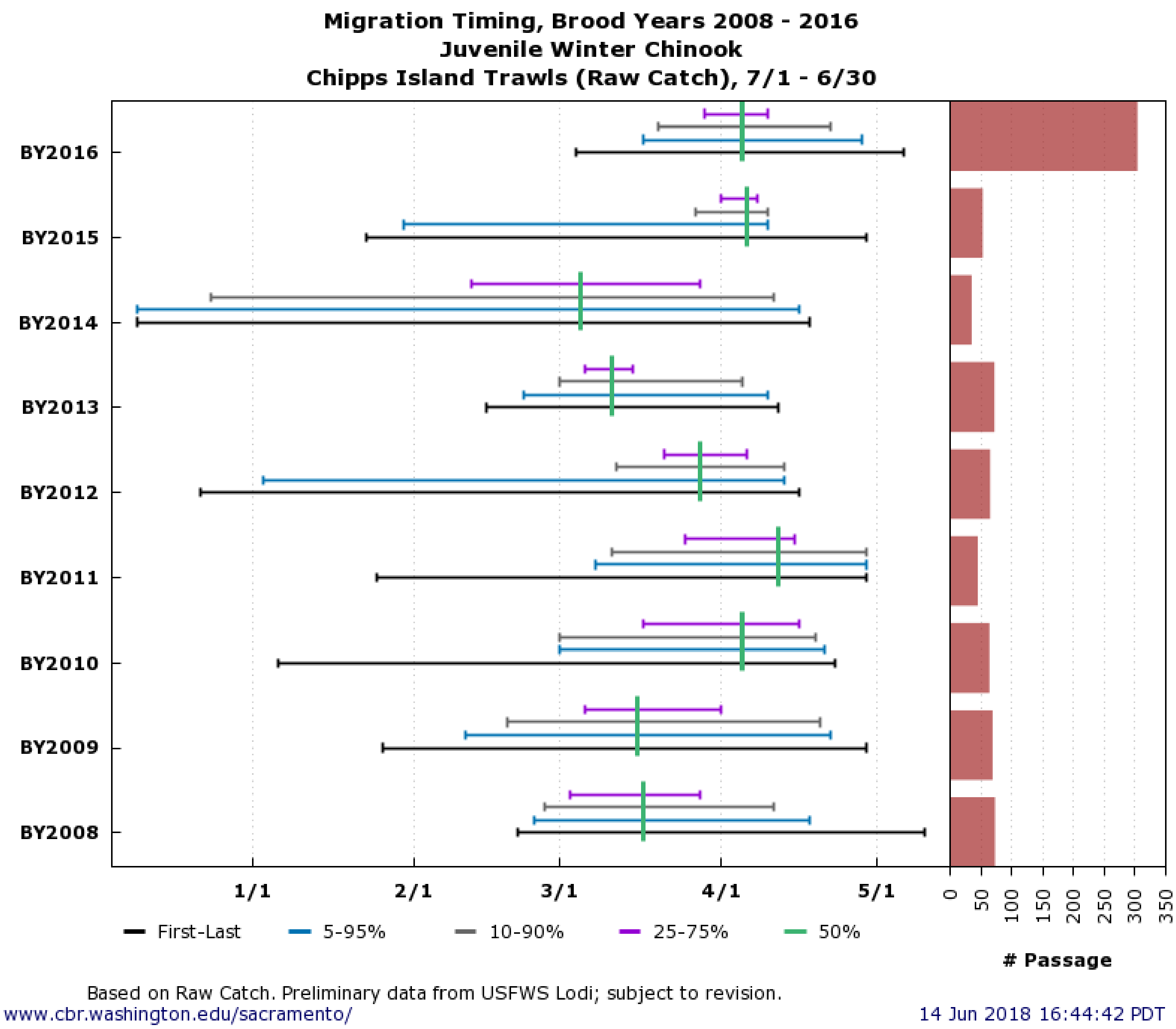
Figure D1.2-7, Winter-Run Juvenile Chinook Salmon Sacramento Beach Seines. Figures from SacPAS, shows Sacramento Beach seine raw catch from 2003 to 2016. Beach seining is used to monitor and assess the effects of water operations on the inter- and intra-annual abundance and distribution of juvenile Chinook Salmon occurring in mostly unobstructed nearshore habitats (for example beaches and boat ramps; Kjelson et al. 1982). Beach seine and trawl data results indicate that fry and smolt sized individuals occupy both open water mid-channel and near shore littoral habitats (Speegle et al. 2013). Delta beach seine data and other investigations (e.g., Kjelson et al. 1982) imply that fry may prefer near-shore littoral habitat and that smolts may prefer to occupy open water mid-channel habitat during the day (Speegle et al. 2013). While beach seine data is used to assist in estimating abundance of out-migrating juvenile Chinook Salmon, it may be representative of Winter-Run Chinook Salmon fry rearing, as beach seines sample from the littoral zone at the edges of the channel.



Source: SacPAS.

Figure D1.2-7. Winter-Run Juvenile Chinook Salmon Sacramento Beach Seines.

Figure D1.2-8, Juvenile Winter-Run Chinook Salmon Migration Timing, below shows the emigration timing of juvenile Winter-Run Chinook Salmon from brood years 2008 through 2016 from SacPAS, based on raw catch data at the Chipps Island trawl from the USFWS in Lodi. As can be seen on the figure, the first fish may begin emigrating out of the Delta as early as December, but in years like 2011, this first fish is not indicative of the whole population. This figure also shows that migration timing is highly variable. In 2015, the majority of the population migrated out of the Delta in early April, but in 2013, the majority migrated out in early March.



Source: SacPAS 2018.

Figure D1.2-8. Juvenile Winter-Run Chinook Salmon Migration Timing.

Comparing Figure D1.2-7 to Figure D1.2-8, juvenile Winter-Run Chinook Salmon are in the littoral zone at a different timing than they are migrating past Chipps Island. This behavior, possible fry rearing, happens earlier in the year.

Relatively limited study has been done of rearing salmonids in the Delta. US DOI Fish and Wildlife Service (1950) stated that "the population of juvenile fish in the Delta from February to June is composed entirely of seaward migrant king salmon." While current populations and species assemblage are certainly much different than those observed in 1950, it appears that some juvenile Chinook Salmon may rear in the Delta before migrating out. Kjelson et al. (1982) demonstrated that coded wire tag fry (<70 mm FL) reared in the Estuary for up to two months, primarily in the upper freshwater portion of the Delta. The relative contribution of delta-reared fry to adult production is unknown but may have been substantial under natural conditions (Brown 2003). High fry densities were found in Steamboat Slough by McLain and Castillo (2009).

Based on the trawl and seine data presented above as well as the studies showing some rearing of salmon in the Delta, Reclamation's CM is that Chinook Salmon migrate downstream to the Delta during the fall and winter, rear (and continue smoltification) in the Delta during the winter and spring and complete the emigration process by leaving the Delta in the spring. Reclamation believes that the purpose of OMR triggers are to identify when a population level effect is about to occur and avoid it before occurrence. Reclamation conceptualizes that rearing in the Delta is done in small groups of juvenile fish, and that these rearing fish are less vulnerable to the effects of exports as they are in slower moving or shallower areas less likely to be drawn toward the facilities. Reclamation conceptualizes that if one of these rearing salmonids is entrained into Jones or Banks Pumping Plants, this entrainment may not indicate a population level effect is imminent, as the rearing salmonids are at a different timing than migratory smolts and may be in smaller groups.

Therefore, Reclamation and DWR propose using 5% of the Winter-Run Chinook Salmon population passing Chipps Island as an alert to Reclamation and DWR that fish are beginning their emigration phase and may be vulnerable to adverse effects due to exports. At this point, Reclamation and DWR would begin the OMR salmonid action with OMR flows no more than −5000 cfs.

Reclamation and DWR propose using the fish distribution estimates produced by DOSS to inform Reclamation and DWR when fish are exhibiting the migratory behavior, and therefore, are at greater risk of adverse effects due to exports. As shown by Figure D1.2-9, Winter-Run Chinook Salmon Weekly DOSS Estimates Compared to Raw Data (A), Adjusted High Values Only (B), and Adjusted Hatchery Release Date Range (C). from the 2015 DOSS report, DOSS fairly accurately predicts on a weekly basis when fish are yet to enter the Delta, in the Delta, and have exited the Delta. The distribution estimates produced by DOSS are based on all relevant monitoring conducted in the region and represent use of the best available scientific data. DOSS' estimate of fish passing Chipps Island exceeding 5% of the Winter-Run Chinook Salmon population will be used as an alert to Reclamation and DWR that fish are beginning their emigration phase and may be vulnerable to adverse effects due to exports. Reclamation and DWR would then use this alert to evaluate initiating the OMR action and likely limit OMR flows to no more negative than -5000 cfs (with the exceptions noted below) until DOSS estimates 95% or more of the Winter-Run Chinook Salmon have passed Chipps Island.

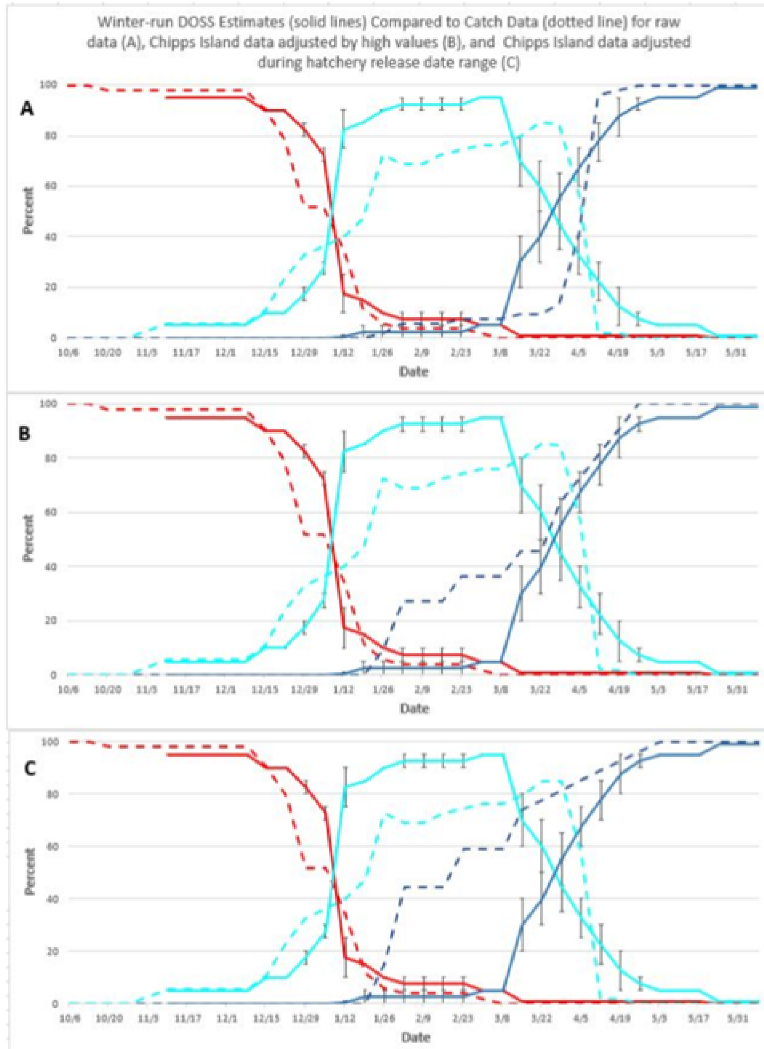


Figure D1.2-9. Winter-Run Chinook Salmon weekly DOSS estimates compared to raw data (A), adjusted high values only (B), and adjusted hatchery release date range (C). Red lines indicate "Yet to Enter the Delta," turquoise lines indicate "In Delta," and dark blue lines indicate "Exited the Delta." Solid lines are weekly DOSS estimates and dashed lines are catch data

Delta Smelt

As stated in the 2008 BO, there are three major factors related to operations of the CVP/SWP affecting Delta Smelt population resilience and long-term viability. It is also recognized that the hydrologic changes from the CVP/SWP result in ecological conditions that influence Delta Smelt interactions with other stressors within the Delta. For purposes of the OMR, these factors are (1) direct mortality associated with entrainment of pre-spawning adult Delta Smelt by CVP/SWP operations and (2) direct mortality of larval and early juvenile Delta Smelt associated with entrainment by CVP/SWP operations. The combination of tidal cycles, hydrologic and meteorological events, and CVP/SWP operations can draw Delta Smelt into the South and Central Delta where they are more susceptible to entrainment by the facilities prior to any observed Delta Smelt salvage. This necessitates an anticipatory strategy in order to sufficiently protect Delta Smelt from entrainment.

Grimaldo et al. (2017) find that "during first flush periods, salvage at each facility was best explained by water exports (sampling effort), precipitation (recently linked to movement and vulnerability to offshore trawling gear), abundance and Yolo Bypass flow. During the entire adult salvage season, SWP salvage was best explained by SWP exports, Yolo Bypass flow, and abundance whereas CVP salvage was best explained by abundance, OMR flows, and turbidity. This study suggests that adult Delta Smelt salvage is influenced by hydrodynamics, water quality, and population abundance." The authors go on to state:

> CVP exports actually played a minor influence in directly affecting CVP salvage and that it had no detectable influence on SWP salvage. OMR flows had a higher influence on CVP salvage, more so than even CVP exports, suggesting an indirect influence of SWP and CVP efforts as they both contribute to net reverse flows in the south Delta (Monsen et al. 2007). But the influence of OMR flow could also be related to San Joaquin River flow dynamics, especially for Delta Smelt that may take multiple routes to the salvage facilities.

According to Grimaldo et al. (2017),

> OMR flows have been used as metric for management of adult entrainment risk, because the magnitude of salvage observations was related to OMR in the US Fish and Wildlife's 2008 Biological Opinion (FWS 2008). Confirming those findings, BRT models of both CVP and SWP expected salvage increased at OMR < -5,000 cfs, when all other variables were held at their averages. While OMR flow was the second most important predictor of CVP salvage, more important than even CVP exports, the OMR threshold of -5,000 cfs was most notable in SWP salvage.

The 2008 Service BO uses information from the FMWT, SKT, and Delta Smelt salvage at the Jones and Banks pumping plants to inform OMR action implementation, but available physical and biological monitoring data other than these are also used. Recent Enhanced Delta Smelt Monitoring (EDSM) may provide information to inform entrainment risk. EDSM also provides dynamic sampling of sub-regions by water year, retains samples for future research, and improves representation of near shore occupancy and abundance. Additionally, Delta Smelt abundance may have declined to levels near the detection threshold of EDSM. As indicated in the 2008 Service BO, "abundances near the detection threshold of the sampling techniques makes it very difficult to draw reliable inferences about how many delta smelt there are, and where they are located."

In addition to enhanced monitoring, there are currently under development or available several Delta Smelt Particle Tracking models. These include several based on DWR's one-dimensional DSM2 model with particle tracking, such as those used by Rose (2013), Wilbur (2000), Miller (2002), and Kimmerer and Nobriga (2008).

For questions involving multiple dimensions (such as salinity in the Delta), Gross et al. (2010, 2018) has developed a three-dimensional Particle Tracking Model (FISH PTM) using the Bay-Delta UnTRIM model (MacWilliams et al. 2008) for the hydrodynamics. The Flexible Integration of Staggered-grid Hydrodynamics Particle Tracking Model (FISH PTM) was developed to represent particle transport processes for a class of hydrodynamic models. The FISH-PTM represents horizontal and vertical transport processes, has flexible particle release capabilities, has representation of movement of particles through structures including culverts and weirs, has representation of particle losses at exports and agricultural diversions, and incorporates vertical swimming behavior. There is ongoing effort to develop swimming behaviors, including that by Korman et al. (2018), who statistically evaluated the Particle-tracking models with swimming behavior to determine which swimming behaviors best fit proportional entrainment loss.

In addition to the particle tracking models, organizations (such as ICF) are developing statistical models to predict entrainment. Machine learning approaches trained on historical data could, based on current and forecasted environmental conditions and water operations, predict a distribution of potential take for smelt.

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D1.2.6.2 *Habitat*

D1.2.6.2.1 Low Salinity Zone – X2 Isohaline for Low Salinity Zone from D-1641 to Fall X2 (No Fall X2)

Summary

Reclamation proposes to operate the Suisun Marsh Salinity Control Gates (SMSCG), in coordination with the Roaring River Distribution System (RRDS) west-side drain, during September and October following above normal and wet water years to achieve a target low salinity zone (LSZ) areal extent. This would replace the existing USFWS (2008) RPA Action 4 for Fall X2 and outflow.

Description

In place of the USFWS (2008) RPA Action 4 for Fall X2 and outflow, Reclamation proposes to operate the SMSCG in coordination with the RRDS west-side drain in September and October following above normal and wet water years. The initial proposal is that operations will be done to achieve a target LSZ areal extent consistent with the existing USFWS (2008) RPA Action 4. Based on modeling, this would require 5,313 hectares of LSZ (i.e., salinity of 1-6) in September and October following above normal years, and 8,380 hectares following wet years (IEP MAST 2015, p.79). Achievement of these targets would be assessed using the UnTRIM Bay-Delta Model (DMA 2014), applying the observed outflow, SMSCG, and RRDS operations, in addition to other necessary inputs to be developed by Reclamation and DWR. The specific target habitat areal extent will be refined from the initial proposal in consultation with USFWS.

Reclamation also proposes to coordinate with USFWS to potentially supplement or replace the LSZ areal extent target approach with an index-based approach. The existing method of Feyrer et al. (2011) gives predictions of an abiotic habitat index as a function of X2, with the index essentially being the area of habitat (hectares) weighted by its suitability for Delta Smelt as a function of Secchi depth, specific conductance, and temperature. From this method, target habitat indices can be developed for fall following above normal (index = 4,835) and wet (index = 7,261) water years (IEP MAST 2015, p.83). With optimal conditions (i.e., habitat suitability = 1 for Secchi depth, specific conductance, and temperature), the habitat indices would be interpreted as 4,835 hectares of optimal habitat following above normal years and 7,261 hectares of optimal habitat following wet years. Use of a habitat index offers the benefit of incorporating the effects of other proposed actions (e.g., the Sediment Augmentation Program for Turbidity) that could influence variables other than just salinity (specific conductance). Reclamation would coordinate with USFWS to assess the potential for updating the habitat index to incorporate biotic elements, in particular food (zooplankton prey density), in order to better capture the potential benefits from actions such as operation of the RRDS west-side drain.

Objectives

- Fundamental objective: Increase abundance of Delta Smelt
- Means objective: Abundance

Conceptual Model (Each Species and Life stage)

The IEP MAST CM for the transition between the sub-adult and adult Delta Smelt life stages posits that hydrology (fall outflow) as an environmental driver acts with wind and winter floods to influence turbidity and therefore the predation risk habitat attribute and influence food availability through action of food production and retention. Fall outflow also interacts with bathymetry to affect the size and location of the LSZ habitat attribute (IEP MAST 2015, p.89-91).

Current Condition

The current USFWS (2008) RPA Action 4 is described as follows:

> Subject to adaptive management…, provide sufficient Delta outflow to maintain average X2 for September and October no greater (more eastward) than 74 km in the fall following wet years and 81km in the fall following above normal years. The monthly average X2 must be maintained at or seaward of these values for each individual month and not averaged over the two month period. In November, the inflow to CVP/SWP reservoirs in the Sacramento Basin will be added to reservoir releases to provide an added increment of Delta inflow and to augment Delta outflow up to the fall target. The action will be evaluated and may be modified or terminated as determined by [USFWS].

Details of current operations of the SMSCG are provided in the description of the Suisun Marsh Salinity Control Gates proposed action, which note that currently the SMSCG are operated between October and May when needed to meet Suisun Marsh salinity standards.

Background

The background and justification for the Fall X2 RPA action is provided by USFWS (2008: p.372-375). In summary, the action was aimed to address the USFWS conclusion that after 1998, fall outflows were similar to historic droughts regardless of water year type. Fall habitat was noted to shift in abundance and distribution largely due to fluctuations in salinity (Feyrer et al. 2007), with more upstream X2 confining the Delta Smelt population in upstream areas of narrow channels, where there may be more exposure to stressors such as agricultural diversions and predation (USFWS 2008, p.372). Exposure of Delta Smelt in the fall to such adverse effects was suggested by USFWS (2008, p.372) to possibly be part of the reason that Feyrer et al. (2007) found a statistical association between Fall X2 and the production of young Delta Smelt the following year following 1987 (i.e., an additive model predicting the summer townet index of one year as a function of the previous fall midwater trawl index, specific conductance, and Secchi depth). Other factors noted to be associated with lower flow conditions by USFWS (2008, p.372) include Microcystis. The Fall X2 action was focused on wet and above normal years because USFWS (2008, p.373) felt that these were the year types in which project operations most significantly adversely affected fall conditions and therefore, actions in these year types would be more likely to benefit Delta Smelt.

Since issuance of the USFWS (2008) BO, the Fall X2 action was triggered twice, in 2011 and 2017, which were both classified as wet years. In both years, the specific requirements of the RPA were modified: in 2011 as a result of legal action, and in 2017 as a result of a temporary modification of the October requirements in response to low reservoir storage caused by damage to the Oroville Dam spillway. Estimates for daily X2 are available from the California Data Exchange Center (CDEC, http://cdec.water.ca.gov/dynamicapp/staMeta?station_id=CX2) and DAYFLOW (https://water.ca.gov/Programs/Environmental-Services/Compliance-Monitoring-And-Assessment/Dayflow-Data). The former is based on linear interpolation of the 2.64 μS/cm electrical conductivity location among four electrical conductivity monitoring stations at Martinez (MRZ, 56 km), Port Chicago (PCT, 64 km), Chipps Island (74 km) and Collinsville (CLL, 81 km), as such, there are no estimates produced for X2 < 56 km and X2 > 81 km. The DAYFLOW estimate is based on an equation predicting daily X2 from Delta outflow and the previous day's X2. Mean September X2 was estimated to be 73.8 km (CDEC) and 75.3 km (DAYFLOW) in 2011, and 74.4 km (CDEC) and 74.5 km (DAYFLOW) in 2017. Mean October X2 was estimated to be 73.3 km (CDEC; note that one day had X2 > 81 km and was not included in the calculation) and 74.0 km (DAYFLOW) in 2011, and 77.4 km in 2017 (only CDEC data were available; note that four days had X2 > 81 km and were not included in the calculation).

A summary of past implementation of SMSCG operations is provided in the *Suisun Marsh Salinity Control Gates* component.

Current Science

The IEP MAST CM was applied to address several hypotheses to address why Delta Smelt abundance increased in the wet year of 2011. First, the hypothesis that food availability affects Delta Smelt abundance and survival was generally supported (IEP MAST 2015, p.140). There was some limited support for the hypothesis that high Microcystis levels may have a negative effect on sub-adult to adult survival, although the lower survival in 2011 compared to 2010 was suggested to potentially have been the result of greater outflow causing Microcystis to be displaced downstream to the LSZ in September (IEP MAST 2015, p.141). IEP MAST (2015) concluded that there was some evidence in support of the hypothesis that the size and position of the low salinity zone during fall affects abundance, survival, and growth of Delta Smelt but cautioned that additional years of data and investigations are needed. A multiplicative stock-recruitment model assessing Delta Smelt survival from fall to summer as a function of September and October X2 and fall stock size (i.e., the fall midwater trawl index) did not find evidence that X2 was an important predictor of survival (Reclamation 2017, Appendix A). In contrast to 2011, the Delta Smelt fall midwater trawl index did not increase in 2017, despite low Fall X2 (see previous section); studies are underway to assess the possible reasons for this difference.

Justification

The habitat-based LSZ management action is proposed in order to specifically accommodate hypothesized Delta Smelt habitat requirements in terms of extent of the LSZ, while reducing the water cost associated with the existing X2-based requirements.

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D1.2.6.2.2 Suisun Marsh Salinity Control Gates

Summary

Reclamation would increase operations of the SMSCG to direct more fresh water into Suisun Marsh, which will reduce salinity in order to improve habitat conditions for Delta Smelt in the region.

Description

Reclamation in partnership with DWR would increase operations of the SMSCG to direct more fresh water into Suisun Marsh by closing the gates on flood tides and opening the gates on ebb tides. This will reduce salinity. As noted in the Delta Smelt Resiliency Strategy, this management action may attract Delta Smelt into the high-quality Suisun Marsh habitat in greater numbers, reducing use of the less food-rich Suisun Bay habitat (CNRA 2016). The timing of the action could be in late spring/summer of drier water years, depending on salinity conditions. Monitoring would be undertaken to ensure that water operations are undertaken as necessary to minimize the potential for unintended salinity changes in the Suisun Bay and the Sacramento-San Joaquin River confluence area. The SMSCG could be potentially operated in coordination with the Roaring River Distribution System action from the Delta Smelt Resiliency Strategy (CNRA 2016).

Objectives

- Fundamental objective: Increase abundance of Delta Smelt
- Means objective: Abundance

Conceptual Model (Each Species and Life stage)

The SMSCG action would primarily influence Delta Smelt; the basic action was originally proposed as part of the Delta Smelt Resiliency Strategy (CNRA 2016). As described in the Resiliency Strategy, the action is intended to benefit the transition between the juvenile and sub-adult life stages during late spring/summer and was originally proposed as an alternative to outflow augmentation. The primary environmental driver relates to food production, as noted in the MAST CM: "Juvenile growth and survival is hypothesized to depend on availability and quantity of food. Food production during this summer period is hypothesized to involve complex interactions of clam grazing, nutrients, hydrology and harmful algal blooms" (IEP MAST 2015, p.90). Reducing salinity in Suisun Marsh through operation of the SMSCG would make conditions more suitable for Delta Smelt (Hasenbein et al. 2013) and therefore facilitate access to habitat with greater food density and opportunity for growth (Hammock et al. 2015).

Current Condition

Operation of the SMSCG began in October 1988 as Phase II of the Plan of Protection for the Suisun Marsh (ICF International 2016, p.3-122). The objective of SMSCG operation is to decrease the salinity of the water in Montezuma Slough. Currently, the US Army Corps of Engineers permit requires the SMSCG to be operated between October and May only when needed to meet Suisun Marsh salinity standards (ICF International 2016, p.3-122). When Delta outflow is low to moderate and the gates are not operating, tidal flow past the gate is approximately 5,000 to 6,000 cfs while the net flow is near zero. When operated, flood tide flows are arrested while ebb tide flows remain in the range of 5,000 to 6,000 cfs. The net flow in Montezuma Slough becomes approximately 2,500 to 2,800 cfs (ICF International 2016, p.3-122).

Background

Historically, the SMSCG have been operated as early as October 1, while in some years (e.g., 1996) the gates were not operated at all (ICF International 2016, p.3-122). When the channel water salinity decreases sufficiently below the salinity standards or at the end of the control season, the removable flashboards are removed and the gates raised to allow unrestricted movement through Montezuma Slough. Other than the pilot study undertaken in August 2018 as part of the Delta Smelt Resiliency Strategy, operation has not occurred outside of the October–May required operating period.

Current Science

Hammock et al. (2015) demonstrated that several indicators of Delta Smelt growth, nutritional status, and health (stomach fullness, liver glycogen depletion, RNA/DNA ratio, hepatosomatic index, condition factor, and lesion score) generally are significantly better in Suisun Marsh than in Suisun Bay and other areas of Delta. Low abundance of Delta Smelt food in Suisun Bay is largely the result of grazing by the invasive clam *P. amurensis* (Kimmerer and Thompson 2014; Kimmerer and Lougee 2015) that may have resulted in earlier peaks in some important zooplankton prey species and therefore affected Delta Smelt (Merz et al. 2016). The abundance of *P. amurensis* in Suisun Marsh is spatially limited, possibly as a result of limited connectivity with Suisun Bay, high detritus loads, and high predation pressure from fish and avian species (Baumsteiger et al. 2017); this presumably results in less grazing pressure than in Suisun Bay. Operation of the SMSCG to be closed on flood tides and open on ebb tides can shift the salinity distribution further upstream in Suisun Bay and the Delta. Modeling undertaken in support of the

2018 pilot SMSCG effort suggested that the typical water cost for this action would be in the low tens of thousands of acre-feet to maintain D-1641 criteria (Zhou 2018). Installation of drain gates on the western end of the Roaring River Distribution System, as being undertaken as part of the Delta Smelt Resiliency Strategy, is intended to allow draining of food-rich water from flooded duck ponds to Suisun Bay (Hobbs et al. 2017) and could be done in association with the SMSCG action.

Justification

Operation of the SMSCG would facilitate lower salinity conditions to occur in Suisun Marsh, particularly in drier years, while allowing Delta outflow to be less than otherwise would be necessary to achieve low salinity in Suisun Marsh. This would provide greater habitat suitability for Delta Smelt in an area that has shown to have good growth and would increase flexibility in water supply management in the Delta.

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D1.2.6.2.3 Barker Slough Pumping Plant Sediment and Aquatic Weed Removal

Summary

Remove sediment and aquatic weeds to maintain pump operation, flows, and fish screen performance at Barker Slough Pumping Plant (BSPP).

Description

Sediment accumulates in the concrete apron sediment trap in front of the BSPP fish screens and within the pump wells behind the fish screens. Sediment removal from the sediment trap and the pump wells would be removed as needed.

Aquatic weeds would be removed, as needed, from in front of the fish screens at BSPP. Aquatic weeds accumulate on the fish screens, blocking water flow, and causing water levels to drop behind the screens in the pump wells. The low water level inside of the pump wells causes the pumps to automatically shut off to protect the pumps from cavitation. Aquatic weed removal system consists of grappling hooks attached by chains to an aluminum frame. A boom truck, staged on the platform in front of the BSPP pumps, will lower the grappling system into the water to retrieve the accumulated aquatic vegetation. The removed aquatic weeds will be transported to two aggregate base spoil sites located near the pumping plant.

Objectives

- Fundamental objective: Maintain minimum population during drought
- Means objective: Abundance

Conceptual Model

The CMs are not directly applicable.

Current Conditions

Sediment accumulates in the concrete apron sediment trap in front of the BSPP fish screens and within the pump wells behind the fish screens. Aquatic weeds accumulate on the fish screens, blocking water flow, and causing water levels to drop behind the screens in the pump wells. The low water level inside of the pump wells causes the pumps to automatically shut off to protect the pumps from cavitation.

Each of the pumps are individually screened with a positive barrier fish screen consisting of a series of flat, stainless steel, wedge-wire panels with a slot width of 3/32 inches. The screen is designed to prevent entrainment of fish larger than 25 millimeters (mm). The screens in front of each bay are entirely submerged and are more than 23 feet below the top of the concrete platform. Each fish screen is 7 feet wide by 10 feet long. The screens are cleaned once a month using a high-pressure hose from the back side of the screens. A truck mounted crane is used to lift the screens up for cleaning and then each screen is lowered back into position along vertical metal slots anchored to the façade of the intake structure.

Background

Sediment and aquatic weeds accumulate in front of the fish screens and pumps. Sediment routinely accumulates in front of and behind the fish screens. Aquatic weed loads have increased in recent years necessitating manual removal from the fish screens.

Current Science

DWR conducted evaluations of the fish screens at BSPP and found that after 2 and 1/3 years of gathering entrainment data, only one larval Delta Smelt was caught (out of more than 8,000 larval fish caught) (DWR 2019).

At the request of DWR, California Department of Boating and Waterways conducts herbicide treatments in Barker Slough, Lindsay Slough, and Liberty Island to manage nuisance aquatic weeds and reduce the accumulation of weed mats in Barker Slough.

Justification

Removal of sediment and aquatic weeds is necessary to maintain flow and pump operations and prevent blockage of fish screens at BSPP.

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D1.2.6.2.4 Clifton Court Forebay Aquatic Weed and Algal Bloom Management

Summary

DWR would expand the existing aquatic weed removal and harmful algal bloom (HAB) control activities in Clifton Court Forebay to include the use of the herbicide Aquathol K and peroxygen-based algaecides and to expand the treatment period beyond the current July 1 to August 31 permissible treatment period. DWR would retain the use of currently approved copper-based herbicides and the approved use of mechanical weed harvesters.

Description

To reduce aquatic weed growth and control HABs, DWR would apply Aquathol K, copper-based herbicides and algaecides, and peroxide-base algaecides to targeted areas within CCF on an as-needed basis. The selected herbicide or algaecide would be dependent upon the aquatic weed species or algal species present. Treatments with Aquathol K and copper-based herbicides would occur as needed from June 28 to August 31; treatments needed outside of the June 28 to August 31 window would only occur under certain conditions and with agreement from NMFS and USFWS. Treatments with peroxygen-based algaecides would occur year-round, as needed.

The target concentration of Aquathol®K treatments would be 2–3 ppm. Applications of copper herbicides would be applied at a concentration of 1 ppm with an expected dilution to 0.75 ppm upon dispersal in the water column. Applications copper-based algaecides would be applied at a concentration of 0.2 to 1 ppm with expected dilution within the water column. PAK®27 algaecide treatments are proposed to occur, as needed, year-round. PAK®27 would be applied in the range of 0.3 to 10.2 ppm hydrogen peroxide. No more than 50% of the forebay would be treated at any one time. DWR would apply herbicides by aircraft or by boat to the areas with high weed growth or high algal bloom concentration.

Protective measures would be implemented to prevent or minimize adverse effects from herbicide applications. Applications of aquatic herbicides and algaecides would be contained within CCF by closing the radial intake gates to CCF prior to, during, and following the application. The radial gates would remain closed during the recommended minimum contact time based on herbicide type, application rate, and aquatic weed or algae assemblage.

Objectives

- Fundamental objective: Maintain minimum population during drought
- Means objective: Abundance

Conceptual Model (Each Species and Life stage)

The IEP MAST CM for Delta Smelt posits that predation may be increased by invasive species such that it is an environmental driver for declining trends in populations (IEP MAST 2015).

The SAIL report for Winter-Run Chinook Salmon posits that predation affects salmonids both directly and indirectly (by limiting food sources and available habitat) (Windell et al. 2017).

Current Condition

Excessive aquatic weed growth in CCF results in significant clogging of the trashracks and vertical louver array, creates an impediment to fish passage into Skinner Fish Facility, and provides cover for predatory fish species. Control of aquatic weeds through the application of herbicides is one of the four interim measures to reduce salmonid predation in the CCF.

Aquatic weed assemblages change from year to year in the CCF from predominantly Egeria (*Egeria densa)* to one dominated by sago pondweed (*Potamogeton pectinalus*), Eurasian watermilfoil (*Myriophyllum spicatum*), coontail (*Cerataphyllum demersum*), American pondweed (*Potamogeton nodosus*), and curly-leaf pondweed (*Potamogeton crispus*). Depending upon the aquatic weed assemblage, DWR annually applies either copper-based herbicides to control Egeria or Aquathol®K to control pondweed species. Egeria is effectively controlled by copper-based herbicides, and pondweed species are effectively controlled by endothall-based herbicides such as Aquathol®K. Therefore, both copper and Aquathol K herbicides are essential to effectively control excessive aquatic weed growth in CCF.

While aquatic weeds begin to grow in April to early June, herbicide treatment is currently restricted to July 1 to August 31. In recent years, DWR has completed annual environmental compliance to allow application of herbicides 48 hours prior to July 1 and the utilization of Aquathol K. Aquathol K is applied at the target concentration of 2–3 ppm. Copper herbicides are applied at a concentration of 1 ppm with an expected dilution to 0.75 ppm upon dispersal in the water column. Treatment areas are typically about 900 acres but no more than 50% of the 2,180 total surface acres. Mechanical harvesters are used to remove floating mats and water hyacinth as needed, but they are inadequate to control the aquatic weeds without the additional use of aquatic herbicides.

DWR monitors taste and odor compounds and cyanotoxin concentrations in CCF. Monitoring locations include CCF inlet and Banks PP. Copper sulfate may be applied to areas of CCF when monitoring results indicate production is occurring within CCF and that the water quality may be significantly degraded for use by downstream municipal users. Applications of copper sulfate for algal control are applied at a concentration of 0.2 to 1 ppm with expected dilution within the water column. No more than 50% of the surface area of CCF is treated at one time.

The current permissible treatment period for herbicide applications is July 1 to August 31. This period coincides with the highest water demand period resulting in a loss of water delivery. It also occurs after the onset of SAV growth and after salmonid smolt outmigration. Herbicide treatment protective measures include full closure of the CCF radial intake gates for 24 hours prior to, during, and after the herbicide application, resulting in limitations to pumping at Banks PP for about 60 hours (48 hours for pre- and post-treatment gate closure plus herbicide contact time).

Background

Excessive growth of submerged aquatic weeds in CCF can cause severe head loss and pump cavitation at Banks Pumping Plant when the stems of rooted plants break free, combine into “mats,” and accumulate on the primary trashracks and secondary louvers. This mass of uprooted and fragmented vegetation essentially forms a watertight plug at the trashracks and vertical louver array. The resulting blockage necessitates a reduction in the water pumping rate to prevent potential equipment damage through pump cavitation and excessive weight on louver array causing collapsed structure. Cavitation creates excessive wear and deterioration of the pump impeller blades.

To avoid the unscheduled shutdowns caused by aquatic weeds (Egeria) and to prevent water quality degradation caused by harmful algal blooms, DWR started applying herbicides in May 1995. From 1995 to 2006, DWR applied complex copper herbicides (Komeen® or Nautique®) once or twice per year, typically during May or June (DWR 2015). DWR temporarily stopped applying copper-based herbicides in 2006 because the North American Green Sturgeon was listed as a threatened species and began using mechanical harvesting (DWR 2015). The mechanical harvesters were inadequate to control the aquatic weeds resulting in significant clogging of the trashracks and vertical louver array, culminating in collapse of the louver structure. DWR resumed copper applications in 2015. However, due to the change in aquatic weed species composition between 2006 and 2014, from an Egeria-dominated community to a mixed pondweed species community, copper-based treatments were no longer effective. Pondweed species are not controlled or killed by copper herbicides. In 2016, DWR received permission to conduct a pilot study to assess the effectiveness of Aquathol K, an endothall-based herbicide, to control the pondweed assemblage. Following a successful treatment resulting in a significant reduction in pondweed biomass, Aquathol K was applied again in 2017 and 2018.

Aquatic weed control has been identified as one of four interim measures to increase salmonid survival in CCF. Dense stands of aquatic weeds provide cover for unwanted predators that may prey on salmonid smolts within CCF. Salmonid smolts are present in CCF during Spring months and during the onset of aquatic weed growth. However, as currently permitted, aquatic weed controlled does not occur until after conditions in CCF are no longer suitable for salmonids (water temperature >25°F). As such, the current aquatic weed control efforts do not benefit salmonid smolts traversing the CCF. Application of Aquathol®K or copper herbicide during Spring months may benefit smolt survival in CCF by reducing predatory fish habitat.

Attached benthic cyanobacteria blooms have occurred in CCF that produce compounds that cause unpleasant tastes and odors to finished drinking water. The highest biomass of taste- and odor-producing cyanobacteria was present in the nearshore areas but not limited to shallow benthic zone. Geosmin and

2-methylisoborneol (MIB) are natural byproducts of algal chlorophyll production. The finished drinking water secondary maximum contaminant level (MCL) for taste and odor compounds is 10 ng/L of geosmin and 5 ng/L of MIB. Historically, copper sulfate was applied to the nearshore areas of CCF when results of solid phase microextraction analysis exceed the control tolerances (MIB < 5 ng/L and geosmin < 10 ng/L) (DWR 2013). Application areas varied considerably in past years based on the distribution of the benthic algal bloom in CCF. Treatments for benthic blooms have not occurred in recent years and are expected to be infrequent in the future.

Harmful algal blooms (HAB) in CCF are of concern as they may produce cyanotoxins which degrade drinking water quality. As part of an early warning system to SWCs, DWR first began monitoring for cyanotoxins in the SWP in 2006. Cyanotoxins can cause skin rashes, gastrointestinal distress, liver failure, and even death in humans, dogs and wildlife. The frequency of occurrence of HAB's is increasing world-wide, including in the Sacramento-San Joaquin Delta. Since its initial observation in 1999 in the San Francisco Estuary, Microcystis blooms have occurred every year in the Delta, typically starting in July and ending in October (Lehman et al. 2013). Recent drought conditions caused enhanced Microcystis blooms in Delta waterways that lasted into December (Lehman et al. 2017). In 2015, the U.S. Environmental Protection Agency (USEPA) published non-regulatory 10-day finished drinking water advisory levels for microcystins and cylindrospermopsin. These are established health-based advisory levels for concentrations at or below which adverse human health effects are not anticipated to occur over a 10-day exposure period (USEPA 2015). In addition, USEPA listed cyanotoxins including microcystin-LR, cylindrospermopsin, and anatoxin–a on the Contaminant Candidate Lists (CCL), which identify contaminants that may need regulation under the Safe Drinking Water Act.

A HAB within CCF may necessitate the application of an algaecide to halt the production of cyanotoxins and protect downstream drinking water. As outlined above, HABs have typically occurred July through October but as late as December in the Delta. The current permissible application period of June 29 to August 31 overlaps with only a portion of the expected bloom period. Treatment of HABs in CCF has not occurred to date, but treatments in upcoming years may be warranted. Depending upon the dominate species, HABs can be effectively controlled with a surface application (treatment of the upper 3 feet of the water column) of either copper sulfate or a peroxide algaecide (e.g., PAK®27). Peroxide-based algaecide treatment are proposed to occur, as needed, year-round. There are no anticipated impacts on fish with the use of peroxide-based aquatic algaecides in CCF during treatment. The oxidation reaction occurs immediately upon contact with the water destroying algal cell membranes and chlorophyll, and the byproducts are hydrogen peroxide and oxygen.

Current Science

Use of Aquathol®K

Aquathol®K (liquid formulation) is a widely used contact herbicide that controls submerged weeds in lakes and ponds, and the short residual contact time (12–48 hours) makes it effective in both still and slow-moving water. Aquathol®K is effective on many weeds, including hydrilla, milfoil, and curly-leaf pondweed, and begins working on contact to break down cell structure and inhibit protein synthesis. Without the ability to grow, the weed dies. Full kill takes place in 1 to 2 weeks. As weeds die, they sink to the bottom and decompose. Aquathol®K is not effective at controlling *E. densa*. With the changing aquatic weed assemblage in CCF, Aquathol®K is an essential tool, alongside of copper herbicides, for aquatic weed management. Aquathol®K is registered for use in California and has effectively controlled pondweeds and southern naiad in CCF and in other lakes.

Endothall has low acute and chronic toxicity effects to fish. The LC_{50} for salmonids is 20–40 times greater than the maximum concentration allowed to treat aquatic weeds. The USEPA maximum concentration allowed for Aquathol®K is 5 parts per million (ppm). A recent study (Courter et al. 2012) of the effect of Cascade® (same endothall formulation as Aquathol®K) on salmon and Steelhead smolts showed no sublethal effects until exposed to 9–12 ppm, that is, 2–3 times greater than the 5 ppm maximum concentration allowed by the USEPA and about 4-6 times greater than the 2–3 ppm applied in past CCF treatments. In the study, Steelhead and salmon smolts showed no statistical difference in mean survival between the control group and treatment groups, however, Steelhead showed slightly lower survival after 9 days at 9–12 ppm. Based on the studies with salmonids, Aquathol®K applied at or below the USEPA maximum allowable concentration of 5 ppm poses a low to no toxicity risk to salmon, Steelhead and other fish. No studies have assessed the exposure risk to Green Sturgeon or Delta Smelt.

When aquatic plant survey results indicate that pondweeds are the dominant species in CCF, Aquathol®K will be selected due to its effectiveness in controlling these species. Aquathol®K will be applied according to the label instructions, with a target concentration dependent upon plant biomass, water volume, and forebay depth. The target concentration of treatments will be 2–3 ppm, which is well below the concentration of 9–12 ppm where sublethal effects have been observed (Courter et al. 2012). DWR will monitor herbicide concentration levels during and after treatment to ensure levels do not exceed the Aquathol®K application limit of 5 ppm. Additional water quality testing may occur following treatment for drinking water intake purposes. Samples will be submitted to a laboratory for analysis. There is no "real time" field test for endothall. No more than 50% of the surface area of CCF will be treated at one time. A minimum contact time of 12 hours is needed for biological uptake and treatment effectiveness, but the contact time may be extended up to 24 hours to reduce the residual endothall concentration for NPDES compliance purposes.

Continuation of Use of Copper-based Aquatic Herbicides and Algaecides

Copper herbicides and algaecides include chelated copper products and copper sulfate pentahydrate crystals. When aquatic plant survey results indicate that *E. densa* is the dominant species, copper-based compounds will be selected due to their effectiveness in controlling this species. *E. densa* is not affected by application of Aquathol®K. Copper-based algaecides are effective at controlling algal blooms (cyanobacteria) that produce cyanotoxins or taste and odor compounds.

Copper herbicides and algaecides will be applied in a manner consistent with the label instructions, with a target concentration dependent upon target species and biomass, water volume and the depth of the forebay. Applications of copper herbicides will be applied at a concentration of 1 ppm with an expected dilution to 0.75 ppm upon dispersal in the water column. Applications for algal control will be applied at a concentration of 0.2 to 1 ppm with expected dilution within the water column. DWR will monitor dissolved copper concentration levels during and after treatment to ensure levels do not exceed the application limit of 1 ppm, per NPDES permit required procedures. Treatment contact time will be up to 24 hours. If the dissolved copper concentration falls below 0.25 ppm during an aquatic weed treatment, DWR may opt to open the radial gates after 12 hours but before 24 hours to resume operations. Opening the radial gates prior to 24 hours would enable the rapid dilution of residual copper and thereby shorten the exposure duration of ESA-listed fish to the treatment. No more than 50% of the surface area of CCF will be treated at one time.

Use of Peroxygen-Based Algaecides

Harmful algal blooms (HAB) in CCF are of concern as they degrade drinking water quality through the production of cyanotoxins that can cause skin rashes, gastrointestinal distress, liver failure, and even death in humans, dogs and wildlife. Microcystis blooms occur annually in the Delta, typically starting in July and ending in October. Recent drought conditions caused enhanced Microcystis blooms in Delta waterways that lasted into December (Lehman et al. 2017). In 2015, the U.S. Environmental Protection Agency (USEPA) published non-regulatory 10-day finished drinking water advisory levels for microcystins and cylindrospermopsin. These are established health-based advisory levels for concentrations at or below which adverse human health effects are not anticipated to occur over a 10-day exposure period (USEPA 2015). In addition, USEPA listed cyanotoxins including microcystin-LR, cylindrospermopsin, and anatoxin–a on the Contaminant Candidate Lists (CCL), which identify contaminants that may need regulation under the Safe Drinking Water Act. DWR first began monitoring for cyanotoxins in the SWP in 2006. A HAB within CCF may necessitate the application of an algaecide to halt the production of cyanotoxins and protect downstream drinking water sourcewaters.

Peroxygen-based algaecides, such as PAK®27, are effective at controlling cyanobacteria. PAK®27 algaecide active ingredient is sodium carbonate peroxyhydrate. An oxidation reaction occurs immediately upon contact with the water destroying algal cell membranes and chlorophyll. There is no contact or holding time requirement, as the oxidation reaction occurs immediately, and the byproducts are hydrogen peroxide and oxygen. There are no fishing, drinking, swimming, or irrigation restrictions following the use of this product. PAK®27 has NSF/ANSI Standard 60 Certification for use in drinking water supplies at maximum-labeled rates and is certified for organic use by the Organic Materials Reviews Institute (OMRI).

PAK®27 will be applied in a manner consistent with the label instructions, with permissible concentrations in the range of 0.3 to 10.2 ppm hydrogen peroxide. No more than 50% of the surface area of CCF will be treated at one time.

Expansion of the Herbicide and Algaecide Use Period

Aquatic weed control has been identified as one of four interim measures to increase salmonid survival in CCF. Dense stands of aquatic weeds provide cover for unwanted predators that may prey on salmonid smolts within CCF. Salmonid smolts are present in CCF during Spring months and during the onset of aquatic weed growth. However, as currently permitted, aquatic weed controlled does not occur until after conditions in CCF are no longer suitable for salmonids (water temperature >25°F). As such, the current aquatic weed control efforts do not benefit salmonid smolts traversing the CCF. Application of Aquathol®K or copper herbicide during Spring months may benefit smolt survival in CCF by reducing predatory fish habitat. The proposed target concentration for Aquathol®K is 2–3 ppm, which is well below the concentration of 9–12 ppm where sublethal effects have been observed (Courter et al. 2012). While an application of copper herbicide may affect salmonid smolts present in CCF during the time of treatment, the reduction in SAV will results in a reduction in predator habitat and may result in an overall greater increase in smolt survival. Additional precautionary measures to protect ESA listed species include meeting with NMFS and USFWS prior to treatment and the closure of the radial gates prior to treatment for a specified time of 24 hours or until the expected Delta Smelt and salmonid smolt survival period with CCF has been exceeded.

Additional protective measures will be implemented to prevent or minimize adverse effects from herbicide applications. As described above, applications of aquatic herbicides and algaecides will be contained within CCF. The radial intake gates to CCF will be closed prior to, during, and following the application. The radial gates will remain closed during the recommended minimum contact time based on herbicide type, application rate, and aquatic weed or algae assemblage. Additionally, following the gate closure and prior to aquatic herbicide the applications of Aquathol®K and copper-based pesticides following gate closures, the water is drawn down in the CCF via the Banks Pumping Plant. This drawdown helps facilitate the movement of fish in the CCF toward the fish diversion screens and into the fish protection facility, and it lowers the water level in the CCF to decrease the total amount of herbicide that would needed to be applied, per volume of water, and aides in the dilution of any residual pesticide post-treatment. Following reopening of the gates and refilling of CCF, the rapid dilution of any residual pesticide and the downstream dispersal of the treated water into the California Aqueduct via Banks PP will reduce the exposure time of any ESA-listed fish species present in CCF.

Peroxide-based algaecide treatment are proposed to occur, as needed, year-round. There are no anticipated impacts on fish with the use of peroxide-based aquatic algaecides in CCF during treatment. The reduction in cyanotoxin production following treatment may benefit fish. The oxidation reaction occurs immediately upon contact with the water destroying algal cell membranes and chlorophyll. There is no contact or holding time proposed as the oxidation reaction occurs immediately and the byproducts are hydrogen peroxide and oxygen.

DWR has worked with NMFS and USFWS to develop a set of operational procedures to minimize the potential effects on listed species during aquatic herbicide treatment. These procedures limit the time of year (and temperatures of Clifton Court Forebay) when DWR could apply herbicides; close the forebay before and after application, monitor potential effects; and monitor conditions before, during, and after applications.

Justification

Use of New Herbicides

With the changing aquatic weed assemblage in CCF, Aquathol K is an essential tool, alongside of copper herbicides, for aquatic weed management. Aquathol K is a widely used contact herbicide that is effective on many weeds, including hydrilla, milfoil, and curly-leaf pondweed. Aquathol®K is not effective at controlling *E. densa*. Endothall has low acute and chronic toxicity effects to fish. Based on the studies with salmonids, Aquathol K applied at or below the EPA maximum allowable concentration of 5 ppm poses a low to no toxicity risk to salmon and Steelhead. The target concentration of treatments will be 2–3 ppm, which is well below the concentration of 9–12 ppm where sublethal effects have been observed (Courter et al. 2012).

When aquatic plant survey results indicate that *E. densa* is the dominant species, copper-based compounds will be selected due to their effectiveness in controlling this species. Copper-based algaecides are effective at controlling algal blooms (cyanobacteria) that produce cyanotoxins or taste and odor compounds.

Harmful algal blooms (HAB) in CCF are of concern as they degrade drinking water quality through the production of cyanotoxins. A HAB within CCF may necessitate the application of an algaecide to halt the production of cyanotoxins and protect downstream drinking water sourcewaters. Peroxygen-based algaecides are effective at controlling cyanobacteria. There is no contact or holding time requirement, as the oxidation reaction occurs immediately, and the byproducts are hydrogen peroxide and oxygen. There are no fishing, drinking, swimming, or irrigation restrictions following the use of this product.

Expansion of the Herbicide and Algaecide Use Period

Aquatic weed control has been identified as one of four interim measures to increase salmonid survival in CCF. Dense stands of aquatic weeds provide cover for unwanted predators that may prey on salmonid smolts within CCF. Salmonid smolts are present in CCF during Spring months and during the onset of aquatic weed growth. However, as currently permitted, aquatic weed controlled does not occur until after conditions in CCF are no longer suitable for salmonids (water temperature >25°F). As such, the current aquatic weed control efforts do not benefit salmonid smolts traversing the CCF. Application of herbicide during Spring months may benefit smolt survival in CCF by reducing predatory fish habitat. The proposed target concentration for Aquathol®K is 2–3 ppm, which is well below the concentration of 9–12 ppm where sublethal effects have been observed (Courter et al. 2012). While an application of copper herbicide may affect salmonid smolts present in CCF during the time of treatment, the reduction in SAV will results in a reduction in predator habitat and may result in an overall greater increase in smolt survival. Additional precautionary measures to protect ESA listed species include meeting with NMFS and USFWS prior to treatment and the closure of the radial gates prior to treatment for a specified time of 24 hours or until the expected Delta Smelt and salmonid smolt survival period with CCF has been exceeded.

Additional protective measures will be implemented to prevent or minimize adverse effects from herbicide applications, as described above.

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D1.2.6.2.5 Tidal and Channel Margin Restoration

Summary

Reclamation and DWR propose to work with partners to restore 8,000 acres of tidal marsh in the Sacramento-San Joaquin Delta. This includes any actions needed to complete the restoration in areas that have been identified as part of the 2008 USFWS BO requirements, California EcoRestore goals, and restoration pursuant to California WaterFix Proposed Action, as well as selecting new areas for restoration. The Delta has lost a diversity of ecosystem services benefits over the last 150 years as much of the land was "reclaimed" for agriculture resulting in channelization of the waterways and an extensive system of levees. Along with these changes came invasive plants and animals that now make up the majority of the Delta's total biomass. Restoration of tidal habitats will reverse some of these changes and benefit multiple species of native fish and wildlife, especially listed salmonids and smelt. Tidal habitats provide multiple benefits including increased food availability and refuge from predators.

Description

Multiple planning efforts and management directives have identified various potential habitat restoration actions in the Delta. Such actions are being considered to fulfill tidal habitat restoration requirements of the BOs and Incidental Take Permit. A number of tidal habitat restoration projects are currently underway or planned under California EcoRestore and the Fish Restoration Program (FRP). The FRP projects currently being planned or implemented are part of the larger effort to meet the following goals (DWR and CDFW 2016):

- Restore 8,000 acres of intertidal and associated sub-tidal habitat in the Delta and Suisun Marsh, including 800 acres of mesohaline habitat to benefit Longfin Smelt, to enhance food production and availability for native Delta fishes;
- Restore processes that will promote primary and secondary productivity and tidal transport of resources to enhance the pelagic food web in the Delta;
- Increase the amount and quality of salmonid rearing and other habitat;
- Increase through-Delta survival of juvenile salmonids by potentially enhancing beneficial migratory pathways.

Objectives

- Fundamental objectives: Increase juveniles at Chipps Island per adult return and maintain minimum population during drought
- Means objectives: Abundance, productivity, spatial structure, and diversity

Conceptual Model (Each Species and Life stage)

Tidal habitat restoration at appropriate sites within the Delta, such as in the North Delta Arc region, would be expected to increase food availability and enhance habitat for smelt and salmonids. This relates specifically to several of the MAST hypotheses for Delta Smelt, including:

- **Adult hypothesis:** Variability in prey availability during winter and spring affects growth and fecundity (eggs per clutch and number of clutches) of female Delta Smelt
- **Larval hypothesis 2:** Increased food availability results in increased larval abundance and survival.
- **Juvenile hypothesis 3:** Juvenile Delta Smelt growth and survival is affected by food availability.
- **Sub-adult hypothesis 1:** Sub-adult Delta Smelt abundance, growth, and survival is affected by food availability.

In addition, restored habitat may affect smelt predation risk by altering interactions among hydrology, turbidity, temperature, and predators (which are covered by various MAST hypotheses).

Habitat restoration in the Delta is also expected to diversify salmonid rearing habitat, which could increase variation in out-migrant timing and population stability (Windell et al. 2017). In particular, this relates to hypotheses in the SAIL CM4 for Winter-Run Chinook Salmon that covers rearing to outmigrating juveniles in the Bay-Delta. Habitat restoration can increase habitat capacity by affecting interactions with predators and competitors, refuge habitat, food availability and quality, and temperature (**H2, H3, H4, H7**). Restoration may also affect stranding risk (**H6**), either positively or negatively depending on design and construction parameters that affect floodwater recession.

The various IEP CMs described by Sherman et al. (2017) were specifically designed to address potential effects of tidal wetland restoration on fish and, therefore, are applicable to this action.

Current Conditions

A wide variety of past planning efforts, state and federal agencies, academic experts, and other stakeholders have recognized the value of habitat restoration in the Delta. Aside from the immediate localized benefits to native species, restoration would also contribute to creating an interconnected series of tidal and other habitats in key portions of the Delta to benefit native fish species. For example, habitat restoration in the North and West Delta could contribute to creating an enhanced series of interconnected habitats running from Yolo Bypass through the Cache-Lindsey Slough-Liberty Island region, down the Sacramento River including Twitchell and Sherman islands, to Suisun Marsh, now commonly referred to as the North Delta Habitat Arc (Moyle et al. 2016).

A number of restoration planning and implementation efforts are in various stages of completion throughout the Delta, with approximately 30 projects currently being tracked under EcoRestore. However, none of the projects to date have yet received official credit under the USFWS 2008 BO.

Background

The Delta Plan, EcoRestore, and various other prior planning efforts such as Delta Vision, Bay Delta Conservation Plan (BDCP), and CALFED planning documents from the 1990s, have identified various strategies and potential locations for restoration based on factors such as current habitat for a wide variety of special-status species, relative ease of restoration, and ability to accommodate sea level rise. Tidal marsh restoration in the Delta is RPA Component 4 of the USFWS 2008 BO.

Current Science

Aside from the MAST and SAIL syntheses and CMs, there are several other efforts that have attempted to summarize our understanding of the key drivers affecting listed species and their habitats in the Delta in the form of various CMs. Two primary efforts include (1) CMs developed under the Delta Regional Ecosystem Restoration Implementation Plan (DRERIP) that cover a broad range of ecosystem processes and stressors (e.g., such as delta food webs [Durand 2008] and mercury [Alpers et al. 2008] and (2) recently published CMs developed by the IEP to guide tidal wetland restoration and monitoring of restoration sites in the Sacramento-San Joaquin Delta and Suisun Marsh (Sherman et al. 2017). The MAST, SAIL, and IEP CMs represent the current best understanding of ecological functions and the influences of landscape patterns and scales on native species life history behaviors.

Our understanding of the Delta ecosystem has increased substantially in recent years, but much uncertainty remains. Monitoring and adaptive management, including use of structured decision making, have been widely discussed as tools for dealing with existing uncertainty related to key management actions in the Delta. For example, monitoring of FRP restoration projects and other areas in the CSC area is being planned by the IEP Tidal Wetlands Project Workgroup to help improve our understanding of how tidal restoration will help Delta Smelt and other native fishes.

Justification

Restored habitat would have long-term benefits of increased physical habitat for Delta Smelt and salmonids, and improve ecosystem functions (i.e., greater food production). Converting agricultural areas to tidal wetlands will provide a net increase in zooplankton and benthic invertebrates (primary food source for smelt and salmon). By establishing open water habitats at intertidal and shallow sub-tidal elevations, habitat restoration could also increase turbidity due to wind-wave resuspension of sediments, a process common to Suisun Bay and important for smelt feeding success (IEP-MAST 2015). This type of restoration fulfills numerous multispecies recovery strategies. However, many projects are only beginning; costs are high and could increase.

This action is consistent with RPA Component 4 of the USFWS 2008 BO, also part of the Sacramento Valley Salmon Resiliency Strategy, California EcoRestore, and the Delta Smelt Resiliency Strategy.

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D1.2.6.3 *Flow Routing*

D1.2.6.3.1 Delta Cross Channel Operational Changes

Summary

Reclamation proposes to conduct October and November Delta Cross Channel (DCC) operations to meet the existing triggers from the NMFS (2009) BO Action IV.1.2 related to the DCC, but to act in advance of projected water quality standard violations, as modeled with DSM2 and in consideration of other data, such as tidal and barometric conditions.

Description

Currently, DCC operations in October and November are governed by D-1641 and the NMFS (2009) BO Action IV.1.2 (see further description below in *Current Conditions (RPA, WQCP, Facility*). Reclamation proposes to conduct October-November DCC operations to meet the existing triggers from the NMFS (2009) BO Action IV.1.2 related to the DCC, but to act in advance of projected water quality standard violations. Reclamation, at its discretion, may close the gates for up to 10 days during the first half of October to reduce the straying of returning adult Fall-Run Chinook Salmon to the Mokelumne River (Reclamation 2012).

The actual timing and duration of the DCC gate closure will be based on DSM2 modeling as well as other data. The DSM2-QUAL model uses Delta inflow, south Delta exports, barrier operations, tide forecasts, in-Delta water use, and initial Delta water quality conditions to model salinity conditions at multiple locations. The primary water quality sampling locations used for decisions regarding DCC management are Jersey Point, Bethel Island, Holland Cut, and Bacon Island, which are monitored and used for modeling electrical conductivity. In addition to DSM2 modeling data, DCC closure considerations will include available data for tides, wind, barometric pressure, and existing water quality.

Modeling results and other data will be reviewed by Reclamation with the CALFED Operations Team and the NMFS-required DOSS Group, and the proposed action will be coordinated through the Water Operations Management Team. These teams will review Delta Smelt and Longfin Smelt distributional information and coordinate with CDFW and USFWS to determine if the proposed action may cause changes in hydrodynamics resulting in increased entrainment of these species into the lower San Joaquin River. Using these various real-time data sources, annual DCC closures in October and November would be scheduled between 0 and 10 days in accordance with proposed water quality concern level targets (Table D1.2-8, Proposed Water Quality Concern Level Targets for Informing Delta Cross Channel Closure Requirements).

Table D1.2-8. Proposed Water Quality Concern Level Targets for Informing Delta Cross Channel Closure Requirements

Water Quality Concern Level Targets (DSM2-Simulated Electrical Conductivity)	
Jersey Point	1,700 µmhos/cm
Bethel Island	1,000 µmhos/cm
Holland Cut	1,000 µmhos/cm
Bacon Island	800 µmhos/cm

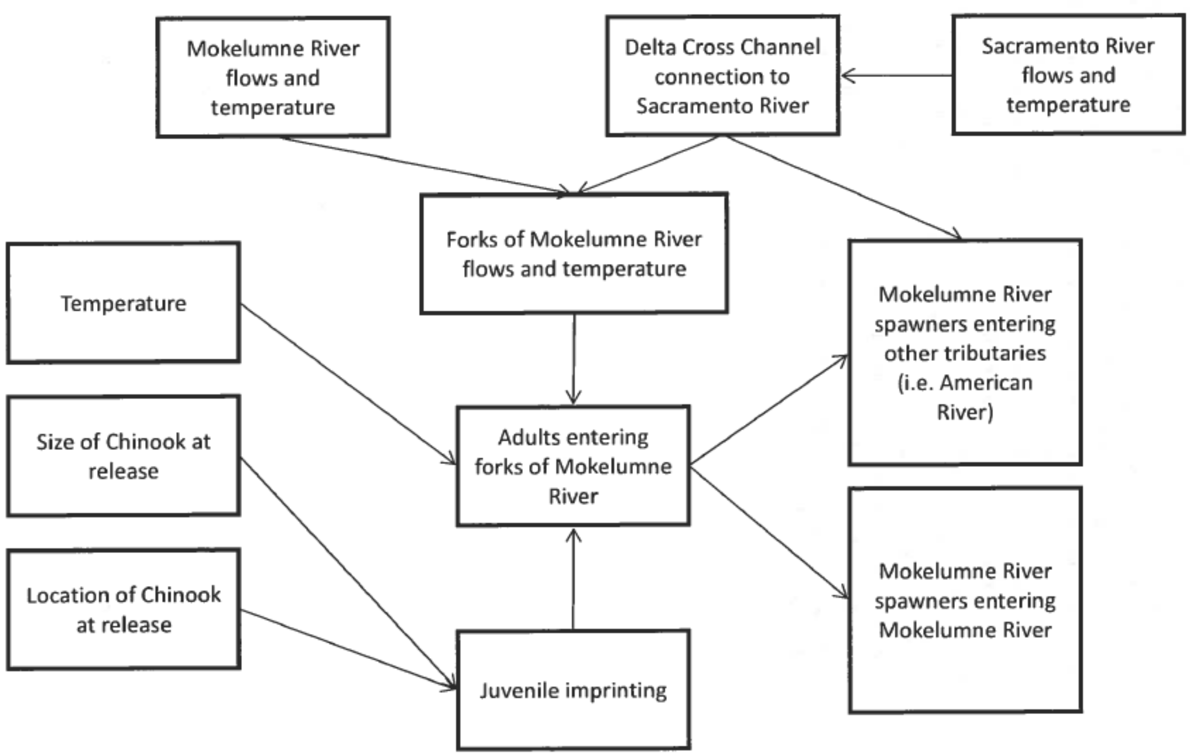
Source: Reclamation 2012.

Objectives

- Fundamental objective: Increase juveniles at Chipps Island for adult returns
- Means objective: Abundance

Conceptual Model (Each Species and Life stage)

As described further in Section D1.3.4.1.1, *Delta Cross Channel Improvements*, the SAIL CM4 for Winter-Run Chinook Salmon (Windell et al. 2017) pertains to rearing to outmigrating juveniles in the Bay-Delta and is also pertinent to Steelhead and Spring-Run Chinook Salmon from the Sacramento River Basin. Per the SAIL CM (Windell et al. 2017, p.23), “Human modification of the Delta has resulted in a channel network that no longer operates across predictable gradients for native fish and provides unnatural cues and routes for migration ... In the interior Delta, longer travel times and lower survival have been documented.” Closure of the DCC reduces juvenile salmonid entry into the interior Delta, thereby potentially reducing the risk of longer travel time and lower survival. In addition, the SAIL CM6 for Winter-Run Chinook Salmon describes potential effects on adult migration from the ocean to the upper Sacramento River, noting that “Natural and artificial barriers can delay the upstream passage and increase energetic costs to migration for salmon” and that “Water operations can influence the routing of Upper Sacramento River-origin water…and can create false attraction cues that cause salmon to deviate from the mainstem Sacramento River migration corridor” (Windell et al. 2017, p.30). These considerations are relevant in consideration of the DCC, for fish returning to the Sacramento River as well as to the San Joaquin River and Mokelumne River basins, for example. From the perspective of Mokelumne River salmonids (Fall-Run Chinook Salmon and Steelhead), the Reclamation (2012) CM of processes influencing adult escapement to the Mokelumne River illustrates the potential importance of the DCC in influencing straying to other basins (e.g., the American River) (Figure D1.2-10, CM of Biological and Physical Processes that May Influence Adult Fall-Run Chinook Salmon Escapement to the Mokelumne River).



Source: Reclamation 2012.

Figure D1.2-10. CM of Biological and Physical Processes that May Influence Adult Fall-Run Chinook Salmon Escapement to the Mokelumne River

Current Conditions

As described further in Section D1.3.4.1.1, DCC gate operations are primarily governed by NMFS (2009) RPA Action IV.1.2 and by D-1641. From October 1 to November 30, the DCC gates may be closed based on exceedance of salmon monitoring density triggers and in consideration of meeting water quality criteria (Table D1.2-7). In addition to management as a result of the NMFS RPA and D-1641, whenever flows in the Sacramento River at Sacramento reach 20,000 to 25,000 cfs (on a sustained basis) the DCC gates are closed to reduce potential scouring and flooding that might occur in the channels on the downstream side of the gates (USFWS 2008). The WIIN Act requires implementation by Reclamation and DWR of a pilot project to test and evaluate the ability to operate the Delta cross-channel gates daily or as otherwise may be appropriate to keep them open to the greatest extent practicable to protect out-migrating salmonids, manage salinities in the interior Delta and any other water quality issues, and maximize CVP and SWP pumping, subject to the condition that the pilot project shall be designed and implemented consistent with operational criteria and monitoring criteria required by the California State Water Resources Control Board (Public Law 114–322 130 stat. 1851).

Table D1.2-9. Operation of the Delta Cross Channel under State Water Board Decision 1641 and the National Marine Fisheries Service (2009) Biological Opinion during October and November

D-1641	
Date	Action
November 1-January 30	DCC gates may be closed for up to a total of 45 days.

NMFS BiOp		
Date	VI. Action Triggers	Action Responses
October 1-November 30	Water quality criteria per D-1641 are met and either the the KLCI or SCI is greater than 5 fish per day	Within 24 hours, close the DCC gates and keep closed until the catch index is less than 3 fish per day at both the Knights Landing and Sacramento monitoring sites.
	Water quality criteria per D-1641 are met, niether Knights Landing Catch Index or the Sacramento Catch Index are greater than 3 fish per day but less than or equal to 5 fish per day	Within 24 hours of trigger, DCC gates are closed. Gates will remain closed for 3 days
	The KLCI or SCI triggers are met but water quality critera are not met per D-1641 crtieria	DOSS reviews monitoring data and makes recommendation to NMFS and WOMT per procedutes in Action IV.5

Source: Reclamation 2012.

Background

As described further in Section D1.3.4.1.1, the basis for DCC operations is largely from studies showing that survival of Sacramento River basin juvenile salmonids through the Delta generally is greater when the DCC is closed (e.g., Newman 2003, Perry et al. 2010, Perry et al. 2012). Since water year 2010, the DCC has been closed for 0 to 18 days in October and November (see Table D1.3-1, Number of Days of Delta Cross Channel Gate Closure, October–June, Water Years 2010–2010). As noted by USFWS (2008, p.174), larval and juvenile Delta Smelt are probably not strongly affected by DCC operations, based on previous studies (Kimmerer and Nobriga 2008), although there could be times when DCC closure affects Delta Smelt by generating flows that draw them into the South Delta.

Current Science

Further studies on the migration success of juvenile salmonids through the Delta have continued to suggest that the interior Delta migration route via the DCC and Georgiana Slough results in lower survival migration through the north Delta and main stem Sacramento River (Singer et al. 2013). Although the number of years for assessment is limited, there is evidence that temporary closure of the DCC in fall reduces the straying rate of adult Fall-Run Chinook Salmon returning to the Mokelumne River (Setka 2017).

Justification

Opening the DCC gates in advance of projected water quality standard exceedances will allow better compliance with water quality standards and increased operational flexibility, potentially decreasing salinity at Jones Pumping plant and reducing the amount of Delta outflow necessary to meet D-161 salinity requirements.

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D1.2.6.4 *Salvage Efficiency*

D1.2.6.4.1 <u>Salvage Release Sites</u>

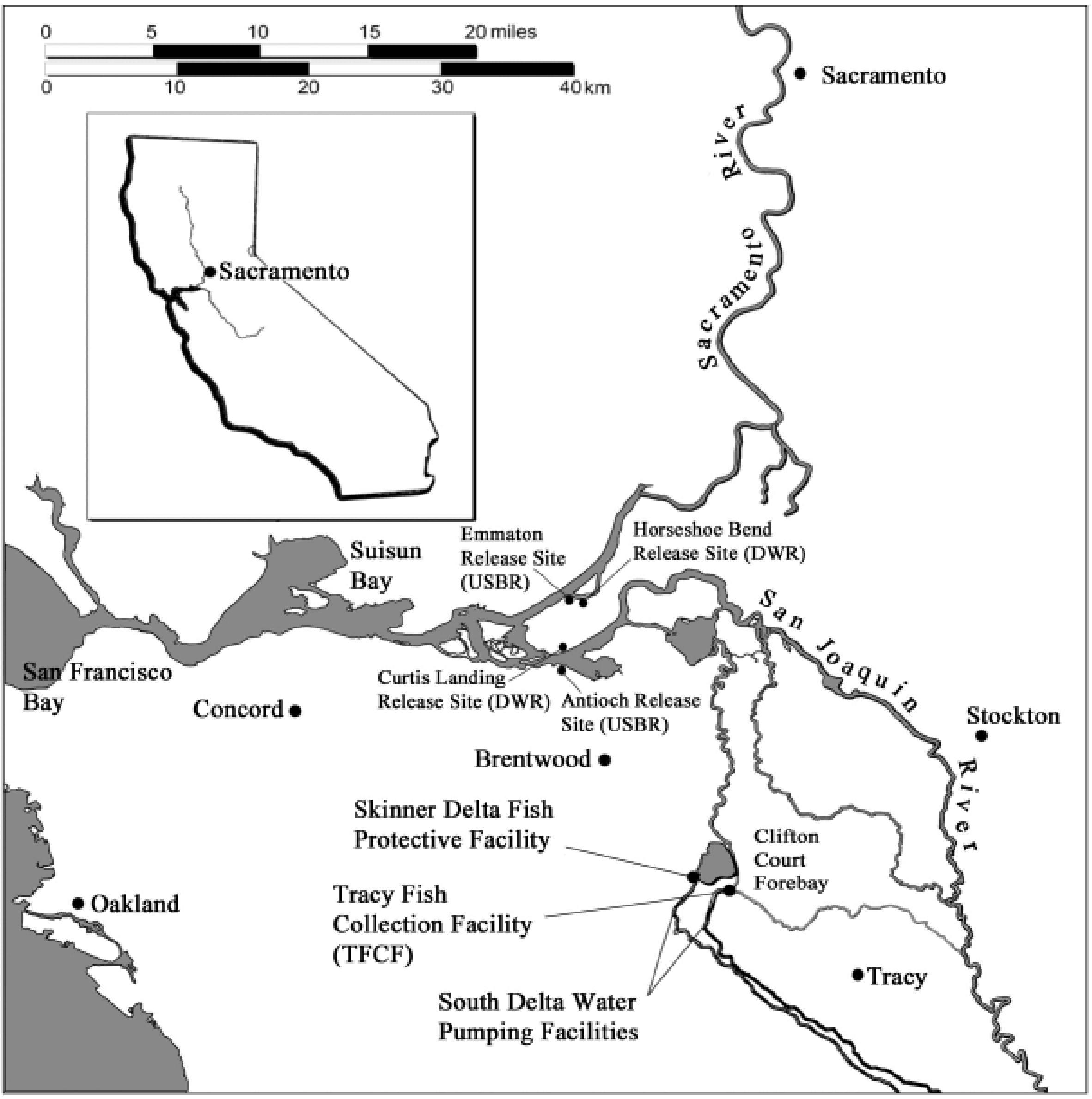
Summary

Reclamation proposes to improve salvage operations at the Tracy Fish Collection Facility (TFCF) by partnering with DWR to reduce predation of salvaged fish during release by varying the release locations used and considering mobile release from barges.

Description

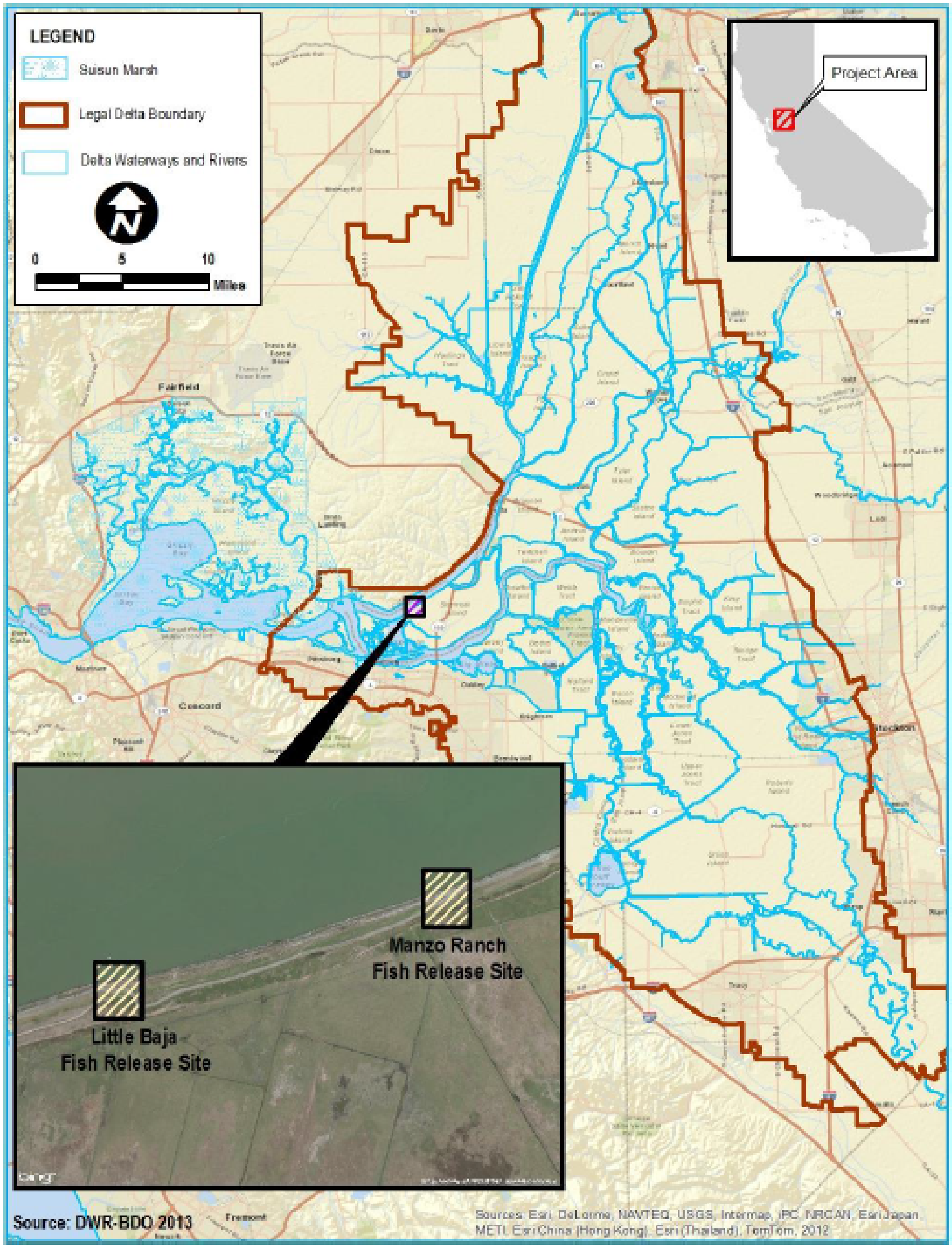
Reclamation would partner with DWR to reduce predation of salvaged fish during release in the west Delta. There are currently six salvage release sites in the west Delta: four of these sites (Curtis Landing, Antioch, Emmaton, and Horseshoe Bend; Figure D1.2-11, Location of The Four Long-Term Fish Salvage Release Locations in the Delta) have had long-term use, whereas two sites (Little Baja and Manzo Ranch; Figure D1.2-12, Location of the Recently Completed Fish Salvage Release Locations in the Delta) were only recently completed. This element will involve use of the six release locations by Reclamation and DWR. As noted by Karp and Bridges (2016), historical operations of the release sites focused on fairly regular schedules, with DWR and Reclamation exclusively using their own release sites except in emergencies. The predictability in release schedules is hypothesized to increase risk of predation for salvaged fish. The proposed action will aim to reduce release site predation through changes to the historical operational scheme based on studies evaluating recommendations by Karp and Bridges (2016). These recommendations included altering the frequency of salvaged fish releases either by reducing the number of releases each day or by using one site every few days. Determining the optimum number of release sites would be based on gradually increasing the number of release sites being used and monitoring changes in predator density over time.

The salvage release action will also consider the use of other release strategies, in particular the use of barges. As summarized by Karp and Bridges (2016), barge releases of salvaged fish could provide several benefits, including allowing: salvaged fish to acclimate to Delta water conditions before release, allowing salvaged fish to recover from transport/handling-induced stress, accommodating a large number of salvaged fish at one time, moving fish away to offshore areas where it is hypothesized that there is less predation, and accommodating night releases when predation by visual predators should be lower. Compared to another potential release method, i.e., the use of net pens, barging allows very large numbers of salvaged fish to be moved long distances because a barge can move fish faster than towing a net pen and requires fewer operators. Barging could be used nearly every day of the year and would not be as limited by weather or fog as is the use of net pens. For feasible implementation, it is likely that barging would involve use of trucks to deliver salvaged fish from the TFCF to barges moored in the west Delta (e.g., Antioch or Rio Vista; Karp and Bridges 2016).



Source: Karp and Bridges 2016.

Figure D1.2-11. Location of The Four Long-Term Fish Salvage Release Locations in the Delta



Source: DWR 2014.

Figure D1.2-12. Location of the Recently Completed Fish Salvage Release Locations in the Delta

Objectives

- Fundamental objective: Increase juveniles at Chipps Island per adult return
- Means objective: Abundance

Conceptual Model (Each Species and Life stage)

As previously noted for other proposed actions, per the SAIL CM4 for Winter-Run Chinook Salmon rearing to outmigrating juveniles in the Bay-Delta (Windell et al. 2017, p.22), "Juvenile salmon arriving in the southern end of the Delta are at risk of entrainment in the Central Valley Project and State Water Project water intakes." The Green Sturgeon SAIL CM for the transition from juvenile to adult/sub-adult notes "both juvenile green sturgeon distribution and behavior suggest that entrainment and impingement in diversions affect survival" (Heublein et al. 2017, p.22).

Current Conditions

The NMFS (2009) RPA Action IV.4.3 requires implementation of state-of-the-art salvage release procedures to improve overall survival of listed species. This involves conducting release site studies to develop methods to reduce predation at the "end of the pipe" following release of salvaged fish. Studies are required to examine but not be limited to a) potential use of barges to release the fish in different locations within the western Delta, with slow dispersion of fish from barge holding tanks to Delta waters; b) multiple release points (up to six) in western Delta with randomized release schedule; and c) conducting a benefit to cost analysis to maximize this ratio while reducing predation at release site to 50% of the current rate. Based on these studies, predation reduction methods are to be implemented that reduce release site predation to 50% of the current rate.

Background

Analysis in the NMFS (2009, p.352) BO identifies prescreen loss (15%), louver efficiency loss (53.2%), collection/handling/transport/release loss (2%), and post-release loss (10%) as the various elements contributing to approximately 35% survival of fish salvaged at the TFCF. Hydroacoustic studies have provided evidence that predators can be abundant at the release sites (Miranda et al. 2010).

Current Science

Studies are underway to determine release site strategies in order to optimize release schedules at the multiple SWP/CVP release sites (Fullard et al. 2017, 2018).

Justification

Changes in salvage release sites could help minimize the effects of the salvage process on listed fishes, in particular juvenile salmonids and Green Sturgeon.

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D1.2.6.5 *Conservation Hatchery*

D1.2.6.5.1 Delta Smelt Conservation Hatchery

Summary

Reclamation would partner with IEP to develop a conservation hatchery for Delta Smelt, which is a rearing facility to breed and propagate a stock of fish with equivalent genetic resources of the native stock, so that they can be returned to the wild to reproduce naturally in their native habitat.

Description

An extreme decline in Delta Smelt abundance has led to a number of management actions to support this endangered species, including the development and refinement of culture techniques and the creation of a Delta Smelt refuge population. Delta Smelt have been cultured since the mid-1990s (Lindberg et al. 2013) and are now held in a refuge population at the UC Davis Fish Culture and Conservation Laboratory (FCCL), with a portion of these fish also held at the Livingston Stone National Fish Hatchery. The goal of the Delta Smelt captive breeding program at the FCCL is to "create a genetically and demographically robust captive population that will act as a genetic bank in the event this species becomes extinct in the wild, as well as potentially serve as a source for supporting wild populations if such a need arises" (Fisch et al. 2012). The captive breeding program operates under a rigorous genetic management plan jointly managed by the FCCL and the Genomic Variation Laboratory (GVL) at UC Davis to maintain genetic diversity and minimize kinship among captive fish (Fisch et al. 2012).

As a result of the recent extreme population declines, interest in the development of a full-scale Conservation Hatchery, and accompanying Hatchery Genetic Management Plan and Supplementation Program, have increased. Toward this goal, the USFWS in collaboration with DWR and Reclamation have been considering the construction of a regional Fish Technology Center to be co-located at the Rio Vista Army Base, Redevelopment Area. This Center's purpose will be to support an expanded refuge population and research toward the development of a full-scale Conservation Hatchery for species supplementation (USFWS 2016). Here supplementation is defined as the intentional movement and release of an organism inside its indigenous range (if the species has disappeared this same action would be considered reintroduction) (IUCN SSC 2013).

Objectives

- Fundamental objective: Maintain minimum population during drought.
- Means objective: Productivity

Conceptual Model (Each Species and Life stage)

The CMs are not directly applicable.

Current Condition

The maximum adult capacity of the FCCL facility is currently only 53,500 adult fish, thus large numbers of cultured animals are culled from the population due to space limitations. If a species supplementation program were to be considered necessary, the FCCL would not be able to accommodate the level of production needed for such a program. As such, a facility dedicated to a full-scale Conservation Hatchery, managed under a Hatchery Genetic Management Plan, is needed. The FTC at Rio Vista is currently in the design and planning stages, and a conservation hatchery is included in the building plans; however, the funding and agreements for the running of the facility has not been defined. This facility will require Congressional approval for funding.

While the FCCL has been successful in refining captive propagation techniques and establishing a refugial population of Delta Smelt that is genetically indistinguishable from the wild using neutral loci (Fisch et al. 2013), there is recent evidence for domestication selection. Finger et al. (*Journal of Heredity*) found that the relative reproductive success (RRS) of pair crosses with one wild and one cultured parent was lower than that of pair crosses with two cultured parents. This trend has continued across a period of nine years, since the inception of the Delta Smelt captive breeding program at the FCCL. Additionally, the RRS of pair crosses with two cultured parents has increased continually over generations, indicating that adaptation to captivity is likely occurring but cannot be detected with the existing panel of microsatellite markers.

The most direct way to minimize hatchery domestication selection is to reduce the amount of time that Delta Smelt spend in the hatchery. This aim could be accomplished by using fish with minimal hatchery ancestry (e.g., pair crosses with one or two wild parents) for population reinforcement or reintroduction and/or by releasing Delta Smelt at the fertilized egg stage. Numerous studies have shown that cultured fish do not perform as well (e.g., survival, growth, behavior, and reproductive success) under natural conditions as wild fish (McGinnity et al. 2003; Berejikian and Ford 2004; Araki et al. 2007, 2008). To minimize the risk of hatchery effects, cultured Delta Smelt could be released at the fertilized egg stage using techniques that have been developed in Japan for a related species, Wakasagi (*Hypomesus nipponensis*).

Background

Delta Smelt is a small (maximum length ~120 mm FL) estuarine fish endemic to the upper reaches of the San Francisco Estuary (SFE) (Moyle 2002; Bennett 2005; IEP-MAST 2015). Once very abundant, Delta Smelt are now rare and are protected under the federal (ESA; threatened) and California Endangered Species Act (CESA; endangered). The species currently consists of a single remnant population (Moyle and Herbold 1992; Fisch et al. 2011) that completes its entire life cycle in the upper SFE. Delta Smelt live one to two years and historically demonstrated high variability in spatial distribution and annual abundance, generally responding better to wetter conditions, high turbidity, moderate temperatures, and improved food availability (Moyle et al. 2016). The decline of this species began during the early 1980s, which ultimately led to its federal listing in 1993 (USFWS 1993). Population abundance decreased further around 2002, which included declines of several other pelagic fishes of the upper SFE, a phenomenon known as the "Pelagic Organism Decline" (POD) (Sommer et al. 2007; Thomson et al. 2010; IEP-MAST 2015).

Current Science

FCCL facility consists of several buildings located at the Skinner Fish Facility adjacent to Clifton Court Forebay. Wild Delta Smelt were captured and first brought to the FCCL for the purpose of establishing a refugial population in 2006 (Fisch et al. 2013). Captive spawning was initiated in 2008, accompanied by an intensive genetic management strategy that involves controlled mate selection to minimize kinship and preserve genetic diversity (Ballou and Lacy 1995; Lindberg et al. 2013); the introduction of wild Delta Smelt into the refugial population each year is also an important factor that retards genetic variation loss. Details of the genetic management plan for Delta Smelt reared at the FCCL are presented in Finger and May (2015).

Approximately 100 wild Delta Smelt are collected from the Delta annually and housed at the FCCL in preparation for spawning. At the beginning of every spawning season, ripe individuals are tagged and fin clips are sent to the Genomic Variation Laboratory (GVL) at UC Davis for genotyping at 12 microsatellite loci (Fisch et al. 2009). The genotype data is used for pedigree reconstruction to identify the family of the tagged fish; wild fish are assumed to be unrelated. The GVL then makes recommendations about which individuals should be crossed to represent the greatest number of pair crosses from the previous year and to maximize the genetic input of wild fish.

Justification

Hatchery production and supplementation using cultured Delta Smelt may be the only viable, short-term means to prevent species extinction. Further declines in wild broodstock availability will reduce successful natural production as well as reduce levels of genetic diversity available for conservation aquaculture, making species recovery that much harder. Given the precarious demographic status of Delta Smelt and the severely degraded conditions of its habitat, the benefits of developing a conservation hatchery and supplementation program now outweigh the risks of such experiments (Anders 1998; Bohling 2016; Hobbs et al. 2017; Lessard et al. 2018).

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D1.2.7 Stanislaus River Basin

D1.2.7.1 *Water Operations*

D1.2.7.1.1 New Melones Revised Plan of Operations

Summary

Reclamation would implement the New Melones Revised Plan of Operation to create a sustainable operation on the Stanislaus River.

Description

Reclamation would operate New Melones Reservoir (as measured at Goodwin Dam) in accordance with a Stepped Release Plan (SRP) that varies by hydrologic condition and water year type as shown in Table D1.2-10, New Melones SRP Annual Releases by Water Year Type.

Table D1.2-10. New Melones SRP Annual Releases by Water Year Type

Water Year Type	Annual Release (TAF)
Critical	184.3
Dry	233.3
Below Normal	344.6
Above Normal	344.6
Wet	476.3

The New Melones SRP would be implemented similarly to the No Action Alternative with a default daily hydrograph and the ability to shape monthly and seasonal flow volumes to meet specific biological objectives. The default daily hydrograph is the same as prescribed under the No Action Alternative for critical, dry, and below-normal water year types. The difference occurs in above-normal and wet years, where the minimum requirement for larger releases is reduced from the No Action Alternative to promote storage for potential future droughts and preserve cold water pool. When compared to minimum daily flows from the No Action Alternative, the daily hydrograph for the New Melones SRP is identical for critical, dry, and below-normal year types; above-normal and wet year types follow daily hydrographs for below-normal and above-normal year types from current operating requirements, respectively.

For the New Melones SRP, Reclamation would classify water year types using the San Joaquin Valley 60-20-20 Water Year Hydrologic Classification (60-20-20) developed for D-1641 implementation. Previous operating plans for New Melones Reservoir relied on the New Melones Index to determine water year type, calculated by summing end-of-February storage and forecasted inflow through September. Because the reservoir can store more than twice its average inflow, the New Melones Index resulted in a water year type determination that was more closely tied to storage rather than hydrology. Changing from the New Melones Index to 60-20-20 is expected to provide operations that better represent current hydrology and correlate more closely to water year types for other nearby tributaries.

Reclamation would convene the Stanislaus Watershed Team (successor to the Stanislaus Operating Group), consisting of agency representatives and local stakeholders having direct interest on the Stanislaus River, at least monthly to share operational information and improve technical dialogue on the implementation of the New Melones SRP. The Stanislaus Watershed Team would provide input on the shaping and timing of monthly or seasonal flow volumes to optimize biological benefits.

During the summer, Reclamation would be required to maintain applicable dissolved oxygen standards on the lower Stanislaus River for species protection. Reclamation currently operates to a 7.0 mg/L dissolved oxygen requirement at Ripon from June 1 to September 30. Reclamation would move the compliance location to Orange Blossom Bridge, where the species are primarily located at that time of year.

Objectives

- Fundamental objectives: Increase juveniles at Chipps Island per adult return and maintain minimum population during drought
- Means objectives: Abundance and productivity

Conceptual Model (Each Species and Life stage)

While Steelhead, Spring-Run Chinook salmon, and Fall-Run Chinook Salmon on the Stanislaus River are not specifically included in the available CMs, this component also relates to the ability to meet flow and water quality requirements at Vernalis. Flow and water quality entering the Delta are key for species residing in, or migrating through, the Delta.

Current Condition

New Melones has been operated under an Interim Plan of Operations since 1997. The IPO was developed prior to completion of current tools to understand hydrology in the basin, and the water releases for different purposes were overallocated in many years. The Interim Plan of Operations requires releases early in the season that have resulted in inadequate water available later in the season to meet requirements. Table D1.2-11, New Melones Interim Plan of Operation Allocations (TAF), shows the Interim Plan of Operations.

Table D1.2-11. New Melones Interim Plan of Operation Allocations (TAF)

New Melones Storage Plus Inflow		Fishery		Vernalis Water Quality		Bay-Delta		CVP Contractors	
From	To	From	To	From	To	From	To	From	To
0	1,400	0	98	0	70	0	0	0	0
1,400	2,000	98	125	70	80	0	0	0	0
2,000	2,500	125	345	80	175	0	0	0	59
2,500	3,000	345	467	175	250	75	75	90	90
3,000	6,000	467	467	250	250	75	75	90	90

Background

Reclamation has been working with water rights holders and CVP contractors on the Stanislaus system to develop the Revised Plan of Operations. This plan strives to meet requirements for fish flows, temperature, water quality, dissolved oxygen, and water deliveries.

Current Science

The NMFS *Recovery Plan for Central Valley Chinook Salmon and Steelhead* (NMFS 2014) identifies recovery actions on the Stanislaus River. These actions include managing flow releases to provide suitable water temperatures and flows for all Steelhead life stages, and the Revised Plan of Operation would improve the ability to manage temperatures under multiple hydrologic conditions. The plan also identifies the need to evaluate whether pulse flows are beneficial to adult Steelhead immigration and juvenile Steelhead emigration. The Revised Plan of Operation identifies blocks of water that could be used for pulse flows or sustained flows over a longer period.

Justification

The *Recovery Plan for Central Valley Chinook Salmon and Steelhead* (NMFS 2014) identifies the Steelhead population on the Stanislaus River below Goodwin as a Core 2 population. The Interim Plan of Operations is not able to maintain temperatures throughout the year under some hydrologic conditions, and the Revised Plan of Operations has addressed several of the issues that lead to the problems experienced in recent years.

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D1.2.7.1.2 Relaxation of Stanislaus River Dissolved Oxygen Requirement

Summary

Reclamation would petition the SWRCB to alter the requirement for DO at Ripon to be 7 milligrams per liter (mg/L) from June through November of dry years.

Description

SWRCB D-1422 requires that water be released from New Melones Reservoir to maintain a DO concentration in the Stanislaus River as specified in the Water Quality Control Plan (WQCP) for the Sacramento and San Joaquin river basins. The 1995 revision to the WQCP established a minimum DO concentration of 7 milligrams per liter (mg/L), as measured on the Stanislaus River near Ripon. In coordination with Reclamation's plan of operation for New Melones Reservoir, Reclamation will petition the SWRCB to modify this requirement to maintain a minimum DO concentration of 5 mg/L at Ripon during dry years. In these years, New Melones Reservoir does not have sufficient inflow to meet all requirements on the lower San Joaquin River. Relaxing the standard would allow an improved ability to maintain temperatures throughout the season.

Objectives

- Fundamental objectives: Increase juveniles at Chipps Island per adult return and maintain minimum population during drought
- Means objectives: Abundance and productivity

Conceptual Model (Each Species and Life stage)

While Fall-Run Chinook Salmon and Steelhead on the Stanislaus River are not specifically included in the available CMs, sufficient dissolved oxygen is recognized as a requirement for anadromous fish within the Stanislaus system. Additionally, water quality entering the Delta is key for species residing in, or migrating through, the Delta.

Current Condition

Reclamation is required to meet the existing DO standard at Ripon unless the SWRCB approves a temporary relaxation.

Background

In 2015, Reclamation submitted a Temporary Urgency Change Petition to the SWRCB because drought conditions prevented Reclamation from meeting all WQCP standards. The SWRCB approved the petition, which included a provision to reduce the DO standard for the Stanislaus River at Ripon from a minimum of 7 mg/L to 5 mg/L.

Current Science

CDFW studied DO concentrations in the Stanislaus River at Ripon and the lower San Joaquin River (at five locations) during 2011 and 2015 to compare non-drought and drought conditions, respectively. Generally, they found that DO concentrations in the summer were lower during 2015 in both the Stanislaus and San Joaquin rivers and fell below 7 mg/L on the Stanislaus River at Ripon (CDFW n.d.). Dissolved oxygen concentrations have been found to be a migration barrier for adult salmon if they are lower than 4.2 mg/L (Hallock et al. 1970), but the 2015 DO concentrations were consistently above this level (CDFW n.d.).

Juvenile Steelhead may be rearing in the uppermost reaches of the river during June through November and adult Steelhead may begin entering the river as early as October. Few Spring-Run Chinook Salmon typically enter the river during the spring period. Based on past multi-year observations (Kennedy and Cannon 2005; Kennedy 2008), oversummering juvenile salmonids are primarily found upstream of

Orange Blossom Bridge, which is 31 miles upstream from Ripon. DO monitoring at the Stanislaus River Weir (about 15 miles upstream from Ripon) indicates that DO concentrations can be 0.5–1 mg/L higher at this location than Ripon (Cramer Fish Sciences 2006a-d). Because the fish are primarily at least twice this distance upstream from Ripon, the DO is likely to be at this level or higher.

Justification

Maintaining DO concentrations above 7 mg/L in the Stanislaus River at Ripon is challenging during drought conditions, and is not necessary for Steelhead, Spring-Run Chinook Salmon, or Fall-Run Chinook Salmon.

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D1.3 Program-Level Components

D1.3.1 Central Valley Wide

D1.3.1.1 *Small Screen Program*

D1.3.1.1.1 Summary

Operating water divisions without screening can result in the entrainment of juvenile fish into the diversions and impact listed and special fish populations in these river systems. Most of the larger diversions in the Central Valley have been screened or are currently proposed for screening. Reclamation and DWR propose to screen remaining small unscreened diversions to reduce entrainment of salmonids.

D1.3.1.1.2 Description

Reclamation and DWR propose implementation the Reclamation Small Screen Program (RSSP) to provide fish screens on small water diversions (less than 150 cfs) to reduce the take of listed fish species. The RSSP would provide additional funding, technical services, and in-kind support for existing screening programs in California to further encourage the conversion of unscreened to screened diversions that meets CDFW and NMFS criteria. This program would leverage existing programs and the collaborative partnerships already established with diversion stakeholders and other State and federal agencies. This program would be administered through 2030 to support efforts to provide fish screens for unscreened diversions with maximum instantaneous flow demands less than 150 cfs. Reclamation and DWR would partner with agencies/groups to address diversions without screening and to perform or supplement the following activities as outlined by existing programs.

The RSSP would provide technical services and/or additional funding to achieve the following tasks:

- Identification, evaluation, and prioritization of unscreened diversions to refine current data sets,
- Promote public education through distribution of educational materials and public outreach,
- Consult with current water right holders to help identify appropriate technical solutions and funding pathways, and
- Offer additional grant funding to be administered through existing screening programs.

Projects seeking funding will be evaluated and prioritized based on biological benefits, the size and location of the diversion, project costs, and the availability of cost-share funding partners. The types of projects eligible for funds under the program include:

- Construction of fish screens on unscreened diversions,
- Rehabilitating existing fish screens,
- Replace/improve existing nonfunctioning fish screens, and
- Relocating water diversion to less fishery-sensitive areas.

D1.3.1.1.3 Objectives

- Fundamental objectives: Increase juveniles at Chipps Island per adult return and maintain minimum population during drought
- Means objective: Abundance

D1.3.1.1.4 Conceptual Model (Each Species and Life stage)

Juvenile Chinook Salmon and Steelhead migrating down the river systems encounter numerous water/irrigation diversions. The entrainment risk associated with unscreened or poorly screened water diversions leads to direct entrainment and mortality and is classified as a Tier 3 driver (habitat attribute) in the SAIL CM for the Rearing Juvenile to Outmigrating Juvenile life stage of Sacramento River Winter-Run Chinook Salmon, affecting smolts migrating in the Upper River (Keswick Dam to RBDD), Middle River (RBDD to Sacramento), and the Bay-Delta reaches (Windell et al. 2017). The construction of screens under the small screen program would improve the migratory conditions and survival of outmigrating juvenile salmonids, and thus, provide immediate and long-term improvement of the resiliency of Sacramento Valley salmon and Steelhead (CNRA 2017). Although the SAIL CM has not been developed for Sacramento River Spring-Run Chinook Salmon and Steelhead, the SAIL CM applies to these species due to the close life cycle similarity and habitat attributes that affect survival. Therefore, the benefits of screening water diversions directly apply to these populations.

The SAIL CM for North American Green Sturgeon and the Sacramento-San Joaquin River White Sturgeon classifies the key factors influencing their populations in the San Francisco Estuary watershed (Heublein et al. 2017a). Entrainment in diversions is identified as a Tier 3 habitat attribute affecting sturgeon abundance for the for two juvenile life history stages: the hatch to metamorphosis and metamorphosis stage and the metamorphosis to ocean migration or 75 cm fork length life stage. Larval sturgeon are present in areas where substantial water volumes are diverted, and, due to small size and relatively poor swimming performance of larvae, it is almost certain that entrainment effects larval survival influences larval and juvenile survival. Although some diversion facilities include modern fish screens to reduce entrainment of juvenile salmonids, the effectiveness of screens and facility operations in reducing larval Green Sturgeon entrainment is poorly understood, and the distribution and behavior of juvenile Green Sturgeon suggest that entrainment and impingement in diversions affect survival (Heublein et al. 2017b). Furthermore, many small-scale unscreened diversions are present throughout larval habitat of both species in the mainstem Sacramento River likely directly affect juvenile White Sturgeon survival. The construction and improvement of fish screens under the proposed small screen program, as well as further study of screen effectiveness for sturgeon, would improve survival of juvenile sturgeon in the Sacramento River and Delta.

D1.3.1.1.5 Current Condition

Query results for unscreened and unassessed diversions were obtained on October 18, 2018, using the CDFW Passage Assessment Database.

- Sacramento River: The database identified 691 unscreened diversions on the Sacramento River, located in 10 different counties (Butte, Colusa, Glenn, Sacramento, Shasta, Solano, Sutter, Tehama, Yolo, and Yuba) between approximately River Mile (RM) 3 and RM 300. In addition to these unscreened diversions, there are 16 unassessed diversions (CDFG 2018).
- American River: The database identified 5 unscreened diversions currently on the American River, all located in the same county (Sacramento), approximately between RM 0 and RM 24. In addition to these five unscreened diversions, three have been identified as unassessed (CDFW 2018).
- Delta: According to the California State Water Resources Control Board (SWRCB) report, there are more than 3,000 known in-Delta water rights and claims. (SWRCB 2014). Fish loss due to entrainment is well documented (Kimmerer 2008; Mussen et al. 2013) and screening of these diversions is a component of recovery of fish in the Bay-Delta (USFWS 1996).

D1.3.1.1.6 Background

The entrainment and loss of fish at unscreened diversions in the Sacramento River basin and Sacramento-San Joaquin River Delta negatively affects the populations of listed species and other special status fish (NMFS 2014). The loss of juvenile salmonids at unscreened water diversions in the Sacramento River and Delta has been identified as a reason for the listing of Winter- and Spring-Run Chinook Salmon and Steelhead. While many of the large water diversions (greater than 150 cfs) on the Sacramento River are screened or are currently proposed for screening, most of the over 3,700 water diversions on the Sacramento River and San Joaquin River watersheds and in the Sacramento-San Joaquin River Delta remain unscreened (Mussen et al. 2013).

Existing Programs

Fish screen programs have been established in the Central Valley to prevent entrainment of fish into water diversions and reduce impacts to the species that inhabit the Sacramento-San Joaquin River Delta and its tributaries. Major restoration efforts that impact salmon and Steelhead recovery in the Central Valley have resulted in the establishment of Reclamation's Anadromous Fish Screen Program (AFSP) in the mid-1990s and the CALFED Sacramento Valley/Delta Fish Screen Program (DFSP). In addition, the Sacramento-Central Valley Fish Screen Program was created by the FWA in 1996 to screen additional diversions that do fit into the scope of work DFSP.

Reclamation's AFSP was initiated to screen irrigation diversions, with primary funding provided through the CVPIA restoration fund, and augmented on occasion by other Reclamation and CALFED Ecosystem Restoration Program (ERP) funds. The AFSP and the DFSP are operated jointly, with the participation of Reclamation, USFWS, CDFW, NMFS, and DWR. Shared purposes of the AFRP and the ERP are to protect and restore diversity within and among the various naturally-producing populations of Chinook Salmon and Steelhead in the Central Valley, and to restore the habitats upon which the populations depend. These programs have supported over 30 projects addressing unscreened diversions throughout the Central Valley, with the majority of projects implemented on relatively large diversions along the mainstem Sacramento River.

Anadromous Fish Screen Program (Reclamation)

The AFSP was established in 1994 to carry out CVPIA Section 3406(b)(21). The CVPIA (Title 34 of Public Law 102-575) required implementation of measures to protect, restore, and enhance fish and wildlife affected by operations of the federal CVP, and directed the Interior to assist the State of California in efforts to implement measures to avoid losses of juvenile anadromous fish from diversions in Sacramento and San Joaquin watersheds and the Delta. The AFSP was specifically developed to help meet the fish restoration objectives of CVPIA and protects juvenile anadromous fish from entrainment in water diversions in California on the Sacramento and San Joaquin rivers, their tributaries, and the Sacramento-San Joaquin Delta. The AFSP is an incentive-based program that encourages the construction of fish screens at water diversions by providing technical assistance and cost-share funding. Fish protected through this program include Chinook Salmon, Steelhead trout, and Green and White Sturgeon.

Ecosystem Restoration Program – Sacramento Valley/Delta Fish Screen Program.

The ERP is CDFW's principal program designed to restore the ecological health of the Bay-Delta ecosystem. The ERP includes actions throughout the Bay-Delta watershed and focuses on the restoration of ecological processes and important habitats. The DFSP is a component of the comprehensive ERP; a multiagency effort aimed at improving and increasing aquatic and terrestrial habitats and ecological function in the Delta and its tributaries. The ERP Focus Area includes the Sacramento-San Joaquin Delta, Suisun Bay, the Sacramento River below Shasta Dam, the San Joaquin River below the confluence with the Merced River, and their major tributary watersheds directly connected to the Bay-Delta system below major dams and reservoirs. The vast majority of these projects focus on fish passage issues, species assessment, ecological processes, environmental water quality, or habitat restoration.

Sacramento-Central Valley Fish Screen Valley Fish Screen Program

The Sacramento-Central Valley Fish Screen Program is managed by the FWA, a 501(c)(3) nonprofit corporation that administers the grant-funded program to install fish screens in the Sacramento River. The program's goal is to benefit threatened and endangered anadromous fish species by screening multiple sites that do not currently fit into the scope of work for the current Sacramento Valley/Delta Fish Screen Program. Since 1996, FWA has been the program manager in cooperation with several State and Federal agencies and private contributors in spearheading research and developing and installing fish screens on small agricultural diversions.

California Department of Fish and Game Watershed Restoration Grants Branch

CDFW provides grant programs for the installation or improvement of fish screens. These grant programs include:

- Proposition 68 Restoration Grant Programs
- Proposition 1 Restoration Grant Programs
- Fisheries Habitat Restoration Grant Program

D1.3.1.1.7 Current Science

Fish exclusion screens and protection devices are a common strategy for reducing entrainment risk of a threatened juvenile fish species while maintaining water-diversion activities. The design and success of a fish screen facility is dependent on a number of factors, such as fish species, swimming ability, and hydraulic conditions. Guidance documents for the placement and design of fish screens are provided below.

- Designing Fish Screens for Fish Protection at Water Diversions (NMFS)
- Fish Screening Passage for Anadromous Salmonids (NMFS)
- Fish Protection at Water Diversions: A guide for planning and designing fish exclusion facilities. (Reclamation)
- California Department of Fish and Wildlife Fish Screening Criteria (CDFW)

D1.3.1.1.8 Justification

Fish screen programs have been established in the Central Valley to reduce entrainment of fish into water diversions and reduce impacts to the species that inhabit the Sacramento-San Joaquin River Delta and its tributaries. The implementation of a fish screen program would offer a variety of benefits for both fish and landowners. The addition of fish screens to a previously unscreened diversion allow for more reliable water flow, prevent system clogging (in turn reducing maintenance), protecting fish from diversions, and meeting state and federal laws.

D1.3.1.1.9 References

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D1.3.2 Upper Sacramento River Basin (Shasta and Sacramento Divisions)

D1.3.2.1 *Temperature Facility Improvements*

D1.3.2.1.1 Shasta Temperature Control Device Improvements

Summary

The current Shasta TCD leaks, and when reservoir levels are below the shutters does not allow for selective withdrawal from the reservoir. Additional flexibility to meet temperature control could be provided with structural modifications. Implementation of the Shasta Dam Raise project would replace or modify the TCD.

Description

Depending upon the type of dam raise proposed, the TCD would be either modified or replaced by Reclamation. For relatively small raises of Shasta Dam, the existing TCD structure would be retrofitted to account for additional dam height, and to reduce leakage of warm water into the structure, but no new structure would be needed. However, modifications to, or replacement of, the existing structure are more likely to be necessary for increasingly higher dam raises. TCD modifications would support the objective of increasing the survival of anadromous fish populations by:

1. Increasing the ability of operators at Shasta Dam to meet downstream temperature requirements for anadromous fish,
2. Providing more flexibility in achieving desirable water temperatures during critical spawning, rearing, and out-migration, and
3. Extending the area of suitable spawning habitat farther downstream in the Sacramento River.

Objectives

- Fundamental objectives: Increase juveniles at Chipps Island per adult return and maintain minimum population during drought.
- Means objectives: Abundance and productivity

Conceptual Model (Each Species and Life stage)

Within the Sacramento River Winter-Run Chinook Salmon functions as a single population across (1) the river below Shasta Dam, (2) areas above Shasta Dam, and (3) within the Livingston Stone National Fish Hatchery (NMFS 2009).

Winter-Run Chinook Salmon spawn in the upper Sacramento River, extending from just below Keswick Dam to approximately 60 miles downstream to RBDD, though most spawning occurs within the first 10 miles below Keswick Dam (NMFS 2017).

Water temperature affects the rate of development of embryos and alevins (Rombough 1988; Beacham and Murray 1990) and temperature should not exceed 56°F (13.3°C) to avoid egg mortality (Myrick and Cech 2004). The amount of cold water available to achieve optimal temperature for this life stage varies as a function of the amount of cumulative precipitation, reservoir stratification, and previous Shasta Reservoir water operations.

Winter-Run Chinook Salmon fry begin to emerge from the gravel and start exogenous feeding from July–October (Fisher 1994). Optimal water temperatures for juvenile Chinook Salmon rearing range from 53.6°F –57.2°F (12–14°C). A daily average water temperature of 60°F (15.5°C) is considered the upper temperature limit for juvenile Chinook Salmon growth and rearing (NMFS 1997). Inhibition of Chinook Salmon smolt development in the Sacramento River may occur at water temperatures above 63°F (17.2°C; Marine and Cech 2004).

Current Condition

The seasonal operation of the TCD is generally as follows: during mid-winter and early spring the highest elevation gates possible are used to draw from the upper portions of the lake to conserve deeper colder resources. During late spring and summer, the operators begin the seasonal progression of opening deeper gates as Shasta Lake elevation decreases and cold water resources are utilized. In late summer and fall, the TCD side gates are opened to utilize the remaining cold water resource below the Shasta Powerplant elevation in Shasta Lake.

The seasonal progression of the Shasta TCD operation is designed to maximize the conservation of cold water resources deep in Shasta Lake, until the time the resource is of greatest management value to fishery management purposes.

The TCD can be used to selectively draw water from different depths within the lake, including the deepest, to help maintain river water temperatures beneficial to salmon. The TCD is effective in helping to reduce Winter-Run Chinook Salmon mortality in some critical years and for Fall- and Spring-Run Chinook Salmon in below normal water years (Reclamation 2015b). However, despite projections and modeling efforts in 2014, Shasta Reservoir ran out of sufficiently cold water in September 2014. After this point, insufficient cold water was available for release to the Sacramento River to manage temperatures. This lack of ability to regulate temperature was a primary factor contributing to the loss of 95% of the 2014 year class of wild Sacramento River Winter-Run Chinook Salmon (Reclamation 2015a).

Background

Construction of the TCD at Shasta Dam was completed in 1997. This device is designed to provide for greater flexibility in managing the cold water reserves in Shasta Lake while enabling hydroelectric power generation to occur and to improve salmon habitat conditions in the upper Sacramento River. The TCD is also designed to enable selective release of water from varying lake levels through the power plant to manage and maintain adequate water temperatures in the Sacramento River downstream of Keswick Dam (Reclamation 2015b).

Current Science

Currently, the Shasta TCD does not function adequately when reservoir levels are below the TCD shutters. A hindcast report issued in March 2015 by Reclamation (Reclamation 2015a) found that the Sacramento River temperature model used to model temperatures and operate the TCD slide gate to manage the cold water pool adequately represented the performance of the Shasta TCD before the side-gate was operational. However, it did a poor job at characterizing the TCD performance once the TCD side gate operation went into real-time effect. These model errors led to an excess expenditure of Shasta cold water pool in the summer of 2014, resulting in early depletion of cold water reserves and loss of temperature control in the river in September 2014. The condition still exists and is proposed to be addressed during the Shasta Dam Raise project (Reclamation 2015a).

Justification

Improving management of the cold water pool in Shasta Reservoir would help Reclamation maintain lower water temperatures into the fall, when they are needed for Winter-Run Chinook Salmon.

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D1.3.2.1.2 Lower Intakes near Wilkins Slough (Meridian Fish Screen)

Summary

Reclamation proposes to provide grants to water users to enable them to install new diversions that would be able to divert at lower flows. This would eliminate a significant restriction to Reclamation's ability to lower flows in the fall time frame to save cold water for the next year, and fix part of a problem that occurred in 2015.

Description

Due to temperature requirements, Sacramento River flows at or near Wilkins Slough can drop below the 5,000 cfs minimum navigational flow set by Congress. As many of the fish screens at diversions in this region were designed to meet the 5,000 cfs minimum, they may not function properly at the lower flows and as a result, not meet state and federal fish screening requirements during the lower flows (NCWA 2014). This could result in take of state and federally protected species that use this section of the river. This action would provide grants to water users within this area to install new diversions and screens that would operate at lower flows, which would allow Reclamation to have greater flexibility in managing Sacramento River flows and temperatures for both water users and wildlife, including listed salmonids (NCWA 2014).

Objectives

- Fundamental objectives: Increase juveniles at Chipps Island per adult return and maintain minimum population during drought.
- Means objective: Abundance

Conceptual Model (Each Species and Life stage)

Juvenile Sacramento River Winter-Run Chinook Salmon spend a varying duration of time rearing in the upper Sacramento River following emergence and before migrating past RBDD into the middle Sacramento River. Juveniles use the middle Sacramento River as a rearing habitat and a migratory corridor to the tidal Delta. The majority of Winter-Run Chinook Salmon juveniles migrate past RBDD from August to December (Poytress et al. 2014) and past Knights Landing at the downstream end of the middle Sacramento River between October and April (del Rosario et al. 2013). Entrainment at unscreened or ineffectively screened water diversions influences salmon survival through this reach.

Current Condition

The NMFS 2009 BO states that flows could be reduced to 3,250 cfs, which is lower than the Wilkins Slough flow requirement. If Reclamation reduced flows below the Wilkins Slough control point requirement and depending on the diversion rate, some screens may not meet the velocity criteria as designed and fish could become entrained, including state and federally listed species such as all life stages of Winter-Run Chinook Salmon.

Due to drought conditions in 2015, Reclamation relaxed the navigational flow requirement at Wilkins Slough to 3,800 cfs in February based on unprecedented warmer temperature within Shasta Reservoir and May 2015 modeling runs that indicated Shasta Reservoir would run out of cold water in mid-August. The resulting reduction in flow at Wilkins Slough potentially subjected fish to velocity criteria at the intake screens that did not meet the state and federal criteria of 0.33 feet per second (NCWA 2014).

Background

When Congress reauthorized the CVP under the Rivers and Harbors Act of 1937, it incorporated by reference and expressly required the implementation of a minimum flow of 5,000 cfs within the Sacramento River between Chico Landing and Sacramento. Congress has taken no subsequent action that has “discontinued” or otherwise changed this minimum navigation flow requirement.

The 1937 act also mandates that CVP "dams and reservoirs shall be used, first, for river regulation, improvement of navigation, and flood control; second, for irrigation and domestic uses; and, third, for power." (50 Stat. 844, 850.) In 1992, Congress explicitly amended this hierarchy of use by enacting CVPIA Sections 3406(a) and (b), which make protection of non-Endangered Species Act (ESA) listed fish and wildlife coequal priorities with irrigation. Even with this amendment, Reclamation's first priority remains river regulation, navigation and flood control.

On the Sacramento River, all major diversions have positive barrier flat-plate fish screens installed that provide protection to listed fishery species. These screens have been designed with an approach velocity of 0.33 feet per second as required by the NMFS and the CDFW.

During design, the screens, velocities, and diversion rates were based upon the Wilkins Slough navigational flow requirement of 5,000 cfs, as this requirement was under federal law.

Current Science

For California, the *Fish Screening for Anadromous Salmonids* (NMFS 1997) states:

- Approach velocity (velocity component perpendicular to the screen face) shall not exceed 0.33 feet per second for on-river screens and 0.4 feet per second for canals. Approach velocity shall be measured approximately three inches in front of the screen surface.
- Screen design must provide for uniform flow distribution over the surface of the screen, thereby minimizing approach velocity. This may be accomplished by providing adjustable porosity control on the downstream side of the screens.
- Sweeping velocity (velocity component parallel to the screen face) shall be greater than approach velocity

Justification

Improved diversion facilities would reduce take of endangered fish in the Sacramento River.

References

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D1.3.2.2 *Habitat*

D1.3.2.2.1 <u>Rearing Habitat</u>

Summary

Reclamation proposes to create approximately 40 to 60 acres of side channel habitat at no fewer than 10 sites in the upper Sacramento River.

Description

Reclamation proposes to create new side channels, modify existing side channels, and add instream habitat structure to increase rearing habitat for juvenile salmonids in the Sacramento. Habitat structure such as woody material and boulders would be incorporated into restoration designs. A total of 40 to 60 acres of spawning and rearing habitat would be created. The potential sites include Salt Creek, Turtle Bay Island, Kutras Lake Rearing Structures, Painter's Riffle maintenance, North Cypress maintenance, Cypress South, North Tobiasson Rearing Structures maintenance, Tobiasson Side Channel, Shea Side Channel, Kapusta Side Channel, Kapusta 1-A Side Channel maintenance, Kapusta 1-B Side Channel, Anderson River Park Side Channels, Cow Creek Side Channel, I-5 Side Channel, China Gardens, Rancheria Island Side Channel, Rancho Breisgau, Lake California Side Channel maintenance, Rio Vista Side Channel, East Sand Slough Side Channel, La Barranca Side Channel, Woodson Bridge Bank Rearing Improvement, Jellys Ferry, Dog Island, Altube Island, Blackberry Island, Oklahoma Avenue, Mooney Island, McClure Creek, Blethen Island, Wilsons Landing, McIntosh Island, Shaw, Larkins, Reilly Island, Hanson Island, and Broderick.

Floodplain and side channel habitat enhancements may consist of new or reconnected side channels and floodplain modifications that are designed to function under flows within the main channel ranging between 3,250 cfs to 7,000 cfs. Floodplain and side channel habitats will be created, reconnected, or modified by excavation using heavy equipment (i.e., bulldozer, front end loader, excavator). Where the excavated material is of the appropriate size distribution it would be sorted and placed into side channel or main channel areas to enhance habitat features. The fines would be distributed over the floodplain to assist in vegetating the area. Instream habitat structure (e.g., woody material such as, trees, trunks, rootwads, and willows; and variable sized large rocks) would be incorporated into the side channels to enhance habitat quality. The woody material would be held in place by partially burying it in the existing substrate or banks or keying into existing material to provide some stability under higher flows (Reclamation 2015)

Objectives

- Fundamental objective: Increase juveniles at Chipps Island per adult return
- Means objective: Abundance

Conceptual Model (Each Species and Life stage)

The salmonid life stage most affected by rearing habitat enhancements is the rearing and outmigrating juveniles. This life stage is addressed by the SAIL CM2 for Winter-Run Chinook Salmon (Windell et al. 2017). CM2 conceptualizes upper Sacramento River from fry rearing to outmigration of juveniles. Per the CM2 framework diagram (Figure 4 in Windell et al. 2017), geomorphology and bathymetry, which are greatly affected by side channel enhancements, is linked to the following environmental drivers for rearing and outmigration of juveniles: shallow water habitat and food production and retention. These drivers, in turn, are linked to the habitat attributes refuge habitat and food availability and quality. Note that refuge habitat provides protection from piscivorous fish. Per the narrative (page 10), “the channelized, leveed, and riprapped reaches of the Upper Sacramento River typically have low habitat complexity and low abundance of food organisms, and offer little protection from predators. Juvenile SRWRC are dependent on the function of … [high quality rearing] habitat for growth and … survival.”

Current Condition

Recruitment of large woody material to the river channel and floodplain has declined due to a reduction in bank erosion and blockage of wood transport by Shasta Dam. The upper Sacramento River has poor rearing habitat. The channelized, leveed, and riprapped river reaches and sloughs that are common in the Sacramento River system typically have low habitat complexity, have low abundance of food organisms, and offer little protection from either fish or avian predators. Juvenile life stages of salmonids are dependent on the function of this habitat for successful survival and recruitment. Some complex, productive habitats with floodplains remain in the system and flood bypasses (i.e., Yolo and Sutter bypasses), but the overall condition of riparian habitat for rearing juvenile salmonid is degraded (NMFS 2009).

Although significant efforts have been made to increase the quantity and quality of spawning habitats below the dams, minimal progress has occurred on rearing habitats. In the upper Sacramento River, the reach of the river in which most salmonids spawn, many of the ideal habitat characteristics for rearing are lacking (e.g., appropriate velocities and cover). Fry emerging from redds in the mainstem riverbed encounter a paucity of velocity and predator refugia (Vogel 2011).

Many habitat restoration projects have been recently implemented in the upper Sacramento River. The following are spawning and rearing habitat projects that were recently completed but will require annual maintenance: Kutras Lake Rearing Structures (RM 296), North Cypress (RM 295), North Tobiasson Side Rearing Structures (RM 292), Kapusta 1-A Side Channel (RM 288), and Lake California Side Channel (RM 270).

Background

Large amounts of rearing habitats for young salmon were lost in the upper Sacramento Valley basin when Shasta and Keswick Dams were built. Loss of this rearing habitat (located in smaller, shallower river channels upstream of the dams, such as the McCloud River) was considered one of the many reasons for the endangered listing of the Winter-Run Chinook Salmon. Since dam construction, young salmon emerging from mainstem spawning areas downstream of the dams must now contend with the severe rigors of a large, deep river channel. It is generally acknowledged that the quality of rearing habitats in those upstream areas was superior to habitats below the dams (Vogel 2011).

In 2014, the NMFS released the Central Valley Salmon and Steelhead Recovery Plan, which identifies two salmonid conservation principles: (1) recovery cannot be achieved without sufficient habitat and (2) species with restricted spatial distribution are at a higher risk of extinction from catastrophic environmental events. The plan identifies loss of riparian habitat, instream cover, and floodplain habitat affecting juvenile rearing and outmigration and places priority on restoring and maintaining riparian and floodplain ecosystems along both banks of the Sacramento River to provide a diversity of habitat types.

Current Science

Recent research using physical modeling experiments to guide river restoration projects yielded three restoration manuals (Stillwater Sciences et al. 2008). The purpose of the research project was to build state-of-the-art flumes and conduct a series of physical modeling experiments to address some of the fundamental and unresolved scientific questions underlying the river restoration strategies of gravel augmentation, dam removal, and channel-floodplain redesign. Three manuals (one for each of the three restoration practices) integrate results from laboratory experiments from this study with theoretical analysis, numerical modeling, and field case studies to produce scientifically based guidelines for assessing, implementing, and predicting the in-channel response of these common restoration strategies. The manuals are intended for use by restoration practitioners and managers.

A research effort entailing over a decade of river restoration field research on the Sacramento River has yielded new understanding of many river processes and new numerical models and decision analysis tools (TNC et al. 2008).

Justification

Floodplain and side channel habitats serve as important refuge and rearing areas for salmonids. Excavation and contouring activities to enhance floodplain and side channel habitats will create instantly available habitat for rearing by up to 15 acres per year (NMFS 2015).

Instream habitat structures such as woody material and boulders contribute to habitat diversity and create and maintain foraging, cover, and resting habitat for both adult and juvenile anadromous fish. Placement of instream woody material on the banks of the active channel will create instantly available habitat by creating diverse cover for juvenile rearing, and possibly for holding adults, by up to four acres each year (NMFS 2015).

The need for the action derives from the declines of naturally spawned salmonid stocks due in part to loss of spawning and rearing habitat through curtailment of gravel recruitment due to blockage of the river channel by dams and the alteration in flow patterns.

References

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D1.3.2.2.2 <u>Sutter Bypass</u>

Summary

Increasing inundation of the Sutter Bypass can increase food and floodplain habitat for listed salmonids, particularly Spring-Run Chinook Salmon. This component includes Tisdale Weir modifications to address fish passage deficiencies.

Description

Sutter Bypass is a floodplain off the east side of the Sacramento River between the Colusa and Verona area. Tisdale Weir releases overflow waters of the Sacramento River into the Sutter Bypass. The weir is fixed crest reinforced concrete and 1,150 feet long. A four-mile leveed bypass channel (Tisdale Bypass) connects the river to the Sutter Bypass. Typically, the Tisdale Weir is the first of the five weirs in the Sacramento River Flood Control System to overtop and continues to spill for the longest duration. Tisdale Weir is 30 years past its engineered life and in need of rehabilitation. As part of the Sacramento River Flood Control Project, the California Department of Water Resources (DWR) is investigating options for rehabilitation of the weir. The project also includes a fish passage facility. Options under consideration currently include an operable gate or a notch that would allow flow and fish to enter and leave the Sutter Bypass at lower Sacramento River elevations.

The Sutter Bypass provides valuable habitat for migrating adult salmon, particularly Spring-Run Chinook Salmon, to Butte Creek. Providing fish passage at Tisdale Weir would facilitate adult migration and increasing inundation of the Sutter Bypass would increase rearing habitat for juveniles.

Objectives

- Fundamental objectives: Increase juveniles at Chipps Island per adult return and maintain minimum population during drought
- Means objectives: Abundance and productivity

Conceptual Model (Each Species and Life stage)

There is a linkage to the Winter-Run Chinook Salmon CM for Spring-Run Chinook Salmon in the Sutter Bypass and Butte Creek. The Sacramento Valley Salmon Resiliency Strategy states the following links to the SAIL CM:

> Winter-run conceptual model of drivers affecting the transition from juvenile rearing in the Upper Sacramento River to migrating into the Middle River (CM2). Reduced access to and quality of non-natal rearing habitats limit food availability and production and lead to reduced fish growth and subsequent survival (H4).

Winter-run conceptual model of drivers affecting the transition from migrating adults to holding adults (CM6). Insufficient adult fish passage at flood bypass weirs combined with attraction flows leads to stranding risk and reduced fish survival, timing, and condition (H3). Winter-run conceptual model of drivers affecting the transition from juvenile rearing in the middle Sacramento River to migrating into the Bay-Delta (CM3). Lack of floodplain connectivity limits food availability and production and leads to reduced fish growth and subsequent survival (H4). (CNRA 2017)

Current Condition

Tisdale Weir is 30 years past its engineered life and in need of rehabilitation. It currently does not have upstream fish passage for fish to pass into the Sacramento River after overtopping events.

Background

Many projects have been implemented by federal, state, and local stakeholders to make structural improvements to Butte Creek that improve the numbers of Spring-Run Chinook Salmon returning to the creek to spawn. Improving habitat within the Sutter Bypass has been part of these efforts. In addition to upstream projects on Butte Creek, fish food production and holding habitat provided in the Sutter Bypass have addressed salmon needs for all lifecycle stages that occur in the creek. The result has been positive and returning adult numbers are now measured in the thousands (NCWA 2017).

Current Science

The 2017 Sacramento Valley Salmon Resiliency Strategy concludes that improvements to the fish passage and habitat in the Sutter Bypass would address the SAIL CM6 of drivers affecting the transition from migrating adults to holding adults and CM3 of drivers affecting the transition from juvenile rearing in the middle Sacramento River to migrating into the Bay-Delta (CNRA 2017).

Justification

Butte Creek provides spawning habitat for adult Spring-Run Chinook Salmon and the Sutter Bypass provides food supply and rearing and holding habitats for adult and juvenile salmon migration conditions to and from Butte Creek. The project is being funded by DWR, CDFW, and local agencies and is estimated to be complete by 2022 (CNRA 2017).

References

Northern California Water Association (NCWA). 2017. *Celebrating the Recovery of Spring-Run Salmon on Butte Creek.* Available: http://www.norcalwater.org/2017/06/15/celebrating-the-recovery-of-spring-run-salmon-on-butte-creek/.

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

D1.3.2.2.3 Putah Creek

Summary

Reclamation and DWR would work to realign the portion of Putah Creek within the Yolo Bypass to improve floodplain habitat and fish passage.

Description

Reclamation and DWR would complete stream realignment and floodplain restoration along the lower Putah Creek that also increases the available floodplain rearing habitat for juveniles. The realignment could include multiple channels in the Yolo Bypass Wildlife Area that would allow for increased rearing habitat on public land and reduce inundation of private lands to the south. The new alignment would connect to the Yolo Bypass Toe Drain (on the east side of the bypass) on the south side of Lisbon Weir (ESA 2016).

The proposal would differ from existing designs by increasing the channel size and number to allow for increased inundation in specific areas after overtopping events or through operation of the Yolo Bypass Salmonid Habitat Restoration and Fish Passage Project notch

Objectives

- Fundamental objective: Increase juveniles at Chipps Island per adult return
- Means objective: Abundance

Conceptual Model (Each Species and Life stage)

The objectives of the project target Fall-Run Chinook Salmon; however, Winter-Run Chinook Salmon, Spring-Run Chinook Salmon, and Steelhead would benefit from the restoration actions through increased freshwater tidal habitat and food web support.

Current Condition

NMFS RPA Action I.6.3 (Lower Putah Creek Enhancements) states that Reclamation and DWR shall complete stream realignment and floodplain restoration along the lower Putah Creek.

Background

Putah Creek restoration planning by the Yolo Basin Foundation (YBF) in close coordination with the CDFW was ongoing between 2012 and 2016. The current project description would create a new creek channel, restore tidal freshwater wetlands, provide a new water control structure to improve anadromous fish access, and restore in-stream habitat. Connectivity created between these habitats would improve migration and spawning opportunities for adult salmon, as well as rearing and outmigration conditions for smolts.

Current Science

In 2016, YBF completed the design of the new creek channel, the tidal wetland, two channel crossings, and alterations to the agricultural water supply infrastructure, and provided 30% design of a new water control structure. YBF previously identified the need for relocation of three petroleum product pipelines that intersect the proposed alignment of the new Putah Creek channel and held preliminary discussions with the respective pipeline owners regarding those relocations.

Justification

The Putah Creek realignment project would improve access for Fall-Run Chinook Salmon to spawning grounds, increase freshwater tidal habitat for salmonids, and improve rearing habitat in the Yolo Bypass through floodplain restoration.

References

ESA. 2016. *Draft Basis of Design Report, Lower Putah Creek Restoration Project, YBWA Reach*. Prepared for Yolo Basin Foundation.

D1.3.2.3 *Conservation Hatchery*

D1.3.2.3.1 <u>Conservation Hatchery</u>

Summary

Reclamation proposes to expand the Livingston-Stone National Fish Hatchery to increase Winter-Run Chinook Salmon production during drought years.

Description

Reclamation would expand the Livingston-Stone National Fish Hatchery, on the upper Sacramento River (at the foot of Shasta Dam). The expanded size would allow increased operation to sustain Winter-Run Chinook Salmon, particularly during drought years. Increased production during drought could help populations persist over multiple years.

Objectives

- Fundamental objective: Maintain minimum population during drought
- Means objective: Abundance

Conceptual Model (Each Species and Life stage)

Hatcheries provide artificial rearing and spawning habitat, and therefore, mitigate for losses at both adult and sub-adult life stages. Consequently, expanded hatchery production during drought could mitigate for losses across nearly all SAIL CM components. Nevertheless, specific effects of hatchery production on specific components will depend on potentially complex interactions among hatchery- and natural-origin fish and the environment. For example, if hatchery production effectively mitigates for lost rearing habitat but fails to mitigate for poor downstream migration (e.g., from elevated temperatures and dewatering associated with the drought) then the overall effect of hatchery production may not be effective. If released hatchery fish are clearly marked, however, the newly proposed monitoring framework described in Johnson et al. (2017) will generally allow for diagnosis of when (life stage) and where (geographic domain) expanded hatchery production provides (or fails to provide) a demographic boost to the population.

Current Condition

Current hatchery operations at LSNFH attempt to produce approximately 200,000 pre-smolts from at least 60 females of entirely natural origin. During extreme drought conditions, however, more juveniles (i.e., greater than 200,000) may need to be produced by fewer females that include hatchery-origin fish.

Background

The Sacramento River Winter-Run Chinook Salmon Evolutionarily Significant Unit (ESU) is listed as endangered under the ESA and currently includes only one naturally spawning population limited to the upper Sacramento River (below Keswick Dam). In 1997, Reclamation constructed the Livingston-Stone

National Fish Hatchery to propagate ESA-listed Sacramento River Winter-Run Chinook Salmon to partially mitigate for construction of Shasta Dam. Livingston-Stone National Fish Hatchery operates an "integrated" hatchery program, as opposed to a "segregated" program (NMFS 2017). The intention of integrated programs is to minimize genetic divergence between hatchery and natural components of the population by exchanging spawners between them (Paquet et al. 2011). The overall influence of the natural component on the entire population (i.e., the combined natural and hatchery components) depends on the proportion of hatchery-origin fish on the spawning grounds (pHOS) and the proportion of natural-origin fish in the broodstock (pNOB). The goal of LSNFH is to use entirely natural-origin adults for spawning (i.e., pNOB=1.00) and obtain at least 60 females and 120 males (NMFS 2017). These criteria may need to be adjusted to include hatchery-origin spawners and variable numbers of males and females under drought conditions.

Current Science

Because of increased hatchery production and poor in-river spawning success during 2014 and 2015, the spawning escapement for 2018 (the source of spawners for the hatchery) will likely contain mostly hatchery-origin fish. This will likely influence the pNOB objective of 1.00 (NMFS 2017).

Justification

Human-caused climate change has substantially increased the overall likelihood of extreme droughts in California (Williams et al. 2015). As water availability continues to decrease, it is likely that expanded hatchery production will be needed to mitigate for overall Winter-Run Chinook Salmon declines.

References

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D1.3.2.4 *Passage and Reintroduction*

D1.3.2.4.1 Sacramento Weir Fish Passage

Summary

Reclamation and DWR, in coordination with the USACE, would provide fish passage at Sacramento Weir.

Description

Sacramento Weir routes high flows from the Sacramento, Feather, and American rivers into the Yolo Bypass. The fish passage structure would allow adults to pass the Sacramento Weir into the Sacramento River, focusing on periods when conditions are not amenable for passage at Fremont Weir. This action would be done in coordination with the Lower Elkhorn Levee Setback project, which would widen and expand the Sacramento Bypass by moving the northern levee of the Sacramento Bypass Wildlife Area and a portion of the eastern levee of the Yolo Bypass

A structure at an expanded section of Sacramento Weir has the potential for a wider window of fish passage than at the Fremont Weir. Fish passage at Sacramento Weir could be amenable during additional months, lower flows, and when the river is at lower water surface elevations than existing conditions.

Objectives

- Fundamental objective: Increase juveniles at Chipps Island per adult return and maintain minimum population during drought
- Means objective: Abundance

Conceptual Model (Each Species and Life stage)

The action focuses on adult fish passage improvements in the Yolo Bypass for four federally listed anadromous species: the Sacramento River Winter-Run Chinook Salmon (*Oncorhynchus tshawytscha*); Central Valley Spring-Run Chinook Salmon (*Oncorhynchus tshawytscha*); and California Central Valley Steelhead (*Oncorhynchus mykiss*), which are collectively referred to as salmonids; and the Southern Distinct Population Segment (Southern DPS) of North American Green Sturgeon (*Acipenser medirostris*).

Current Condition

NMFS RPA Action I.7 states the need to reduce migratory delays and mortalities of federally listed fish species within the Yolo Bypass. Current proposals to replace Agricultural Road Crossing #4 at or near its current location to allow for improved fish passage while maintaining water impoundment for adjacent landowners.

Background

In 2018, Reclamation and DWR implemented the Fremont Weir Adult Fish Passage Modification Project, which replaced the existing fish ladder at Fremont Weir, removed an agricultural road crossing in the Tule Canal and replaced another crossing. These actions were taken to improve connectivity within the Yolo Bypass and between the Yolo Bypass and the Sacramento River.

Reclamation and DWR are also working on the Yolo Bypass Salmonid Habitat Restoration and Fish Passage Project which will add two additional passage structures at Fremont Weir and replace an agricultural road crossing.

Current Science

A number of modeling and research tools have recently been developed to assist in creating facilities to reduce stranding of fish in the bypasses. These include the following (Reclamation and DWR 2017; DWR 2017):

- YBPASS Tool combined with and HEC-RAS modeling to compare modeled water depths and velocities in the alternative-specific intake structures and transport channels to against adult Chinook Salmon and sturgeon fish passage criteria.
- Sedimentation and River Hydraulics – SRH-2D modeling along the Fremont Weir section of the Sacramento River to predict the hydrodynamics under the influence of various Fremont Weir notch configurations.
- Daily hydrodynamic TUFLOW modeling in the Yolo Bypass and Sacramento River downstream of Fremont Weir to evaluate hydraulic conditions in the Yolo Bypass and Sacramento River associated with changes in Sacramento River flows entering the Yolo Bypass at Fremont Weir.

Justification

This project would allow for fish passage at Sacramento Weir, which has a potential wider window of amenable fish passage than the Fremont Weir.

References

California Department of Water Resources (DWR). 2017. Yolo Bypass Salmonid Habitat Restoration and Fish Passage. Draft Environmental Impact Statement/Environmental Impact Report. December.

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D1.3.2.4.2 Juvenile Trap and Haul

Summary

During drought, Reclamation proposes to create juvenile collection weirs at key feasible locations after the spawning area on the Sacramento River and collect Winter-Run Chinook Salmon juveniles that were naturally spawned and trap and haul them down to the Delta to improve returns and maintain the population during severe droughts.

Description

Reclamation proposes implementation of a downstream trap and haul strategy for the capture and transport of juvenile Chinook Salmon and Steelhead in the Sacramento River watershed in drought years when low flows and resulting high water temperatures are unsuitable for volitional downstream migration and survival. Temporary juvenile collection weirs will be placed at key feasible locations, downstream of spawning areas in the Sacramento River. Collected fish will be transported to a safe release location in the Delta.

Juvenile trap and haul activities would occur from December 1 through May 31, consistent with the migration period for juvenile Chinook Salmon and Steelhead (NMFS 2014), depending on hydrologic conditions. In the event of high river flows or potential flooding, the fish weirs would be removed.

Objectives

- Fundamental objectives: Increase juveniles at Chipps Island per adult return and maintain minimum population during drought
- Means objective: Abundance

Conceptual Model (Each Species and Life stage)

The SAIL CM for the Rearing Juvenile to Outmigrating Juvenile life stage of Sacramento River Winter-Run Chinook Salmon identified water temperature as a Tier 3 Habitat Attribute affecting survival, residence time and migration, and condition of juvenile salmon in for the Upper River, Middle River, and Bay-Delta Reaches (Windell et al. 2017). Winter-Run Chinook Salmon juveniles begin to emigrate from the Upper Sacramento River (past RBDD) as early as mid-July, with peak abundance occurring in September and extending through November; although emigration can continue through May of the next year in dry water years. Since salmon experience high water temperatures in low water-type years, lethal water temperatures identified as a factor affecting survival through the Sacramento River in the SAIL CM. In addition, the presence or lack of accessible refugia from extreme temperatures, predators, and anthropogenic structures and diversions can decrease or increase risk of thermal stress, predation, stranding, and entrainment, thereby providing or depriving juvenile Chinook Salmon an opportunity to use and benefit from rearing and migratory habitats within the Sacramento River and Bay-Delta. Implementation of the proposed wild fish trap and haul program is anticipated to reduce the risk to salmon populations by high temperatures in the Sacramento River and tributaries. Although the SAIL CM has not been developed for Sacramento River Spring-Run Chinook Salmon and Steelhead, the SAIL CM applies to these species due to the close life cycle similarity and habitat attributes that affect survival; therefore, the benefits of the proposed wild fish trap and haul Program also directly applies to these populations as well.

Current Condition

Water delivery and hydroelectric operations on the Sacramento River and the resulting reduction or elimination of in-stream flows during migration periods has been identified as one of the threats to for Chinook Salmon and Steelhead habitat (NMFS 2014). Factors determining successful outmigration of Chinook Salmon and Steelhead include suitable water temperatures, adequate and timely flow for downstream movement, and a passable watercourse, none of which are available in low water years. The successful outmigration of juvenile salmon is critical for survival to adulthood and to support the restoration goals.

Background

During low hydrologic water-year types, low water conditions and high water temperatures exceeding salmon thermal tolerance limits will cause physical and environmental barriers to downstream migration and result in lower salmon survival. Under these conditions, instream flows are not sufficient to support juvenile salmon and Steelhead downstream migration, impeding volitional for fish emigrate and survival. River conditions remain largely impassable downstream and are not conducive to juvenile salmon survival. Thus, the CDFW currently transports juvenile hatchery Chinook Salmon downstream to release in areas in Sacramento River where conditions are suitable, in order to improve survival in draught years. Similar actions such as the trap and haul effort to transport fish downstream of these obstacles could improve survival of wild Chinook Salmon and Steelhead in the Sacramento River basin during draught years

Current Science

Trap and haul is a common strategy to manage Pacific coast salmonids, has been a solution to move fish around obstacles or in suitable habitat for decades, and has been studied extensively in the Columbia River basin (Lusardi and Moyle 2017). Recently, the success of downstream trap and transport of juvenile salmonids using temporary weir has been studied in the San Joaquin River as a feasible option to improve survival in low flow years (SJRRP Program 2016).

Justification

Outmigration of juvenile salmon is critical for survival to adulthood. During low water years, river conditions are largely impassable downstream and are not conducive to juvenile salmon survival. Therefore, the implementation of a juvenile trap and haul strategy is a prudent action to improve survival in drought years.

References

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D1.3.2.5 *Diversion Screening*

D1.3.2.5.1 Sacramento River Man Made Structures – Keswick to Verona

Summary

This component would implement projects for structural habitat improvements from Keswick to Verona.

Description

Reclamation and the Sacramento River Settlement Contractors (SRSC) propose to complete remaining high-priority fish screen projects in this reach of the Sacramento River. Reclamation and the SRSC propose to reduce lighting to 3 lux or less at fish screens and bridges within 5 years. The SRSC propose to incorporate ongoing redd dewatering coordination with Anderson Cottonwood Irrigation District. The SRSC also propose to address fish passage issues at Weir 1 and Weir 2 in the Sutter Bypass within 5 years.

Specific projects may include: reduced lighting at Sacramento River fish screens, reduced lighting at Sacramento River bridges; Sutter Bypass Weir 1 - Rehabilitation of weir structure and fish ladder (Coupled with new Lower Butte / Sutter Bypass water management plan); Sutter Bypass Weir 2 Multi Benefit Project; Screen Meridian Farms Water Company; Screen Natomas Mutual Water Company; and, Anderson Cottonwood Irrigation District Dam operations to protect salmon redds.

Objectives

- Fundamental objective: Increase juveniles at Chipps Island per adult return
- Means objectives: Abundance and productivity

Conceptual Model (Each Species and Life stage)

Stable and continuous river flows are important to the early life history (egg incubation to emergence from the gravel) of salmonids. If redds are dewatered or exposed to warm, deoxygenated water, incubating eggs/larval fish may not survive. After emergence from their redd, juvenile salmon can become stranded in shallow isolated water and be exposed to poor environmental conditions as well as increased predation.

Fish screens focus on protecting juvenile fish from entrainment during out migration. Juvenile Sacramento River Winter-Run Chinook Salmon spend a varying duration of time rearing in the upper Sacramento River following emergence and before migrating past RBDD into the middle Sacramento River. Juveniles use the middle Sacramento River as a rearing habitat and a migratory corridor to the tidal Delta. The majority of Winter-Run Chinook Salmon juveniles migrate past RBDD from August to December (Poytress et al. 2014) and past Knights Landing at the downstream end of the middle Sacramento River between October and April (del Rosario et al. 2013). Entrainment at unscreened or ineffectively screened water diversions influences salmon survival through this reach.

Current Condition

The Sacramento Valley Salmon Recovery Program includes high priority fish screens on the Sacramento River, including the Meridian Mutual Water Company and Natomas Mutual Water Company screens. Both projects had finished design and environmental documentation and were waiting for funding. With the completion of these projects, all of the original high-priority diversions in the region will be screened.

Anderson Cottonwood Irrigation District Dam creates a deep water pool in the Sacramento River in Redding (RM 298). An additional management action taken to protect these upstream Winter-Run Chinook Salmon redds was to request that the dam be kept in place until November 2, to prevent dewatering of those redds above the dam. The seasonal flashboard dam is normally taken out in October but by keeping the dam in place through November redds upstream remained flooded, allowing Winter-Run Chinook Salmon juveniles the opportunity to emerge without difficulties.

Background

CDFW, DWR, and other Settling Parties developed an Agreement Framework for analysis, adoption and implementation of voluntary agreements to support amendments to the Bay-Delta Water Quality Control

Plan for protection of fish and wildlife beneficial uses (CDFW and DWR 2018). The agreement includes habitat improvement and other non-flow measures.

Current Science

Fish exclusion screens and protection devices are a common strategy for reducing entrainment risk of a threatened juvenile fish species while maintaining water-diversion activities. The design and success of a fish screen facility is dependent on a number of factors, such as fish species, swimming ability, and hydraulic conditions. Guidance documents for the placement and design of fish screens are provided below.

- Designing Fish Screens for Fish Protection at Water Diversions (NMFS)
- Fish Screening Passage for Anadromous Salmonids (NMFS)
- Fish Protection at Water Diversions: A guide for planning and designing fish exclusion facilities. (Reclamation)
- California Department of Fish and Wildlife Fish Screening Criteria (CDFW)

Observations for the Sacramento River below Keswick during the 2016–2017 and prior years indicate that oscillating river flows have the potential to dewater redds and strand juvenile salmonids repeatedly in the same locations. Juvenile salmon move between shallow, slow moving waters to rest between venturing into swifter food carrying waters. This tendency makes them particularly susceptible to stranding as flows recede isolating the shallow river margin areas. During typical winter dry periods with steady or decreasing tributary inputs, small flow changes (up or down) from Keswick Dam can result in repeated flooding and dewatering of pool and side channels throughout the upper Sacramento River. The 2016–2017 season experienced significant winter rain events that resulted in flooding and major tributary stream influences. Although the increased tributary inputs substantially reduced redd dewatering below Clear Creek, many stranding sites became inundated then swiftly isolated as floods receded. These flood events combined with decreased Keswick flow releases resulted in the bulk of observed stranded juvenile salmonids (Revnek et al. 2017).

Justification

The actions within this component would reduce stranding, entrainment, and predation of juvenile salmonids.

References

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D1.3.3 American River Basin

D1.3.3.1 *Water Operations*

D1.3.3.2 *Temperature Facility Improvements*

D1.3.3.2.1 Drought Temperature Management

Summary

In severe or worse droughts, Reclamation proposes to modify the TCD shutters so that they are automatic to operate and fix the leaks on the existing Folsom TCD by installing seals, such as vertical rubber J-seals or bulb-seals, that close the interface between the panel sides and panel guides. Horizontal seals are also required, consisting of J-seals or bulb-seals that close the interface between the lowest panel and the sill and between contiguous panels.

Description

Water temperature conditions in the lower American River are often sub-optimal for recovery and enhancement of native salmonid species. Folsom Dam operations, coupled with the existing Folsom TCD are used during the spring, summer, and autumn to selectively withdraw stratified cold water impounded by Folsom Dam for the benefit of these salmonid species. However, the current TCD is not adequate to provide optimal thermal conditions (TCI 2014). Modifications of the TCD at Folsom Dam would improve lower American River thermal conditions and help meet temperature requirements in the lower American River.

Objectives

- Fundamental objective: Increase juveniles at Chipps Island per adult return
- Means objectives: Abundance and productivity

Conceptual Model (Each Species and Life stage)

The SAIL CM considers different factors that affect salmonids. Within the LAR, the amount of cold water available to achieve optimal temperature for each life stage varies as a function of the amount of cumulative precipitation, reservoir stratification, and previous Folsom Reservoir water operations. Maintaining adequate maximum river temperatures is key to sustained immigration, spawning, and incubation of Fall-Run Chinook Salmon and Steelhead within the LAR (Bratovich et al. 2012).

Current Condition

Folsom Dam was designed to be able to release water from various elevations within the reservoir simultaneously. Dam operators modify TCD shutters on each of the three powerhouse generation penstocks to take water from different depths in the reservoir and blend outflows in order to meet downstream regulatory temperature requirements/targets. Operators also adjust the elevation of the

Municipal Water Supply Intake and operate the low-level outlets on the dam to modify outflow water temperatures and preserve cold water resources in the reservoir.

The existing shutter system leaks through gaps between the shutter guides and the superstructure, gaps in the superstructure itself, gaps between contiguous shutter gangs, and gaps between the lowest shutter and the sill. The leakage has been estimated to range from 20% to 40% of the flow through the TCD, which reduces the effectiveness in thermal management (TCI 2014). Additionally, the current shutter lifting system of the TCD would be modified to operate mechanically so that shutter locations can be modified in minutes without shutting down the Folsom power plant.

Background

The repair of the Folsom TCD is in part an extension of the requirements contained in the NMFS 2009 BO (Reasonable and Prudent Alternative) that require Reclamation to identify and evaluate structural solutions to the cold water pool issues in the lower American River.

Later in 2007, there were more studies that focused on modeling efforts (four models: Nimbus Tail water, Lake Natoma/Nimbus Dam, Nimbus Dam forebay and Folsom Lake) that recommended potential structural and operations changes that could lead to a temperature benefit (i.e., cooling of Folsom Dam releases, cooling of Nimbus Dam releases, or a reduction in Folsom Dam releases resulting from an increased cold water balance in the system).

Current Science

A 2014 value planning study (TCI 2014) analyzed potential temperature solutions at Folsom Dam and Reservoir. The purpose of the study was to identify, preliminarily evaluate and develop infrastructure-related alternatives, or a combination of infrastructure-related alternatives at Folsom Dam and Reservoir, that will best improve water temperature management capabilities in the lower American River. There was also an emphasis in trying to tie into efforts already underway under U.S. Army Corps of Engineers authority (the ecosystem restoration component of the Folsom Dam Raise authority) which directs the U.S. Army Corps of Engineers to mechanize and reconfigure the Folsom Dam temperature shutters. This project is a combination of 2 Alternatives (Leak Reduction and TCD mechanization) analyzed within the study.

Justification

Improving the TCD would improve Reclamation’s ability to manage temperatures in the Lower American River for Central Valley Steelhead (summer rearing) and Fall-Run Chinook Salmon (fall spawning).

References

Bratovich, P., C. Addley, D. Simodynes, and H. Bowen. 2012. *Water Temperature Considerations for Yuba River Basin Anadromous Salmonid Reintroduction Evaluations*. Prepared for Yuba Salmon Forum Technical Working Group.

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D1.3.3.3 *Habitat*

D1.3.3.3.1 Rearing Habitat

Summary

Reclamation proposes to conduct a restoration project at William Pond Outlet to create rearing habitat.

Description

The lower American River currently provides rearing habitat for Fall-Run Chinook Salmon and Steelhead. Recent evidence suggests the lower American River may also be used for rearing by juvenile Winter-Run Chinook Salmon that spawn in other nearby rivers (Phillis et al. 2018). This component focuses on restoring rearing habitat William Pond Outlet, where the bed is too fine for spawning. Similar to previous restoration projects on the lower American River (e.g., cbec 2015), the project could involve using large woody debris structures, side channel construction, and bar reshaping to improve rearing habitat and floodplain inundation.

Objectives

- Fundamental objective: Increase juveniles at Chipps Island per adult return
- Means objective: Abundance

Conceptual Model (Each Species and Life stage)

Increased rearing habitat would improve Fall-Run Chinook Salmon, Winter-Run Chinook Salmon, and CV Steelhead escapement from the lower American River by increasing the survival of juveniles through increased refuge during high flows, food availability, and cover from predators. This component addresses SAIL middle river juvenile hypothesis refuge habitat (H3) and the large woody debris structures and altered bar morphology might also affect food availability and quantity (H4) (Windell et al. 2017).

Current Condition

Reclamation has been building rearing habitat intermittently since 2007 in coordination with other restoration projects. Thus far, Reclamation has created roughly 5.5 acres of habitat in the lower American River. Constructing rearing habitat alongside spawning habitat has been a successful approach for Reclamation, but potential rearing habitat could be built downstream of River Bend where the river becomes sand bedded.

Background

Rearing habitat in the lower American River has been constrained by a legacy of land use in the watershed. Nineteenth century hydraulic mining caused widespread aggradation (James 1997) that was subsequently dredger mined, resulting in channel simplification and disturbed and disconnected floodplains (RCMP 2002). Levees and bank revetment confine the channel, particularly downstream of River Bend, further disconnecting the floodplain from the channel. The construction of Nimbus and Folsom dams decreases winter discharge and intercepted all large woody debris and coarse sediment supplied from upstream, leading to further habitat simplification. The dams also limited access to extensive spawning and rearing habitat upstream. Taken together, this land use history limits salmonid habitat in the lower American River and improving rearing habitat requires placing large woody debris structures and bar and floodplain regrading downstream of Lake Natoma.

Current Science

Restoration actions that increase floodplain inundation by bar reshaping during gravel augmentation and increased side channel habitat have increased rearing habitat in the lower American River. The CVPIA Science Integration Team assumes that two large Chinook emigrants will be produced per square meter (10.8 square feet) of rearing habitat (Reclamation and USFWS 2018). Existing gravel augmentation projects in the lower American River have improved connectivity and inundation of the floodplain, and juvenile abundance of fall Chinook Salmon and Steelhead (Sellheim et al. 2015). Gravel projects have increased the density of fish in side channel habitat's from less than 3 juvenile salmon per 25 square meters to more than 82 juvenile salmon per 25 square meters. An experimental release of juvenile Chinook Salmon from the Sunrise boat launch suggested that juvenile survival was on average 94% through the lower American River but that survival decreased once the juveniles entered the Sacramento River and the Delta (Zeug 2016).

Justification

Increasing the extent of rearing habitat in the lower American River is explicitly called for in CVPIA Section 3406 (b)(13) to partially mitigate for CVP impacts through impaired habitat in the lower American River and lack of access to habitat upstream of Nimbus Dam. Channel simplification and trapping of large woody debris and gravel upstream of Nimbus and Folsom dams has decreased the quality and extent of juvenile rearing habitat in the lower American River. Increased rearing habitat availability should increase smolt survival (Windell et al. 2017).

References

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D1.3.4 Bay-Delta

D1.3.4.1 *Facility Improvements*

D1.3.4.1.1 Delta Cross Channel Improvements

Summary

Reclamation proposes to improve operations of the DCC by modernizing the gate materials/mechanics together with more comprehensive control systems to allow more frequent operation (e.g., tidally), in association with increased monitoring.

Description

The DCC is more than 65 years old and its gates rely on remote operators to travel to the facility to change their position. When the gates are open, they provide a critical diversion structure for freshwater reaching the CVP South Delta pumping station. The gates are closed to prevent scouring (during high flows), reduce salinity intrusion in the western Delta, and protect Sacramento River ESA-listed and non-listed salmonids. Frequent use of the DCC increases its risk of failure. Opening the DCC more frequently decreases salinity at Jones Pumping Plant and reduces the amount of outflow required to meet salinity requirements and therefore is desired. In particular, increasing the flexibility to operate the gates diurnally (closed in the evening and open during the day) could offer fish protection while also providing water quality and water supply benefits. Although this matter has been discussed by agencies and stakeholders it has not been attempted due to recent mechanical concerns and ongoing risks at the facility. Reclamation proposes to modernize DCC's gate materials and mechanics to include adding industrial control systems, increasing additional staff time, and improve physical and biological monitoring associated with the DCC daily and/or tidal operations as necessary to maximize water supply deliveries.

Objectives

- Fundamental objective: Increase juveniles at Chipps Island per adult return
- Means objective: Abundance

Conceptual Model (Each Species and Life stage)

The SAIL CM4 for Winter-Run Chinook Salmon (Windell et al. 2017) pertains to rearing to outmigrating juveniles in the Bay-Delta and is also pertinent to Steelhead and Spring-Run Chinook Salmon from the Sacramento River basin. Per the SAIL model (Windell et al. 2017, p.23): "Human modification of the Delta has resulted in a channel network that no longer operates across predictable gradients for native fish and provides unnatural cues and routes for migration. In the interior Delta, longer travel times and lower survival have been documented." Closure of the DCC reduces juvenile salmonid entry into the interior Delta, thereby potentially reducing the risk of longer travel time and lower survival. In addition, the SAIL CM6 for Winter-Run Chinook Salmon describes potential effects on adult migration from the ocean to the upper Sacramento River, noting that "Natural and artificial barriers can delay the upstream passage and increase energetic costs to migration for salmon" and that "Water operations can influence the routing of Upper Sacramento River-origin water…and can create false attraction cues that cause salmon to deviate from the mainstem Sacramento River migration corridor" (Windell et al. 2017, p.30). Although these linkages are provided primarily in consideration of potential effects from stranding in the Yolo Bypass at Fremont Weir, they are relevant in consideration of the DCC and for fish returning to the Sacramento River, as well as to the San Joaquin River and Mokelumne River basins.

Current Conditions (RPA, WQCP, Facility)

DCC gate operations are primarily governed by NMFS RPA Action IV.1.2 and by the terms of the Bay-Delta Water Quality Control Plan (implementing D-1641). In summary, the DCC gates are closed between February 1 and May 15. From October 1 to November 30, the DCC gates may be closed based on exceedance of salmon monitoring density triggers and in consideration of meeting water quality criteria (Figure D1.3-1, Summary of NMFS RPA Action IV.1 for Delta Cross Channel Operations). From December 1 to December 14, the DCC gates are closed, except with approval from NMFS for salmon migration experiments, or to meet water quality criteria (in consideration of salmon monitoring density trigger values). From December 15 to January 31, the gates are also generally closed, with short-term exceptions for NMFS-approved experiments or to maintain Delta water quality in association with reduced south Delta exports. From May 16 to June 15, the DCC gates may be closed for up to 14 days (consistent with D-1641) if NMFS determines it is necessary. In addition to management as a result of the NMFS RPA and D-1641, whenever flows in the Sacramento River at Sacramento reach 20,000 to 25,000 cfs (on a sustained basis) the DCC gates are closed to reduce potential scouring and flooding that might occur in the channels on the downstream side of the gates (USFWS 2008). The WIIN Act requires the Interior and U.S. Department of Commerce (Department of Commerce) to "in close coordination with the DWR and the CDFW, implement a pilot project to test and evaluate the ability to operate the Delta cross-channel gates daily or as otherwise may be appropriate to keep them open to the greatest extent practicable to protect out-migrating salmonids, manage salinities in the interior Delta and any other water quality issues, and maximize CVP and SWP pumping, subject to the condition that the pilot project shall be designed and implemented consistent with operational criteria and monitoring criteria required by the California State Water Resources Control Board" (Public Law 114–322 130 stat. 1851).

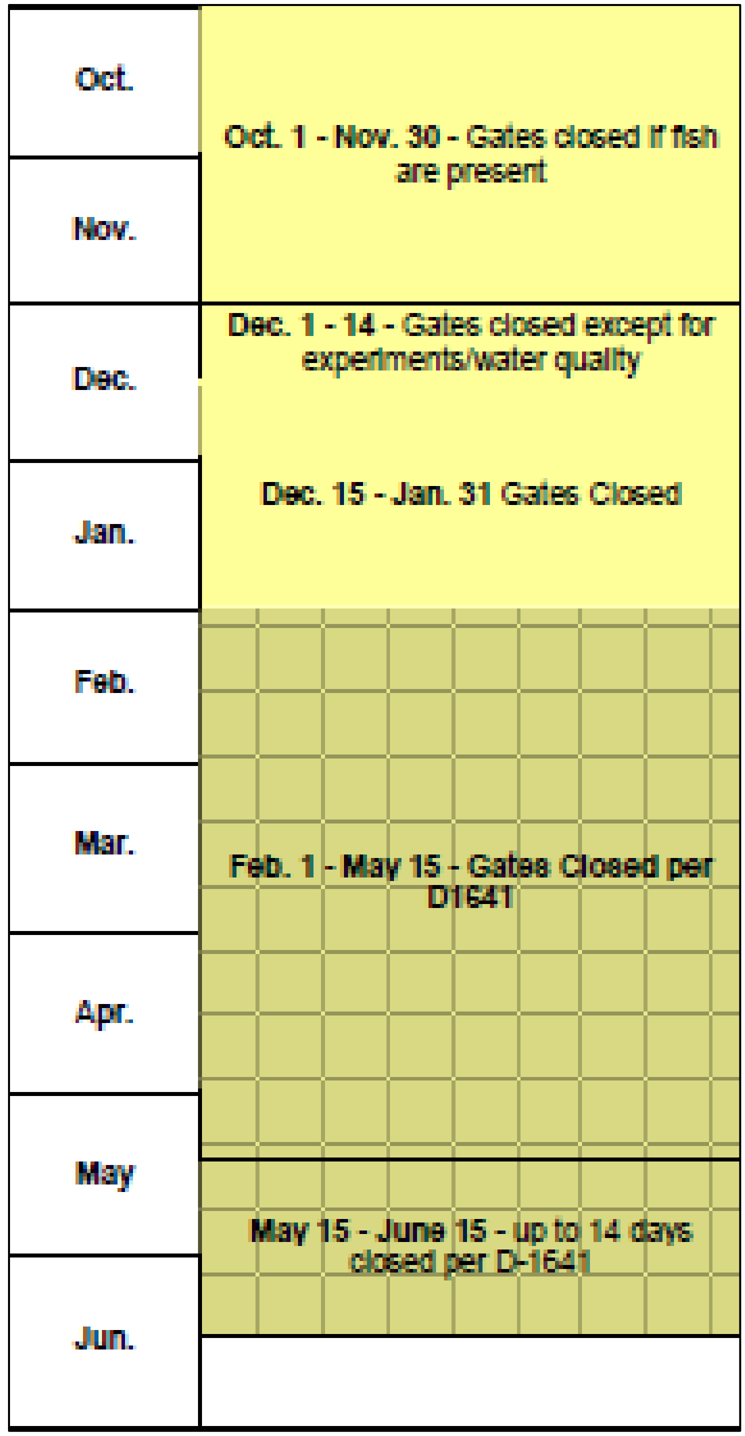

Figure D1.3-1. Summary of NMFS RPA Action IV.1 for Delta Cross Channel Operations (NMFS 2009)

Background (Old Science, Past Implementation, If Any)

The basis for DCC operations is largely from studies showing that survival of Sacramento River basin juvenile salmonids through the Delta generally is greater when the DCC is closed (e.g., Newman 2003). Survival through the interior Delta via the DCC generally has been shown to be lower than for fish migrating through north Delta channels (Sutter Slough, Steamboat Slough, and the Sacramento River) (e.g., Perry et al. 2010; Perry et al. 2012). Management since implementation of the 2009 NMFS RPA has resulted in DCC closures primarily in December-May, with closures in October through November, ranging from 0 to 18 days, and closures in June, ranging from 8 to 30 days (Table D1.3-1).

Table D1.3-1. Number of Days of Delta Cross Channel Gate Closure, October–June, Water Years 2010–2010

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
2010	4	9	18	31	28	31	30	27	14
2011	2	3	31	31	28	31	30	31	30
2012	10	0	31	31	29	31	30	24	20
2013	0	4	31	31	28	31	30	27	8
2014	13	13	31	31	19	31	30	27	9
2015	2	5	31	31	28	31	30	20	13
2016	1	3	20	31	29	31	30	27	11
2017	0	10	31	31	28	31	30	31	22
2018	18	17	31	31	28	31	30	27	8

Source: http://www.usbr.gov/mp/cvo/vungvari/Ccgates.pdf.

Current Science Related to Idea/Topic

Recent studies of acoustically tagged juvenile Chinook Salmon have shown that these fish tend to migrate at night and therefore tend to arrive at the DCC at night: although night made up 63% of the study period (November11, 2008 to February 3, 2009) and 61% of fish were released at night, 83% of fish arrived at the DCC at night (Plumb et al. 2016). These authors concluded that "Given that tidal effects and night-time fish arrival will be high when river flows are low, nighttime closure and daytime opening of the DCC during the winter months may represent one of the rare instances when operational changes may be used to minimize fish mortality and allow for water diversion."

Justification for Action

This action will increase flexibility in DCC operations, allowing greater opening frequency and therefore improving interior Delta water quality by reducing salinity. This will decrease salinity at Jones Pumping Plant and reduce the amount of Delta outflow necessary to meet D-1641 salinity requirements.

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D1.3.4.2 *Habitat*

D1.3.4.2.1 Predator Hotspot Removal (including Old River Habitat Improvements)

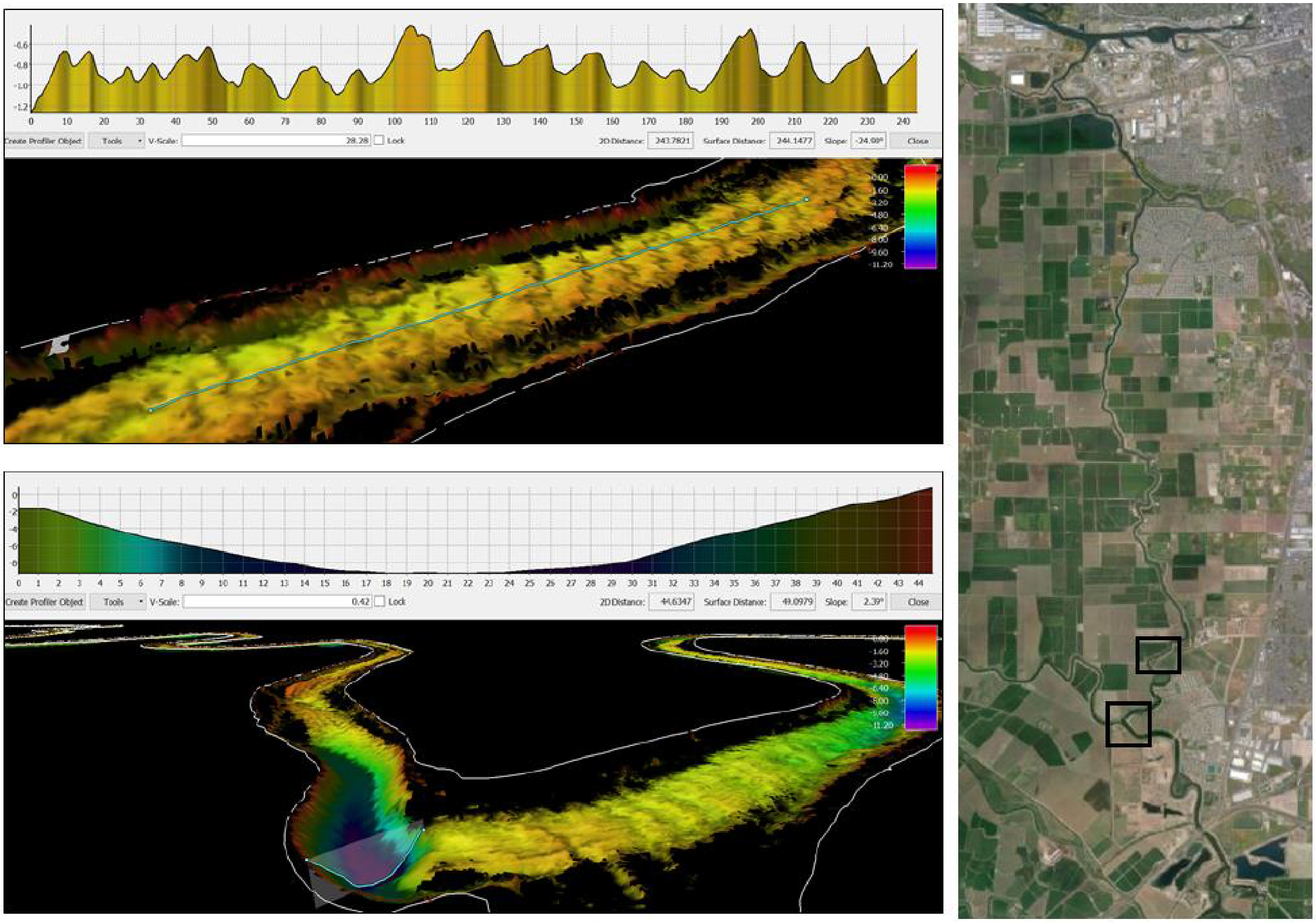
Summary

Reclamation and DWR propose to fill the scour hole near the Head of Old River in order to remove the predator hotspot. In addition, reconfiguration of the San Joaquin River–Old River junction area will be considered in order to increase passage down the San Joaquin River.

Description

Reclamation and DWR propose to fill the scour hole in the San Joaquin River just downstream of its junction with the Head of Old River. The scour hole is over 30 feet deep (Figure D1.3-2, Bathymetry of the Scour Hole at the Head of Old River [Lower Left Figures] and An Additional Location Further Downstream [Upper Left Figures]) and would be filled with sufficient materials such as rip rap in order to achieve a river bottom elevation similar to the remaining bathymetry of the junction. Substrate composition would be monitored to examine the extent to which spaces between the rip rap had been infilled with sediment from upstream to ensure that benthic predator ambush habitat was not created; surveys for predatory fish (e.g., with sonar imaging cameras) would also be undertaken to support this evaluation. To the extent necessary, interstitial spaces between the larger substrates (e.g., rip rap) used to fill the scour hole would be filled with additional small-diameter substrates if natural filling with sediment from upstream had not progressed to a satisfactory level. Detailed geotechnical investigations and modeling would be undertaken in order to ensure that filling the scour hole does not compromise flood protection. As such, based on the results of the modeling analysis, additional levee reinforcement would be undertaken as necessary in coordination with the appropriate authorities (e.g., Reclamation Districts 544, 2062, and 17, and others).

In conjunction with filling the scour hole, Reclamation and DWR propose to also investigate potential reconfiguration options for the entire junction area. One potential configuration that has been the subject of a pre-feasibility study is to modify the existing Y-shaped split between the San Joaquin River and Old River to create a new channel intended to keep most juvenile salmonids in the San Joaquin River as opposed to entering Old River (Figure D1.3-3, Potential Reconfiguration at the Junction of the San Joaquin River and the Head of Old River). In this concept, a new channel and 200-year flood levee would be constructed, and the new floodplain and upland habitat would be created by setting back the existing levee on the right bank of the San Joaquin River. A flood weir would be constructed in the San Joaquin River at the south end of the newly diverted channel in order to ensure that flows remained in the river under most flow conditions for which the existing Head of Old River Barrier (i.e., less than 10,000 cfs at Vernalis). A flood weir would be placed in the San Joaquin River at the northern end of the new channel to restrict flood flow and fish from entering the south Delta through Old River. The flood and training weirs would be overtopped during river flood flows. This reconfiguration represents one possibility for the junction that Reclamation and DWR may investigate further.



Source: Cutter et al. 2017. Notes: Elevations are in meters in relation to North American Vertical Datum of 1988 (NAVD 88). The Head of Old River bathymetry figure in the bottom left is oriented moving from upstream on the right to downstream on the left, with the Old River junction at the bottom of the figure.

Figure D1.3-2. Bathymetry of the Scour Hole at the Head of Old River (Lower Left Figures) and An Additional Location Further Downstream (Upper Left Figures)

Source: Stantec 2017.

Figure D1.3-3. Potential Reconfiguration at the Junction of the San Joaquin River and the Head of Old River

Objectives

- Fundamental objective: Increase juveniles at Chipps Island per adult return
- Means objective: Abundance

Conceptual Model (Each Species and Life stage)

Although Winter-Run Chinook Salmon juveniles would not occur at the Head of Old River junction, the SAIL CM generally describes the issue of the "extremely poor survival rate in the South Delta, which is hypothesized to result from poor rearing conditions (such as low refuge habitat and food availability) and high predation risk" in affecting the transition from rearing to outmigrating juveniles (Windell et al. 2017, p.22). Features such as scour holes are bathymetric landscape attributes, which influence the amount of shallow water habitat as an environmental driver and therefore predation as a habitat attribute acting on survival of juvenile salmonids, per SAIL CM4 (Windell et al. 2017, p.24).

Current Conditions (RPA, WQCP, Facility)

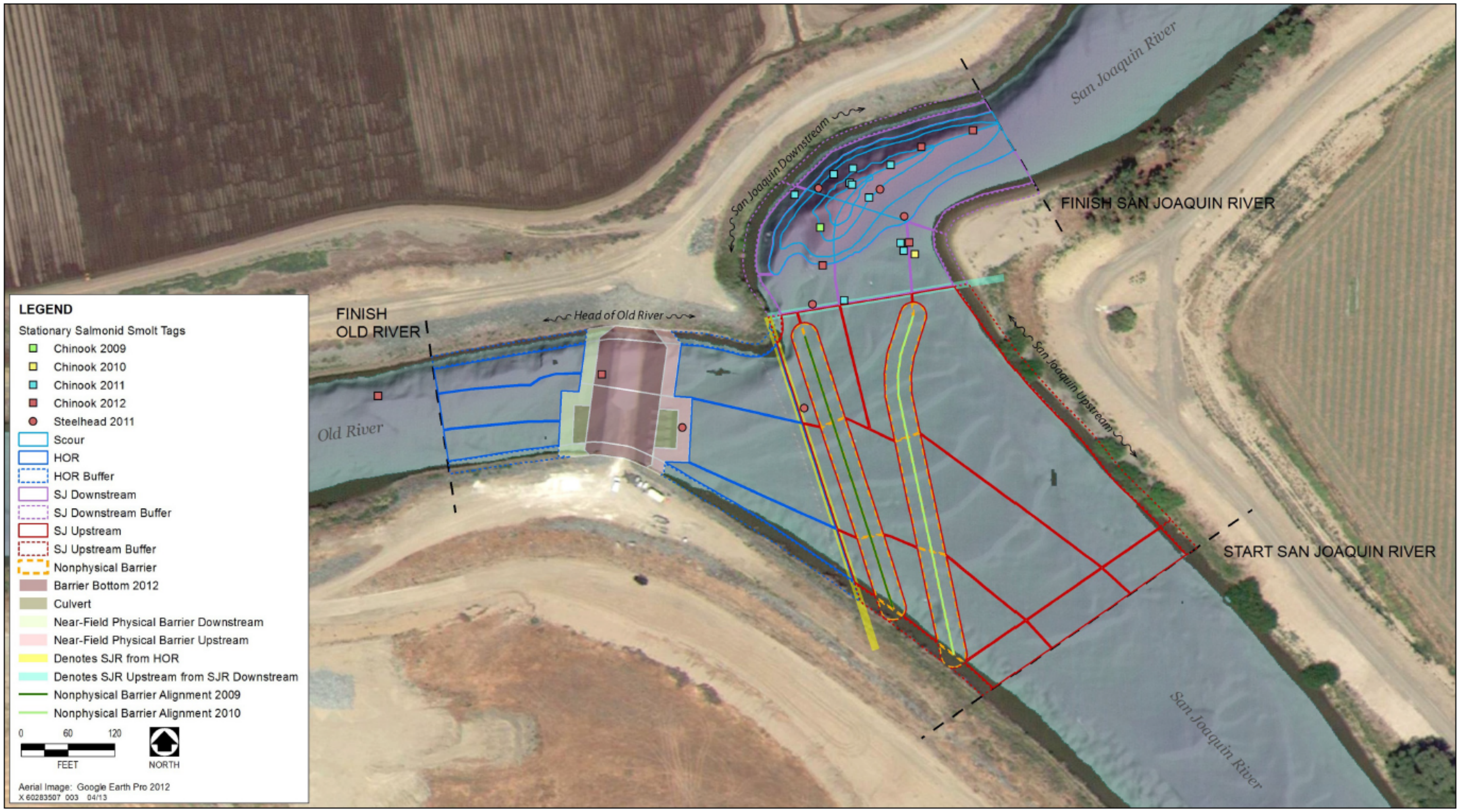
Action IV.1.3 of the NMFS RPA directs DWR and Reclamation to consider engineering solutions for further reducing diversion of emigrating juvenile salmonids to the interior and southern Delta. Action IV.1.3's objectives include preventing emigrating juvenile salmonids from entering channels in the south Delta, including Old River, that increase entrainment risk to Steelhead migrating from the San Joaquin River through the Delta. Investigations in support of Action IV.1.3 have highlighted the importance of predation in the scour hole just downstream of the Head of Old River as an impediment to effective implementation of barriers installed at the Head of Old River to reduce entry into Old River (DWR 2015).

Background (Old Science, Past Implementation, If Any)

The importance of the scour hole and the Head of Old River as a predator and predation hotspot was originally suggested by Vogel (2007, 2010; as cited by SJRGA 2011). This inference was made by detection of many stationary acoustic tags originally implanted in juvenile Chinook Salmon, indicating that the tags had been consumed by predators and defecated in the scour hole. Large concentrations of fish in deep holes have been observed in other locations in the Delta, such as Horseshoe Bend in the Sacramento River (Miranda et al. 2010).

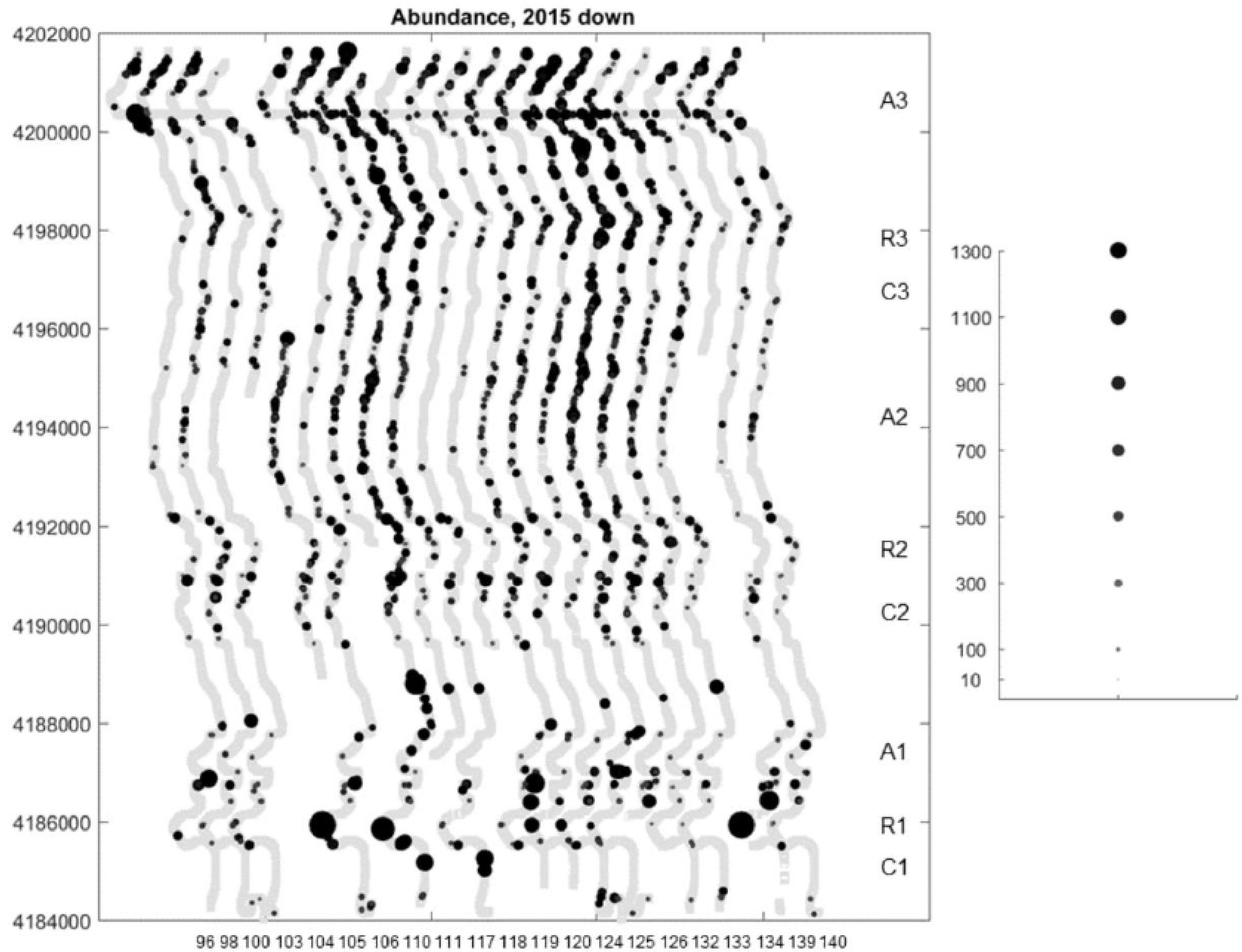
Current Science Related to Idea/Topic

Recent studies have confirmed that the scour hole at the Head of Old River is an area of high predation and high predator abundance. DWR (2015) found high predation (10–40%) of juvenile Chinook Salmon and Steelhead entering the junction and hydroacoustic surveys showed that predator density was high in the scour hole. Consistent with Vogel (2007, 2010; as cited by SJRGA 2011), stationary acoustic tags that were originally implanted in juvenile salmonids were found to occur in high number in or near the scour hole, indicating consumption and defecation by predators (DWR 2015; Figure D1.3-4, Locations of Stationary Juvenile Salmonid Acoustic Tags at the Head of Old River, 2009–2012). Relative to other locations in the San Joaquin River between Lathrop and Stockton, the abundance of predators at the scour hole can be relatively high, although not always so (Cutter et al. 2017; Figure D1.3-5, Abundance of Predatory Fish in the San Joaquin River between Lathrop (South End of Map) and Stockton (North End of Map), As Estimated by Downward Pointing Hydroacoustic Surveys). Assessment of survival of juvenile Chinook Salmon tethered to predation event recorders (Demetras et al. 2016) in various study reaches in the San Joaquin River between Lathrop and Stockton found survival to be significantly negatively related to increasing depth, with the predicted proportion alive after around 1 hour being almost zero at 11 meters compared to around 50% at less than 1 meter depth (Smith et al. 2017; Figure D1.3-6, Predicted Survival Plot for Juvenile Chinook Salmon Tethered to Predation Event Recorders As a Function of Water Depth in the San Joaquin River Between Lathrop and Stockton).



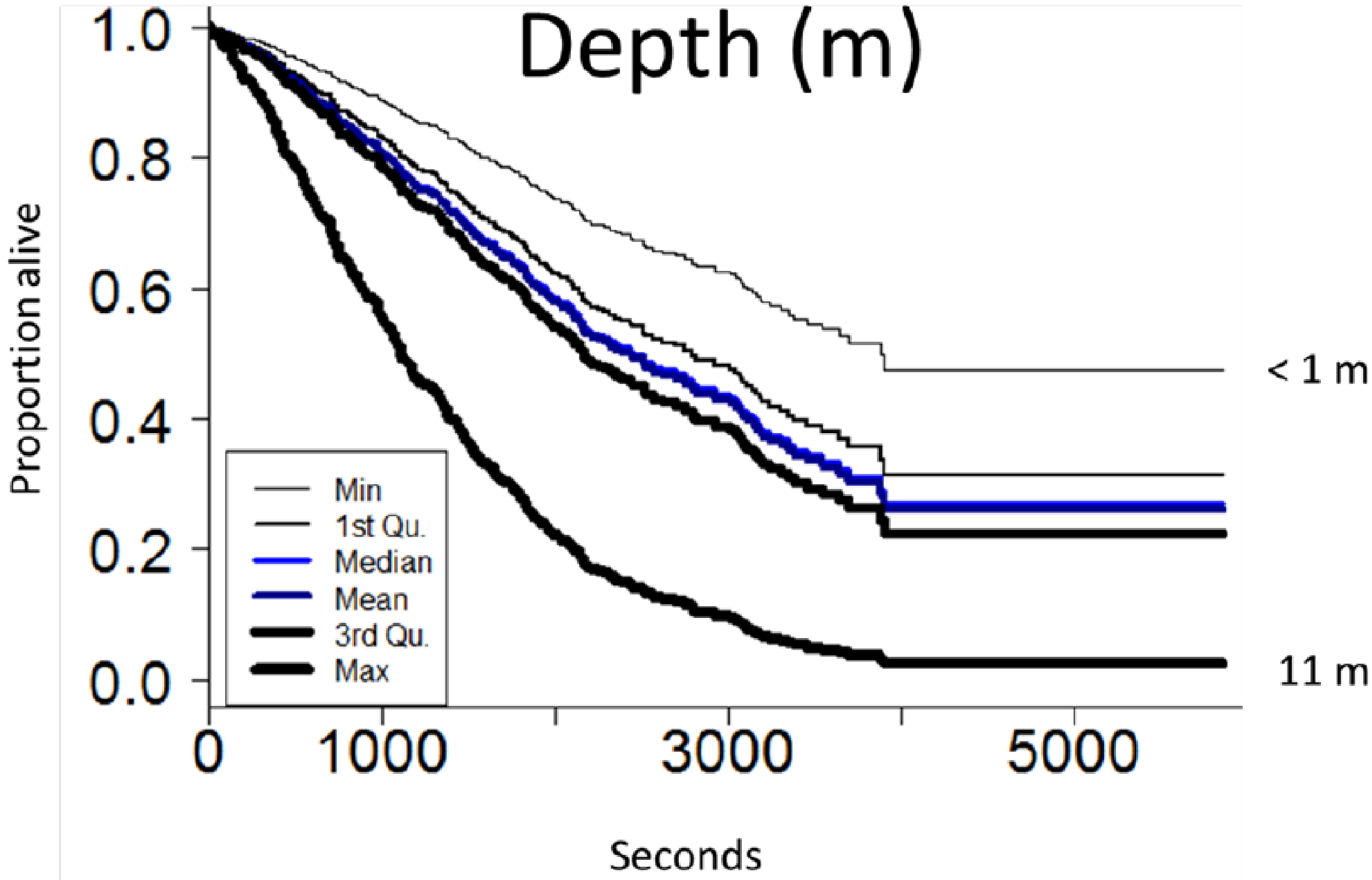
Source: DWR 2015.

Figure D1.3-4. Locations of Stationary Juvenile Salmonid Acoustic Tags at the Head of Old River, 2009–2012



Source: Cutter et al. 2017. Notes: Head of Old River is indicated by R1 on the right-hand side of the figure. Size of filled dots indicate abundance estimates. Numbers on horizontal axis indicate Julian day of the year. Numbers on left vertical axis indicate northing (meters).

Figure D1.3-5. Abundance of Predatory Fish in the San Joaquin River between Lathrop (South End of Map) and Stockton (North End of Map), As Estimated by Downward Pointing Hydroacoustic Surveys



Source: Smith et al. 2017.

Figure D1.3-6. Predicted Survival Plot for Juvenile Chinook Salmon Tethered to Predation Event Recorders As a Function of Water Depth in the San Joaquin River Between Lathrop and Stockton

Justification for Action

Filling the scour hole at the Head of Old River as well as potential reconfiguration of the junction aims to increase juvenile salmonid survival through this area of the south Delta, which is considerably lower than survival in other parts of the Delta and elsewhere.

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D1.3.4.2.2 North Delta Food Subsidies

Summary

Reclamation would work with partners to flush agricultural drainage (i.e., nutrients) from the Colusa Basin Drain through Knight's Landing Ridge Cut and the Tule Canal to Cache Slough, improving the aquatic food web in the North Delta for fish species. Reclamation would work with DWR and partners to augment flow in the Yolo Bypass in July and/or September by closing Knights Landing Outfall Gates and routing water from Colusa Basin into Yolo Bypass to promote fish food production.

Description

Historically, the slow-moving wetlands and waterways of the Delta generated prodigious amounts of the microscopic plants and animals—phytoplankton and zooplankton—that support Delta Smelt. In the current Delta, Delta Smelt face a shortage of food, particularly during summer and fall. The project will augment flow in the Yolo Bypass by closing Knights Landing Outfall Gates and route water from Colusa Basin into Yolo Bypass in July and/or September to promote food production and export into areas where Delta Smelt are known to occur. Zooplankton produced on the Yolo Bypass would move downstream into an area where juvenile and adult Delta Smelt are known to occur at a time of year when food availability may be a limiting factor. Food web enhancement flows will also be considered for additional months in ways that will not conflict with agricultural and waterfowl management actions based on the availability of water to augment flows in the Yolo Bypass. The project could also increase outflow from the Yolo Bypass during the spring. The project is a collaboration between DWR, Reclamation, Glenn-Colusa Irrigation District, Reclamation District 108, USGS, Knaggs Ranch, and Conaway Preservation Group.

Objectives

- Fundamental objective: Maintain minimum population during drought
- Means objective: Abundance

Conceptual Model (Each Species and Life stage)

This measure would benefit Delta Smelt juvenile and sub-adult life stages and the Habitat Attributes that would be affected include Food Availability and Quality.

The IEP MAST CM specifically states that "Growth and survival are hypothesized to depend on food availability and food production and availability depends on interactions of a variety of landscape attributes and environmental drivers."

> Juvenile growth and survival is hypothesized to depend on availability and quantity of food. Food production during this summer period is hypothesized to involve complex interactions of clam grazing, nutrients, hydrology and harmful algal blooms. The probability of observing a harmful algal bloom is hypothesized to be a function of the same factors but with temperature playing an important role.
>
> Food availability and visibility are hypothesized to be important with respect to providing nutrition that allows Delta Smelt to grow into healthy, large adults that can produce a large numbers of high quality eggs as well as multiple clutches of eggs over the spawning season. The availability of food is considered dependent on both food production and the availability of such food to the fish.

Current Condition

This project is being studied as part of the Delta Smelt Resiliency Strategy, which is being implemented by CDFW, DWR, Division of Boating and Waterways, USFWS, and Reclamation (CNRA 2016).

Background

In 2011 and 2012, following larger-than-normal agricultural return-flows from the Yolo Bypass, scientists observed an unusual phytoplankton bloom in the Rio Vista area of the lower Sacramento River. Scientists theorized that this production could benefit Delta Smelt if it could be replicated annually. In 2016 and 2018, state, federal and local water district officials partnered to send water through a wetland and tidal slough corridor of the Sacramento River system and into the Delta where it created a phytoplankton bloom, the foundation of the food web for Delta Smelt.

Current Science

Monitoring of the pilot studies shows that nutrient-rich "pulse flow" successfully generated a phytoplankton bloom and enhanced zooplankton growth and egg production. Data is still being analyzed on water quality, contaminants, and plankton that were collected before, during, and after the experimental flows.

Justification

Pilot studies for this project have shown promising results. In the summer of 2016, DWR and numerous partners piloted this action and monitoring indicated that the nutrient-rich "pulse flow" generated a phytoplankton bloom and led to enhanced zooplankton growth. Some of this water was donated, and the total water cost was $230,000 (200 to 500 cubic cfs for about 2½ weeks).

The project has is part of the Delta Smelt Resiliency Strategy, as well as ranking high on the Collaborative Adaptive Management Team (CAMT) structured decision-making process.

References

California Natural Resources Agency (CNRA). 2016. *Delta Smelt Resiliency Strategy*. Available: http://resources.ca.gov/docs/Delta-Smelt-Resiliency-Strategy-FINAL070816.pdf.

D1.3.4.2.3 Sacramento Deepwater Ship Channel

Summary

Reclamation proposed to repair or replace the West Sacramento lock system to hydraulically reconnect the ship channel with the main stem of the Sacramento River. When combined with an ongoing food web study, the reconnected ship channel has the potential to flush food production into the north Delta. An increase in food supply is likely to benefit Delta Smelt and their habitat.

Description

Reclamation is currently conducting a food web related pilot study in the Sacramento Deep Water Ship Channel (SSC). The pilot study involves the addition of nitrogen into the SSC at levels that naturally occur in the summer season. When timed with the maximum solar radiation outputs, the nitrogen should enhance a phytoplankton and zooplankton bloom, which would promote food for listed species, such as Delta Smelt.

The SSC does not exchange water with the rest of the Delta. Water from the Sacramento River is impeded by the West Sacramento lock system and provides little to no flow into the SSC. Reclamation proposes to work with the Port of Sacramento to repair and operate the West Sacramento lock system. Through the operation of the locks, Reclamation could hydraulically reconnect the ship channel with the main stem of the Sacramento River. A functioning sector gate could be used to adaptively manage net flow of the Sacramento River down the ship channel as a way to export ship channel plankton to stimulate plankton production in the North Delta.

Objectives

- Fundamental objective: Increase abundance of Delta Smelt
- Means objective: Abundance

Conceptual Model (Each Species and Life stage)

Delta Smelt: Open waters of the Delta are considered food-limited (Kimmerer 2002). Increasing food resources (i.e., phytoplankton and zooplankton) would be expected to have a beneficial effect on the entire system, as well as for endangered native species such as Delta Smelt. Increasing nitrogen within an N-limited system should stimulate phytoplankton and zooplankton growth, which when combined with modifications to the West Sacramento lock system should make this additional food available to Delta Smelt.

Current Condition

Currently the West Sacramento lock system does not allow SSC to exchange water with the rest of the Delta or provide potential food for species such as Delta Smelt.

Background

Reclamation operates the CVP, a system of reservoirs, power plants, operable gates, pumping plants and canals that supply water for irrigation, municipal and industrial use and for wildlife refuges in the Central Valley. CVP operations are thought to contribute to the decline of Delta Smelt, an endemic fish listed as threatened under the ESA, by adversely affecting the extent and quality of its critical habitat. Under the CVPIA, Reclamation has the authority to fund activities that have the potential to reduce CVP impacts on

Delta Smelt and their critical habitat and to undertake actions to improve Delta habitat conditions (Reclamation 2018).

Current Science

The CMs for the pelagic organism decline in the Sacramento-San Joaquin Delta suggest the potential for both “top-down” and “bottom-up” drivers of fish abundance. As in many estuaries, fish and other higher trophic level production in the open waters of the Delta region is fueled by phytoplankton production. However, the Delta has notably low phytoplankton production and biomass (Van Nieuwenhuyse 2007; Jassby 2008) resulting in low overall aquatic ecosystem productivity compared to other systems. Consequently, open waters of the Delta are considered food-limited (Kimmerer 2002). Increasing food resources (i.e., phytoplankton and zooplankton) would thus be expected to have a beneficial effect on the entire system, as well as for endangered native species such as Delta Smelt.

Previous research on the Toe Drain in the Yolo Bypass (Frantzich and Sommer 2015) demonstrated that pulses of algae-rich waters associated with enhanced net flows through the Toe Drain (as measured at the Lisbon Weir) can “seed” a significant algal bloom throughout the north Delta. A plausible mechanism for this phytoplankton bloom initiation is that the input of a large algal seed source from the Toe Drain into the relatively nutrient-rich waters from the lower Sacramento River (primary nutrient source is Sacramento Regional wastewater treatment facility) results in greatly enhanced phytoplankton production rates that exceed zooplankton and clam (*Corbicula*) grazing pressures. This allows the phytoplankton bloom to persist and propagate downstream until it is exported to the Bay.

A goal for food resource management in the north Delta would be to increase the standing stock of algal biomass (chlorophyll concentration) from the current range of 1 to 3 μg/L (microgram/Liter) to approx. 10 μg/L. A chlorophyll level of approximately 10 μg/L could support relatively high zooplankton production (Mueller-Solger et al. 2002) without adversely affecting water quality (e.g., dissolved oxygen concentration).

To optimize the export of food resources from the SSC, Reclamation’s multi-year (2012–present) dataset suggests that nitrogen additions should enhance both primary (phytoplankton) and secondary (zooplankton) production and standing crops. It is hypothesized that it should be possible to manipulate the SSC in a manner that would allow Reclamation to grow up standing stocks of phytoplankton and zooplankton and pulse these food resources into the north Delta where the phytoplankton/zooplankton bloom may be self-sustaining for a period of time (approximately 1 month but depending on river flows). In the SSC, there is the potential to control both water flow rates (diversions from Sacramento River) and nutrient concentrations (e.g., through nutrient additions) should preliminary studies support the efficacy of the system to enhance food resources in the north Delta (Reclamation 2018).

The SSC consists of three longitudinally distinct zones as illustrated by the specific conductance (electrical conductivity). These zones include an area of trapped water in the upper section (lentic conditions), a zone of mixing in the mid-reach, and the lower zone that experiences tidal exchange twice a day. Seasonally, small blooms of phytoplankton and zooplankton are observed in the “old water” zone; however, these food resources are trapped in this zone with minimal advection to the tidal mixing zone where it could enter into the north Delta. The more persistent blooms observed below the gates in the West Sacramento Port (WSP) are believed to be due to nutrient inputs from leakage through the gate (especially during high flow periods) and groundwater inputs from the Sacramento River. These observations suggest that nutrient enrichment has the potential to stimulate algal and zooplankton production in the SSC.

Given the consumption of nutrients by algal growth, dissolved inorganic nitrogen (DIN) (NH_4 + NO_3) is depleted to low levels (<0.1 mg N/L) in the upper SSC during the summer months. Thus, primary production is limited by the lack of bioavailable N for much of the spring-summer-fall period. Nitrogen is depleted faster than phosphorus (the other major potentially limiting nutrient) in part because denitrification (microbial conversion of nitrate to nitrogen gas) results in the permanent loss of nitrogen from the water column over time. By contrast, no such loss process exists for phosphorus. Thus, the DIN:PO_4-P molar ratio is generally less than 6 throughout the year compared to a Redfield N:P ratio of approximately 16 for algae. These conditions suggest that nitrogen enrichment, especially during the summer growing season, could stimulate primary production that in turn should theoretically lead to higher production of zooplankton.

Justification

Within the Delta, fish and other higher trophic level production in the open waters of the Delta region is fueled by phytoplankton production. However, the Delta has notably low phytoplankton production and biomass resulting in low overall aquatic ecosystem productivity compared to other systems. Consequently, open waters of the Delta are considered food-limited. Increasing food resources (i.e., phytoplankton and zooplankton) would thus be expected to have a beneficial effect on the entire system, as well as for endangered native species such as Delta Smelt.

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D1.3.4.2.4 Introduce Dredge Material for Turbidity

Summary

Reclamation and DWR propose to obtain sediment for introduction into the Bay-Delta in order to increase turbidity and thereby benefit Delta Smelt and juvenile salmonids, primarily through reduction in predation risk. Sediment for augmentation would be sourced from Bay-Delta watershed dredging projects and reservoirs.

Description

Reclamation and DWR will partner to augment sediment supply in the Bay-Delta by introducing sediment obtained from upstream reservoirs and Bay-Delta watershed dredging undertaken at locations such as marinas, ports, and shipping channels. Conceptually, this is similar to the California WaterFix proposed action to reintroduce sediment entrained at the proposed north Delta diversions (ICF International 2016, Chapter 3, p.3-88), from which the following description below has been partly adapted. In order to achieve the objective of sediment augmentation, Reclamation and DWR will collaborate with USFWS, NMFS, and CDFW to develop and implement a sediment augmentation program that provides the desired beneficial habitat effects of increased turbidity while addressing related permitting concerns (the proposed sediment augmentation is expected to require permits from the Central Valley Regional Water Quality Control Board and USACE). USFWS, NMFS, and CDFW will have approval authority for the sediment augmentation program and for monitoring measures, to be specified in the program, to assess its effectiveness. Modeling will be undertaken in order to assess potential sediment placement sites to maximize the habitat benefits (e.g., UnTRIM/SWAN/SediMorph: Bever and MacWilliams 2018; Bever et al. 2018; DSM2-STM: Hsu et al. 2018). In essence, the sediment augmentation program may consist of placement of sediment during low flow periods at seasonally inundated locations, such as channel margin benches constructed for the purpose along the mainstem Sacramento River. The sediment would then be mobilized and carried downstream following inundation during seasonal high flows (generally, the winter and spring months). Another option would be continuous introduction of batch sediment slurry that could be done during the low-flow months (Bever and MacWilliams 2018). The sediment augmentation program would be designed for consistency with Basin Plan objectives for turbidity, i.e., except for periods of storm runoff, turbidity of Delta waters not exceeding 50 NTU in the waters of the Central Delta and 150 NTU in other Delta waters. Exceptions to these Delta-specific objectives are considered when a dredging operation can cause an increase in turbidity, in which case, an allowable zone of dilution within which turbidity in excess of limits can be tolerated will be defined for the operation and prescribed in a discharge permit (Central Valley Water Board 1998, p. III-9.00).

Objectives

- Fundamental objective: Increase juveniles at Chipps Island per adult return
- Means objective: Abundance

Conceptual Model (Each Species and Life stage)

As described in the Delta Smelt Resiliency Strategy (CNRA 2016, p.8), per the IEP MAST Delta Smelt (2015) CM turbidity influences predation risk during the transitions between all life stages (adults to eggs/larvae in December-May; eggs/larvae to juveniles in March-June; juveniles to sub-adults in June-September; and sub-adults to adults in September-December) and is a function of the landscape attribute of erodible sediment supply. A similar mechanism is postulated for turbidity and predation risk affecting the transition from rearing to outmigrating juvenile in the Winter-Run Chinook Salmon SAIL CM (Windell et al. 2017, p.24) and for the transition from juvenile to sub-adult/adult in the SAIL Green Sturgeon CM (Heublein et al. 2017, p.21). Turbidity also is hypothesized to improve growth and survival in the transition between the Delta Smelt larval and juvenile life stages, presumably by providing a background of stationary particles that helps small larvae detect moving prey (IEP MAST 2015, p.53).

Current Conditions (RPA, WQCP, Facility)

As described in some detail in the IEP MAST CM for Delta Smelt (IEP MAST 2015: 49-55), turbidity in the Bay-Delta is spatially variable, tending to be highest in the Suisun and Cache Slough Complex regions. There has been a long-term decline in turbidity, e.g., total suspended sediment delivery from the Sacramento River watershed decreased ~50% from 1957 to 2001 (Wright and Schoellhamer 2004), and Delta-wide turbidity and associated suspended sediment decreased 40% (Cloern et al. 2011); these changes have resulted in a decline in abiotic habitat quality for Delta Smelt over time (Feyrer et al. 2011). RPA Action 4 of the USFWS (2008) SWP and CVP BO includes Fall X2 criteria for wet and above normal years which position the low salinity zone over shallower areas that tend to have higher turbidity (Brown et al. 2014), and therefore greater habitat suitability for Delta Smelt (Feyrer et al. 2011).

Background (Old Science, Past Implementation, If Any)

Turbid conditions are associated with increased presence of Delta Smelt (Sommer and Mejia 2013). Survival of juvenile Chinook Salmon through the Delta was shown to be positively related to turbidity by Newman (2003). There has been no past implementation of a sediment augmentation program to increase turbidity in the Bay-Delta, although this is a proposed action for the Delta Smelt Resiliency Strategy (CNRA 2016) which is being investigated for its feasibility (Bever and MacWilliams 2018). Sediment reintroduction is also required to mitigate sediment entrainment by the California WaterFix project's proposed north Delta diversions on the Sacramento River in the north Delta (CDFW 2017, p.46-47 and p.162-163).

Current Science Related to Idea/Topic

Field studies have confirmed previous findings that the probability of predation on juvenile Chinook Salmon increases with decreasing turbidity (DWR 2015, 2016). Although there has been much focus on reduced sediment supply to the Bay-Delta resulting in decreases in suspended sediment concentration and turbidity (Schoellhamer et al. 2014), recent studies have shown that long-term reductions in wind speed have also been a major contributor to reductions in turbidity (Bever et al. 2018). In addition, approximately 21–70% of the declining trend in turbidity has been attributed to expansion of invasive submerged aquatic vegetation in the tidal freshwater Delta (Hestir et al. 2016). The Delta Smelt Resiliency Strategy proposes to increase the treatment of aquatic weeds through coordination with the Department of Boating and Waterways (CNRA 2016, p.7). An initial study informing the sediment augmentation proposed as part of the Delta Smelt Resiliency Strategy was recently completed by Bever and MacWilliams (2018). This study assumed that sediment was introduced to the Sacramento River at Decker Island as a continuous batch slurry with a flow rate of 5 m^3/s (~180 cfs) between May 1 and September 30, in order to achieve a 10-NTU turbidity increase between Emmaton and Mallard Island. The amount of sediment necessary to achieve this targeted increase was estimated at just over 3,500 cubic yards per day, and it was found that the effectiveness of the augmentation was increased during periods of lower Delta outflow.

Justification for Action

The decline in turbidity has resulted in decreases in abiotic habitat suitability for Delta Smelt (Feyrer et al. 2011). Augmenting sediment supply to the Bay-Delta has the potential to reverse the decline in turbidity and improve habitat suitability for Delta Smelt, juvenile salmonids, and Green Sturgeon, primarily by reducing predation risk (IEP MAST 2015; Windell et al. 2017; Heublein et al. 2017). Positioning the low salinity zone in areas of higher turbidity through increased Delta outflow as required by the USFWS RPA Action 4 affects water supply; sediment augmentation aims to increase turbidity in the Bay-Delta.

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D1.3.4.3 *Salvage Efficiency*

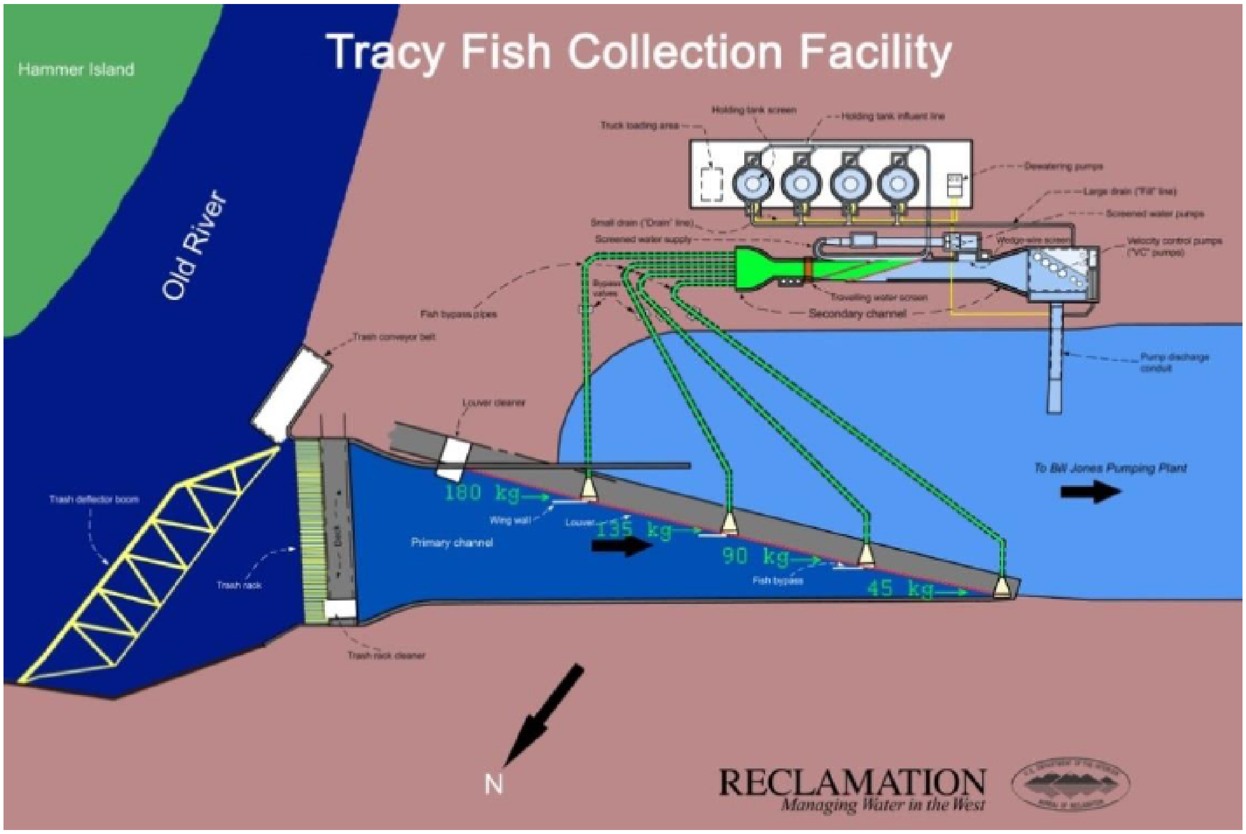
D1.3.4.3.1 <u>Tracy Fish Facility Improvements</u>

Summary

Reclamation proposes to improve salvage operations at the Tracy Fish Collection Facility (TFCF) by increasing predator removal activities, through (a) periodic large-scale application of carbon dioxide (CO_2) for the primary channel, (b) authorizing angling in the primary channel by Reclamation workers, and (c) installing a CO2 injection device to allow remote anesthetization of predators within the salvage facility. Adaptive management actions are proposed for consideration in the form of (1) incorporating state of the art fish exclusion barrier technology into the primary fish removal barriers, (2) incorporating state of the art debris removal systems at each trash removal barrier, screen, and fish barrier, (3) constructing additional channels to distribute the fish collection and debris removal among redundant paths through the facility, (4) separating predators from other salvaged fish in the holding tanks, (5) installing smaller-mesh screens in the holding tank area to retain smaller fish, (6) constructing additional fish handling systems and holding tanks to improve system reliability, and (7) incorporating supervisory control and data acquisition (SCADA) into the design and construction of the facility.

Description

Reclamation proposes two main elements to improve salvage operations at the TFCF. The first element is increase of predator removal activities. This will be comprised of three activities. Large-scale application of solid CO2 (i.e., dry ice) to the primary channel will be done several times per year, with particular emphasis on the period before the late fall/winter period when salvage of listed species (smelts and salmonids) is most likely to begin. Application of CO2 results in anesthetization of the predatory fish and makes collection easier. The main focal area for CO2 application will be the upper primary channel, where predators occur most frequently (Wu et al. 2015). Angling in the primary channel for predatory fish by Reclamation workers will be authorized and will require that all applicable state regulations for size and daily catch limits are observed. Installation of a CO2 injection device will allow remote anesthetization of predators in the secondary channels of the TFCF. A pilot implementation of this process was tested by Wu and Bridges using blocks of dry ice placed into the primary fish bypass entrances (2014; Figure D1.3-7, Schematic of the Tracy Fish Collection Facility Illustrating Dry Ice Injection Locations, Mass of Dry Ice Injected, and Treatment Area) and the procedure is currently done manually on a monthly basis. Injection of carbon dioxide would allow predatory fish to be collected from the TFCF bypass tubes and secondary channel, thereby reducing residence time and the risk of predation for prey fish. The injection device may use liquid CO2 or dry ice, with the specific locations of the injection to be determined by further study (e.g., directly into the secondary channel or at the front of the bypass tubes; Wu and Bridges 2014).



Source: Wu and Bridges 2014.

Figure D1.3-7. Schematic of the Tracy Fish Collection Facility Illustrating Dry Ice Injection Locations (Green Arrows), Mass of Dry Ice Injected (Green Text), and Treatment Area (Green Fill)

<u>Adaptive management of additional activities</u>

Several additional TFCF activities to improve salvage efficiency will be considered through adaptive management. First, a state of the art fish exclusion barrier technology will be considered for incorporation into the primary fish removal barriers. This technology could consist of large rotating fish screens replacing the primary louvers, thereby replacing a behavioral screening device with a physical barrier that would screen all but the smallest life stages, depending on the final mesh size. Although generally used for smaller intakes (i.e., less than 100 cfs), traveling screens have been implemented at larger intakes (e.g., 500 to 750 cfs) and are excellent for handling debris (Reclamation 2006).

Second, a state-of-the-art debris removal system will be considered for installation at each trash removal barrier and fish screening area. As noted above, traveling screens have excellent debris handling abilities and could be considered for the primary louvers. For the trash removal barrier in Old River, preliminary investigations have been undertaken to investigate the potential for modifying or replacing the existing conveyor system (Bhattacharya et al. 2016), which would allow more effective management of floating and submerged aquatic vegetation, including water hyacinth and *Egeria densa*. Traveling screens have also shown good potential for trash removal in the secondary channel at TFCF, while protecting fish (Vermeyen and Heiner 2015).

Third, additional channels will be considered for construction to distribute the fish collection and debris removal among redundant paths through the facility. This would allow cleaning and other maintenance to occur as necessary in some pathways while others remain open to facilitate continued effective salvage. Such modifications would require an overall enlarging of the TFCF, possibly doubling the size.

Separation of small predatory fish occurring in the holding tanks will be considered. This program would begin with manual separation of predatory fish during the regular fish counts, which sample 25% of salvaged fish. Based upon study of the effectiveness of this initial effort, additional efforts in the form of automatic fish separators could be considered.

Replacement of screens in the holding tank area will be considered. Currently, most of the screens in this area are 4-mm mesh, allowing retention of fish 30–35 mm in length. Replacement with screens of 2.1–2.3-mm mesh would allow retention of fish as small as 20 mm in length.

Additional fish handling systems and holding tanks will be considered for construction to improve system reliability, again to reduce risks associated with cleaning and maintenance. Concept-level designs for additional holding tanks have been completed, which aim to address the shortcomings of the existing holding tanks: these existing tanks are able to hold approximately 150,000 fish per tank, but the existing facility design only allows active fish collection from one tank at a time; when tanks are not actively collecting fish, but are used for short term storage of fish, water quality is diminished due to lack of fresh water (Heiner 2011).

Finally, in addition to these other potential activities, SCADA will be considered for incorporation into the design and construction of the TFCF, allowing local and remote automatic and manual control and monitoring of TFCF systems. SCADA systems have been used in water resources management in various locations worldwide (e.g., Gensler et al. 2009; Alghazali et al. 2013), and SCADA is proposed for inclusion in the California WaterFix project (California WaterFix 2018). Use of SCADA in the PA will improve the coordination between operations of the TFCF and the Jones Pumping Plant, e.g., by optimizing pump operations (number of pumps operating) given available diversion capacity, observed environmental and biological conditions, and factors such as louver efficiency and the need to shut down some systems for cleaning or other maintenance.

Objectives

- Fundamental objective: Increase juveniles at Chipps Island per adult return
- Means objective: Abundance

Conceptual Model (Each Species and Life stage)

As previously noted for other proposed actions, per the SAIL CM4 for Winter-Run Chinook Salmon rearing to outmigrating juveniles in the Bay-Delta (Windell et al. 2017, p.22), "Juvenile salmon arriving in the southern end of the Delta are at risk of entrainment in the Central Valley Project and State Water Project water intakes." The Green Sturgeon SAIL CM for the transition from juvenile to adult/sub-adult notes "both juvenile green sturgeon distribution and behavior suggest that entrainment and impingement in diversions affect survival" (Heublein et al. 2017, p.22).

Current Conditions (RPA, WQCP, Facility)

The NMFS (2009) RPA Action IV.4.1 requires Reclamation to implement specific measures to reduce pre-screen loss and improve salvage efficiency at TFCF. Whole facility efficiency for salvage of Chinook Salmon, Steelhead, and Green Sturgeon is required to be greater than 75% for each species. This is to be achieved through a number of actions including removal of predators in the primary channel so that prescreen loss is less than 10% of exposed salmonids; redesign of the secondary channel to enhance screening, fish survival, and predation reduction; reductions in Chinook Salmon and Green Sturgeon loss during louver cleaning operations; at least weekly removal of predators in the secondary channel; and various flow operational criteria to increase screening efficiency per design criteria.

Background (Old Science, Past Implementation, If Any)

Analysis in the NMFS (2009, p.352) BO identifies prescreen loss (15%), louver efficiency loss (53.2%), collection/handling/transport/release loss (2%), and post-release loss (10%) as the various elements contributing to approximately 35% survival of fish salvaged at the TFCF. Hydroacoustic studies have provided evidence that predators can be abundant at the release sites (Miranda et al. 2010).

Current Science Related to Idea/Topic

Recent tests with acoustically tagged juvenile Chinook Salmon suggest that the TFCF is likely not meeting the 75% whole facility efficiency required by NMFS RPA Action IV.4.1. Primary and secondary louver efficiency is high (75%–100%) and it is predation loss that drives the whole facility efficiency estimates ranging from 0-40% with one Jones Pumping Plant pump operating to 45-75% with three to five pumps operating (Wu et al. 2018). Residence time of predatory fish in the TFCF can be very long, averaging ~75.4 days for Striped Bass (range = 0.01–290 days), which most frequently inhabited the upper primary channel and secondary channel (Wu et al. 2015). Removal of predatory fish from the primary channel has been shown to lead to significant reductions in prescreen loss of juvenile Chinook Salmon (Bridges et al. in draft, as cited by Sutphin 2014). Pilot testing of CO_2 injection into the primary bypass tubes (Figure D1.3-7) resulted in significantly greater numbers of predators (492 Striped Bass and 558 White Catfish) collected in the holding tanks than during a control period when no CO2 was injected (0 Striped Bass and 11 White Catfish) (Wu and Bridges 2014). Studies are underway to determine release site strategies in order to optimize release schedules at the multiple SWP/CVP release sites (Fullard et al. 2017, 2018). Consistent with the findings for Chinook Salmon (Wu et al. 2018), holding tank survival of Delta Smelt is high, indicating that holding tank conditions generally are relatively benign (Karp and Lyons 2015; although see Heiner 2011).

Justification for Action

Upgrades to the TFCF will aim to meet the requirements of the NMFS RPA by minimizing the effects of the salvage process on listed fishes, in particular juvenile salmonids and Green Sturgeon. Salvage improvements will improve survival of salvaged fish and potentially allow reduction of the expansion factors used to extrapolate take estimates from observed salvage. This may allow for additional certainty in OMR flow management by reducing pumping impacts to juvenile salmonids and Green Sturgeon.

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D1.3.4.4 *Routing*

D1.3.4.4.1 North Delta Arc Routing into Sutter and Steamboat Sloughs

Summary

The north Delta contains an “Arc” of suitable habitat for salmonid species in areas such as the Yolo Bypass, the Sacramento River, and Suisun Marsh. Reclamation proposes to manage and implement barriers throughout the “Arc” to maximize the benefits of these habitats and direct listed salmonids into these habitats.

Description

The University of California, Davis (UC Davis) Center for Watershed Sciences has identified Yolo Bypass as primary component of the North Delta Habitat Arc. It consists of a reconciled ecosystem strategy to create an arc of habitats connected by the flows of the Sacramento River. The Yolo Bypass is the upstream end of the arc, which continues through the Cache-Lindsey Slough-Liberty Island region, down the Sacramento River including Twitchell and Sherman Islands, and into Suisun.

Objectives

- Fundamental objective: Increase juveniles at Chipps Island per adult return

- Means objective: Abundance

Conceptual Model (Each Species and Life stage)

Focusing on habitat restoration and directed management actions in and adjacent to tidal marsh and other wetlands along the northern Delta arc of shoals, shallows, and open waters to improve habitat for native fish species.

Current Condition

Moyle et al. (2018) state that the North Delta Habitat Arc has a strong potential for habitat restoration. They note that the flows of the river are highly managed but provide basic connectivity needed—North Delta Arc needs to be recognized as an area in which natural and restoration sites are managed as an interconnected whole. EcoRestore projects have been ongoing and largely concentrated in the North Delta arc of habitat (Moyle et al. 2018) and additional projects should continue to be implemented.

Background

According to Durand (2012), the North Delta Arc refers to the suite of interconnected littoral and shallow water habitats along the northern rim of Suisun Bay and Delta which wrap the base of the Montezuma Hills. The Arc includes Suisun Marsh, Sherman Lake, the Cache-Lindsey Slough Complex, and Liberty Island. Durand (2012) describes these habitats as having more tendency to be more productive and biologically diverse than other regions in the Delta. Durand (2012) states that while multiple stressors have been implicated with fish declines throughout the Bay-Delta estuary, there are multiple physical and trophic drivers that support fishes in the Arc, providing a slower rate of declines for a number of native species. Conditions such as geomorphic structure, bathymetric gradient extending from above to below sea level, tidal exchange, freshwater flows promote the essential needs of local fishes by providing physical and hydrodynamic structure for habitat, trophic structure that supports foraging strategies, and corridors for transit or recruitment among habitats (Durand 2012). Comparisons with other regions of the Delta demonstrate that these conditions are not met throughout much of the ecosystem; the North Delta Arc is an exception (Durand 2012).

Current Science

Moyle et al. (2018) identified several initiatives to improve welfare of native fishes in the Delta and help to create a novel aquatic ecosystem with many desirable features. One of those initiatives was to expand restoration projects in the North Delta Habitat Arc. Moyle et al. (2008) states:

> Restoration projects in the North Delta Habitat Arc represent the best model for future projects because they consist of a portfolio of projects that are diverse in size, connectivity, and location; all are linked to the Sacramento River and its riparian zone. The river provides a corridor that connects projects and habitats by water and land, providing opportunities for a dynamic biota to exist, and to expand as restoration projects are added to the portfolio.

Further restoration projects in the “Arc” are recommended that improve connectivity to other restoration sites and the Sacramento River (Moyle et al. 2008).

North Delta Arc areas with current restoration activities such as Yolo Bypass, North Delta (Lindsey-Cache Slough-Liberty Island), Sacramento River (Twitchell and Sherman Islands), and Suisun Marsh, each have their own distinctive characteristics and faunas (Moyle et al. 2016). Collectively, these projects should be regarded as a large-scale example of reconciliation ecology where new habitats are crated and closely managed to meet specific goals (Moyle et al. 2016). Moyle et al. (2016) recommends viewing the Arc as a large, interconnected and reconciled ecosystems to help with:

- Managing projects to benefit a full range of life history stages for key species
- Coordinating management of restoration projects with water project operations.
- Managing the system in a changing climate: longer droughts, bigger floods and warmer temperatures.
- Restoring tidal marshes as sources of food for pelagic fishes such as Delta Smelt.
- Comparing outcomes of different restoration strategies.
- Assessing how tidal marsh restoration projects affect tidal flow in projects, given that total tidal energy is more or less fixed.
- UC Davis Center for Watershed Sciences conducted preliminary research and identified several mechanisms critical to supporting the resiliency in the region's [North Delta Arc] ecosystem, including habitat complexity, tidal interactions with the shore, water quality dynamics, and interconnected habitats (Schlesinger *date unknown*). Schlesinger (*date unknown*) states that the research indicates that tidal exchange of sediment and phytoplankton in the water help maintain a variety of habitats that may be beneficial to both native and desirable invasive species. UC Davis Center for Watershed Sciences researchers noted that phytoplankton growth appears to be most concentrated in the upper reaches of dead-end sloughs, possibly contributing to the local food web. Because these sloughs are well connected to the main channels of the estuary, aquatic life can readily move between them in search of food or refuge.

Justification

Moyle et al. (2016) states that native fishes in the Delta are in desperate conditions, with over 90% of fish sampled being non-native species. Native fish such as the Delta Smelt are nearing extinction (Moyle et al. 2016). Researchers, such as Moyle et al. (2016), state that if the trend toward extinction is to be reversed, there is a need to re-create a functioning estuary. An inter-connected series of habitats, mostly tidal, is needed with a unified conceptual, scientific, institutional and applied approach. The US Davis Center for Watershed Sciences conducted preliminary research and identified several mechanisms critical to supporting the resiliency in the region's [North Delta Arc] ecosystem, including habitat complexity, tidal interactions with the shore, water quality dynamics, and interconnected habitats (Schlesinger n.d.). Schlesinger (n.d.) states that the research indicates that tidal exchange of sediment and phytoplankton in the water help maintain a variety of habitats that may be beneficial to both native and desirable invasive species. The UC Davis Center for Watershed Sciences researchers noted that phytoplankton growth appears to be most concentrated in the upper reaches of dead-end sloughs, possibly contributing to the local food web. Because these sloughs are well connected to the main channels of the estuary, aquatic life can readily move between them in search of food or refuge.

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D1.3.4.5 *Conservation Hatchery*

D1.3.4.5.1 Rio Vista Research Station

Summary

Reclamation would work with partner agencies to develop an Estuarine Research Station at the Rio Vista Army Reserve Center.

Description

The Rio Vista Research Station would:

- Establish a research station in a central location within the Bay-Delta to facilitate conducting monitoring and research;
- Co-locate the research station with a facility capable of studying fish in captivity (the Delta Smelt Conservation Hatchery); and
- Provide facilities to conduct monitoring and research on the Bay-Delta's aquatic resources. (USFWS 2017)

The Rio Vista Research Station will be located on the upper terrace of the center and will consist of a two-story office building, laboratory building, dry-dock boat storage building, open dry-dock boat storage area, shop building, storage area, restroom facility, and open field experimental yard. A marina, including a fixed pier, gangway, and boat launch, will be excavated on the shoreline of the Sacramento River.

Objectives

- Fundamental objective: Maintain minimum population during drought.
- Means objective: Productivity

Conceptual Model (Each Species and Life stage)

The Research Station would not specifically contribute to a portion of the conceptual model for Delta Smelt or salmon, but would enable monitoring and research to refine these models and increase understanding.

Current Condition

IEP research and monitoring activities are spread over a large geographical area, which limits interagency coordination and collaboration.

Background

This facility has been in discussion since 2015, and USFWS completed a BO in 2017 (USFWS 2017).

Current Science

A centralized location for scientific research and monitoring would improve the collaboration and scientific opportunities available.

Justification

This facility would help improve understanding of the various factors that affect listed species and ways to improve conditions.

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D1.3.5 Stanislaus River

D1.3.5.1 *Habitat*

D1.3.5.1.1 <u>Spawning Habitat</u>

Summary

Reclamation proposes to place 4,500 tons of gravel per year in the Stanislaus River to provide spawning habitat.

Description

Reclamation will primarily create spawning habitat via gravel augmentation. Key considerations involve substrate size and risk of sedimentation.

Objectives

- Fundamental objective: Increase juveniles at Chipps Island per adult return.
- Means objective: Productivity

Conceptual Model (Each Species and Life stage)

The overall SAIL CM (Windell et al. 2017) for Chinook Salmon comprises several separate CMs describing life stages, including “Egg to Fry Emergence.” Each of the life stage-specific CMs includes numerous hypotheses about how habitat attributes affect that life stage.

The proposed spawning habitat improvements target the ‘Egg to Fry Emergence’ stage; SAIL includes nine hypotheses about how habitat attributes affect this life stage. Gravel augmentation is most likely to affect the hypotheses related to redd quality, stranding and dewatering, and sedimentation and gravel quantity.

Egg survival depends largely on redd quality and substrate size (Windell et al. 2017). Redd quality is affected by many habitat attributes including a couple affected by gravel augmentation, i.e., gravel size and composition, sedimentation. Gravel augmentation potentially reduces stranding and dewatering by changing water depth. Because sedimentation negatively affects egg survival, gravel should be cleaned before placement.

Current Condition

Stanislaus River riparian areas historically supported a diverse, dynamic ecosystem complex of seasonal wetlands, oxbow lakes and extensive forested floodplains, with meandering side channels (Elias 1924). However, historic gold and gravel mining have greatly altered geomorphic and hydraulic conditions under which Stanislaus River salmon populations evolved. Extensive alterations to Stanislaus River streambeds deeply incised the main channel, disconnected side channels and floodplains, and altered riparian vegetation. Regulated flows compounded incision, further eroded beds and banks, coarsened bed material, and inhibited the flushing of fine particles from the gravel (DWR 1994; Kondolf 1997). These impacts have reduced total salmonid spawning habitat extent and degraded remaining habitat.

Historically, both Spring- and Fall-Run Chinook Salmon were known to exist in the Stanislaus River, up to elevations of ~2,000feet (Yoshiyama et al. 2001). By 1926, Goodwin Dam and Melones Dam had eliminated access to the upper Stanislaus River (Yoshiyama et al. 1996). Currently, spawning activity occurs primarily within the 12-mile reach between Goodwin Dam and Orange Blossom Bridge (Mesick 2001).

There is limited information on Chinook Salmon and Steelhead populations in the Stanislaus River. Annual carcass surveys have been conducted by CDFW since 1975, and adult population estimates from these surveys range from 0 to 13,473 (average 3,370) returning spawners (CDFW 2018).

Background

Gravel augmentation is a widely accepted technique for rehabilitating anadromous salmonid spawning habitats within regulated streams of the California Central Valley (Wheaton et al. 2004a, 2004b). Several studies have demonstrated that gravel augmentation can increase Chinook Salmon spawning activity (Merz and Setka 2004; Zeug et al. 2013). Ideally placed gravels contain a range of substrate sizes appropriate for successful redd construction by all salmonids present at the site (Kondolf and Wolman 1993).

Physical and biological effects of gravel augmentation projects are influenced by a suite of intermediate mechanisms and external factors related to hydrodynamics, geomorphology, and ecology (Downs and Kondolf 2002). Therefore, the overall effects of restoration projects on river ecosystems and specified life stages of target species, and secondary influences on non-target organisms, are highly variable both within and among ecosystems. In addition, because even heavily regulated rivers are dynamic and both flow and physical engineering of spawning beds by salmon cause downstream sediment transport, a gravel augmentation project is not expected to function indefinitely and will be reduced as sediment is carried downstream (Merz et al. 2006; Humphries et al. 2012).

In the past two decades, several rehabilitation efforts have been undertaken on the Stanislaus River to improve the quality and quantity of salmonid spawning habitat. These are summarized in Table D1.3-2.

Table D1.3-2. CVPIA gravel augmentation on the Stanislaus River from 1997–2015

Year	Gravel augmentation (tons)
1997	2,000
1998	3,000
2000	1,300
2001	500
2002	4,000
2004	1,200
2005	2,500
2006	2,500
2007	4,100
2011	5,000
2012	3,000
2015	8,000
2017	4,000
TOTAL	29,100

Source: Reclamation, unpublished data.

Current Science

Few studies have been conducted on the Stanislaus River to assess gravel augmentation success. Mesick (2001) monitored spawning activity at augmented and unaugmented sites between Goodwin Dam and Riverbank from 1994 and 1997 and found variable habitat quality and spawning activity in augmented areas. Multiple effectiveness monitoring studies have been implemented on the nearby American River to test the effects of gravel augmentation on salmon adults, embryos, and juveniles; since the Stanislaus River has many of the same historical impacts and habitat limitations, this information is likely relevant to Stanislaus River gravel augmentation projects, so it is summarized below.

Zeug et al. (2013) found that gravel augmentation increased site utilization, but the degree to which a particular augmentation action was effective depended upon the species (Chinook salmon or Steelhead) and substrate size. Cramer Fish Sciences (2017a) found that substrate size impacts benthic invertebrate prey production, with lower prey density in smaller gravels. Merz et al. (in press) also observed conflicting optimal gravel sizes between adult spawners and salmon embryos, with higher spawning activity in small gravel and higher embryo survival in large gravel. Cramer Fish Sciences (2017b) assessed gravel augmentation site longevity and that the positive effects of gravel augmentation (i.e., increased habitat utilization) declined to pre-project levels within 5 to 6 years after implementation.

Justification

In DWR’s Comprehensive Salmonid Assessment (DWR 1994), Salmon habitat restoration sites were identified on the Stanislaus River from Knight’s Ferry (RM 54.5) to Oakdale (RM 39.0). Recommendations included replacing gravel, cobble, and structure. The San Joaquin River Management Plan (1995) also suggests improving gravel quality to increase survival of salmonid eggs and enhance the channel and riparian corridor of the tributaries to the San Joaquin River, including the Stanislaus River. The USFWS (1995) Working Paper on salmonid restoration in the Central Valley identified the need to restore and protect instream and riparian habitat in the Stanislaus River to ensure the long-term sustainability of physical, chemical, and biological conditions needed to meet production goals for Chinook Salmon. The Stanislaus River is listed as high priority in the AFRP Final Restoration Plan

(USFWS 2001), and collaboration among landowners, Stanislaus County, CDFW, USFWS, and Reclamation for projects that improve watershed management to restore and protect instream and riparian habitat, including restoring and replenishing spawning gravel, are also high priority. In the Central Valley Salmonid Recovery Plan, NMFS (2014) recommends as high priority recovery actions in the Stanislaus River: (1) continue to implement projects that increase the availability and quality of spawning and rearing habitat and (2) identify and implement floodplain and side channel projects to improve river function and increase habitat diversity.

Modeling Science

The proposed actions can be evaluated with a couple of different models. The Chinook Carrying Capacity Calculator (https://flowwest.shinyapps.io/carrying-capacity-app/) estimates spawning habitat need and availability for many rivers in the Central Valley, including the Stanislaus River.

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D1.3.5.1.2 Rearing Habitat

Summary

Reclamation proposes to create another 171 acres of side channel and floodplain rearing habitat in the Stanislaus River by 2030.

Description

Reclamation will primarily create rearing habitat via gravel augmentation, floodplain improvements, and side channel development. Key considerations involve the potential to inundate edge habitats and floodplains by increasing local water surface elevation. Side channel excavation, floodplain lowering, and woody debris placement will also be considered for the creation of juvenile rearing habitat.

Objectives

- Fundamental objective: Increase juveniles at Chipps Island per adult return
- Means objectives: Abundance

Conceptual Model (Each Species and Life stage)

The overall SAIL CM (Windell et al. 2017) for Chinook Salmon comprises several separate CMs describing life stages, including Rearing to Outmigrating Juveniles. Each of the life stage-specific CMs includes numerous hypotheses about how habitat attributes affect that life stage.

The proposed rearing habitat improvements target the Rearing to Outmigrating Juveniles stage; SAIL includes nine hypotheses about how habitat attributes affect this life stage. Gravel augmentation, side channel excavation, floodplain lowering, and woody debris placement are most likely to affect the hypotheses related to predation and competition, refuge habitat, and food availability and quality.

Fry survival depends largely on the quantity and quality of rearing habitat. Inundation of edge and floodplain habitats provides refuge from fast moving water, increased food availability, and reduced predation risk.

Current Condition

Stanislaus River riparian areas historically supported a diverse, dynamic ecosystem complex of seasonal wetlands, oxbow lakes and extensive forested floodplains, with meandering side channels (Elias 1924). However, historic gold and gravel mining have greatly altered geomorphic and hydraulic conditions under which Stanislaus River salmon populations evolved. Extensive alterations to Stanislaus River streambeds deeply incised the main channel, disconnected side channels and floodplains, and altered riparian vegetation. Regulated flows compounded incision, further eroded beds and banks, coarsened bed material, and inhibited the flushing of fine particles from the gravel (DWR 1994; Kondolf 1997). These impacts have reduced total salmonid rearing habitat extent and degraded remaining habitat.

Historically, both Spring- and Fall-Run Chinook Salmon were known to exist in the Stanislaus River, up to elevations of ~2,000feet (Yoshiyama et al. 2001). By 1926, Goodwin Dam and Melones Dam had eliminated access to the upper Stanislaus River (Yoshiyama et al. 1996). Currently, spawning activity occurs primarily within the 12-mile reach between Goodwin Dam and Orange Blossom Bridge (Mesick 2001).

There is limited information on Chinook Salmon and Steelhead populations in the Stanislaus River. Recent monitoring efforts by state and federal resource agencies have provided some information on juvenile salmon response to flow regimes (Zeug et al. 2014) and how juvenile outmigration strategies impact survival to adulthood (Sturrock et al. 2015).

Background

Physical and biological effects of gravel augmentation projects are influenced by a suite of intermediate mechanisms and external factors related to hydrodynamics, geomorphology, and ecology (Downs and Kondolf 2002). Therefore, the overall effects of restoration projects on river ecosystems and specified life stages of target species, and secondary influences on non-target organisms, are highly variable both within and among ecosystems. In addition, because even heavily regulated rivers are dynamic and both flow and physical engineering of spawning beds by salmon cause downstream sediment transport, a gravel augmentation project is not expected to function indefinitely and will be reduced as sediment is carried downstream (Merz et al. 2006; Humphries et al. 2012).

Current Science

Few studies have been conducted on the Stanislaus River to assess gravel augmentation success. Multiple effectiveness monitoring studies have been implemented on the nearby American River to test the effects of gravel augmentation on salmon adults, embryos, and juveniles; since the Stanislaus River has many of the same historical impacts and habitat limitations, this information is likely relevant to Stanislaus River gravel augmentation projects, so it is summarized below.

Cramer Fish Sciences (2017a) found that substrate size impacts benthic invertebrate prey production, with lower prey density in smaller gravels. Merz et al. (2019) also observed conflicting optimal gravel sizes between adult spawners and salmon embryos, with higher spawning activity in small gravel and higher embryo survival in large gravel. Sellheim et al. (2015) found that gravel augmentation improved juvenile rearing habitat by reconnecting remnant floodplains under lower streamflow conditions. Cramer Fish Sciences (2017b) assessed gravel augmentation site longevity and that the positive effects of gravel augmentation (i.e., increased habitat utilization) declined to pre-project levels within 5 to 6 years after implementation.

Justification

In DWR's Comprehensive Salmonid Assessment (DWR 1994), Salmon habitat restoration sites were identified on the Stanislaus River from Knight's Ferry (RM 54.5) to Oakdale (RM 39.0). Recommendations included replacing gravel, cobble and structure. The San Joaquin River Management Plan (1995) also suggests improving gravel quality to increase survival of salmonid eggs and enhance the channel and riparian corridor of the tributaries to the San Joaquin River, including the Stanislaus River. The USFWS (1995) working paper on salmonid restoration in the Central Valley identified the need to restore and protect instream and riparian habitat in the Stanislaus River to ensure the long-term sustainability of physical, chemical, and biological conditions needed to meet production goals for Chinook Salmon. The Stanislaus River is listed as high priority in the AFRP Final Restoration Plan (USFWS 2001), and collaboration among landowners, Stanislaus County, CDFW, USFWS, and Reclamation for projects that improve watershed management to restore and protect instream and riparian habitat are also high priority. In the *Central Valley Salmonid Recovery Plan*, NMFS (2014) recommends as high priority recovery actions in the Stanislaus River: (1) continue to implement projects that increase the availability and quality of rearing habitat and (2) identify and implement floodplain and side channel projects to improve river function and increase habitat diversity.

Modeling Science

The proposed actions can be evaluated with a couple of different models. The Chinook Carrying Capacity Calculator (https://flowwest.shinyapps.io/carrying-capacity-app/) estimates rearing habitat need and availability for many rivers in the Central Valley, including the Stanislaus River. The Emigrating Salmonid Habitat Estimation (ESHE) modeling framework estimates only juvenile rearing habitat need but provides more detailed estimates in time and space than the Chinook Carrying Capacity Calculator. Two separate ESHE modeling efforts, with different modeling assumptions, involved the Stanislaus River: San Joaquin River Basin ESHE (https://fishsciences.shinyapps.io/san-joaquin-eshe/) and Stanislaus ESHE (https://fishsciences.shinyapps.io/stanislaus-eshe/).

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D1.3.6 San Joaquin River Lower Basin

D1.3.6.1 *Habitat*

D1.3.6.1.1 Lower San Joaquin River Rearing Habitat

Summary

Reclamation will increase rearing habitat in the San Joaquin River by modifying channel topography to create seasonally-inundated floodplains. Key considerations involve the potential to inundate edge habitats and floodplains by increasing local water surface elevation. Side channel excavation, floodplain lowering, and woody debris placement will also be considered for the creation of juvenile rearing habitat.

Description

Reclamation proposes to create a regional partnership to define and implement a large-scale floodplain habitat restoration effort in the Lower San Joaquin River. This stretch of the San Joaquin River is cut-off from its floodplain due to an extensive levee system, with two notable exceptions at Dos Rios Ranch (1,600 acres) and the San Joaquin River National Wildlife Refuge (2,200 acres). In recent years, there has been growing interest in multi-benefit floodplain habitat restoration projects in the Central Valley that can provide increased flood protection for urban and agricultural lands, improved riparian corridors for terrestrial plants and wildlife, and enhanced floodplain habitat for fish. The resulting restoration could include thousands of acres of interconnected (or closely spaced) floodplain areas with coordinated and/or collaborative funding and management. Such a largescale effort along this corridor would require significant support from a variety of stakeholders, which could be facilitated through a regional partnership.

Objectives

- Fundamental objective: Increase juveniles at Chipps Island per adult
- Means objectives: Abundance, productivity, and spatial structure

Conceptual Model (Each Species and Life stage)

Restoration efforts target juvenile Chinook Salmon and Steelhead during the in-river rearing phase of their life history, prior to outmigration. Restoration activities can reduce multiple stressors during this life stage including: reducing predation, providing refuge habitat, and increasing food availability (Windell et al. 2017).

Current Condition

The San Joaquin River is heavily impacted by water diversion, levees, flow regulation, and agricultural and urban runoff (SJRRP 2010). These factors have degraded salmon habitat quality throughout the San Joaquin River below Friant Dam. Physical barriers, reaches with poor water quality or no surface flow, and the presence of false migration pathways have reduced habitat connectivity for anadromous and resident fishes (SJRRP 2010, 2016, and references therein).

Background

Historically, several Chinook Salmon runs were present in the San Joaquin River, with population estimates in the hundreds of thousands (Yoshiyama et al. 1998). Following European expansion starting in the mid-1800's, the San Joaquin River Spring-Run Chinook Salmon population was extirpated. Fall-Run and Spring-Run Chinook Salmon were extirpated from the San Joaquin River following the completion of Friant Dam and resultant channel dewatering over 60 years ago. The last documented run of Spring-Run Chinook Salmon in the upper San Joaquin River Basin was observed in 1950 and consisted of only 36 individuals (Warner 1991). Since the 1950s, only Fall-Run Chinook Salmon remained in the San Joaquin River, found in its major tributaries (SJRRP 2010).

Current Science

Restoring side channel and floodplain connectivity in heavily impacted rivers can recover productive rearing habitat for juvenile salmonids (Richards et al. 1992; Heady and Merz 2006). Rearing habitat is described as the physical conditions, including water temperature, dissolved oxygen (DO), turbidity, substrate size and composition, water velocity and depth, and available cover (Bjornn and Reiser 1991; Healey 1991; Jackson 1992), which maintain the biological components (e.g., invertebrate prey resources) critical to habitat productivity for fish (Simenstad and Cordell 2000). The importance of floodplain habitats as productive foraging areas and predator refuge for rearing juvenile salmon, compared to main river channels, has been well documented (Grosholz and Gallo 2006; Jeffres et al. 2008; Bellmore et al. 2013). Previous studies in the Central Valley and in other systems have demonstrated that creating or enhancing off-channel floodplain habitat can increase the quantity and quality of floodplain rearing habitat under a range of flow conditions, and that juvenile salmonids utilize these restored habitats (Sellheim et al. 2015; CFS 2013; Ogston et al. 2014). Inundated floodplains can enhance juvenile salmonid growth and survival because water temperatures, prey biomass, and velocities are more favorable compared to main channel habitat (Kjelson et al. 1981; Ahearn et al. 2006). Juveniles that spend more time rearing in off-channel habitats and enter the ocean environment at a larger body size have increased survivorship (Sommer et al. 2001).

A recent study examined rearing habitat quality and juvenile Chinook Salmon growth within three distinct reaches of the San Joaquin River between Friant Dam and the SJNWR (Zeug et al., in revision). This study found that water quality, prey densities, and juvenile growth rates were highest in the site furthest downstream, which was within the Merced NWR. Rearing conditions were best early in the rearing period, before late spring when water temperatures became stressful.

Justification

Floodplain restoration areas could offer increased flood protection for urban (i.e., Stockton, Manteca, and Lathrop) and agricultural lands, especially in high runoff years like 2011 and 2017. Greater riparian habitat would support sensitive plant and wildlife species (e.g., riparian brush rabbit, Swainson's hawks, giant garter snakes). The Stanislaus, Tuolumne, Merced tributaries, and increasingly the San Joaquin River, all support populations of migratory salmonids that would benefit from floodplain access. Outmigrating juvenile salmonids utilizing floodplains grow faster, which may lead to increased survival through the South Delta, a region with unusually low survival.

Local agencies, NGOs, and private entities in the area would likely all be supportive of some form of multi-benefit restoration planning in the region, as long as they had opportunities for input in the process and had clear and direct benefits. The Bay-Delta Conservation Plan, The Delta Conservation Framework, and A Delta Renewed guide have identified the lower San Joaquin River and South Delta region as needing multi-benefit restoration projects to support the ecosystem and local landowners. Multi-benefit flood control projects are in keeping with the FloodSAFE California initiative and the Central Valley Flood Protection Plan. Several organizations and State and Federal agencies are involved in Central Delta Corridor Partnership (a similar partnership) and may be supportive of an effort in the lower San Joaquin River: TNC, Metropolitan Water District of Southern California, DWR, California Department of Parks and Recreation, California Waterfowl Association, Bureau of Land Management, USFWS, and CDFW.

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