Attachment 5: Effects Analysis

Sites Reservoir Project Operations Effects on Delta Smelt (*Hypomesus transpacificus*), Longfin Smelt (*Spirinchus thaleichthys*) Sacramento River Winter-run Chinook Salmon (*Oncorhynchus tshawytscha*), Central Valley Spring-run Chinook Salmon (*O. tshawytscha*), and California White Sturgeon (*Acipenser transmontanus*)

Prepared by California Department of Fish and Wildlife
Water Branch

Water Branch
1010 Riverside Parkway
West Sacramento, California

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List of Acronyms and Abbreviations

°C	degrees Celsius
°F	degrees Fahrenheit
AF	acre-feet
Alt3B	Project with exchanges
BBR	CDEC station for Bend Bridge
Cal. Code Regs.	California Code of Regulations
CalSim II	California Water Resources Simulation Model II
CBD	Colusa Basin Drain
CCF	Clifton Court Forebay
CDEC	California Data Exchange Center
CDFG	California Department of Fish and Game
CDFW	California Department of Fish and Wildlife
CESA	California Endangered Species Act
cfs	cubic feet per second
CHNFR	fall-run Chinook Salmon (*Oncorhynchus tshawytscha*)
CHNLFR	late fall-run Chinook Salmon (*Oncorhynchus tshawytscha*)
CHNSR	spring-run Chinook Salmon (*Oncorhynchus tshawytscha*)
CHNWR	winter-run Chinook Salmon (*Oncorhynchus tshawytscha*)
CIMIS	California Irrigation Management Information System
cm	centimeter(s)
CNFH	Coleman National Fish Hatchery
Commission	California Fish and Game Commission
CPUE	Catch per unit effort
CT	Central Tendency
CTmax	Critical thermal maxima
CVP	Central Valley Project
D-1641	SWRCB Water Rights Decision 1641
DCC	Delta Cross Channel
DDFT	Daily Divertible Flow Tool
Delta	Sacramento-San Joaquin Delta
DIDSON	Dual-frequency identification sonar
DMCP	Delta Mercury Control Program
DO	Dissolved oxygen
Dph	Day(s) post-hatch
DPM	Delta Passage Model
DRAT	Diversion Routing Analysis Tool
DS	Delta Smelt (*Hypomesus transpacificus*)
DSM2	Delta Simulation Model 2
DWR	California Department of Water Resources
ECO-PTM	Ecological Particle Tracking Model
ECPUE	Expected catch per unit effort
ESA	Endangered Species Act
ESU	Evolutionarily Significant Unit
FEIR	Final Environmental Impact Report
FL	Fork length

fps	Feet per second
FR	Federal Register
FRFH	Feather River Fish Hatchery
ft	foot (feet)
GCID	Glenn Colusa Irrigation District
GLMM	Generalized Linear Mixed Model
HAB	Harmful algal bloom
HCFS	Hamilton City Fish Screen
HMC	CDEC station for Hamilton City
IOS	Interactive Object-oriented Simulation
ITP	Incidental Take Permit
IUCN	International Union for Conservation of Nature
JPE	Juvenile Production Estimate
JSATS	Juvenile Salmon Acoustic Telemetry System
KLOG	Knights Landing Outfall Gates
KLRC	Knights Landing Ridgecut Slough
km	kilometer
LFS	Longfin Smelt (*Spirinchus thaleichthys*)
LFSLCM	Longfin Smelt life cycle model
LSZ	Low salinity zone
LOO	Leave-One-Out cross validation
LSNFH	Livingston Stone National Fish Hatchery
m	meter
MAF	million acre feet
m/s	meter(s) per second
mm	millimeter(s)
NAA	Baseline conditions with no Project; No Action Alternative
NDFS	North Delta Food Subsidy
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NoSha	Project without exchanges with Shasta Reservoir
NoShaOro	Project without exchanges with Shasta or Oroville Reservoir
OBAN	Oncorhynchus Bayesian Analysis
OMR	Old and Middle River
Oxbow	Hamilton City Oxbow
Permittee	Sites Project Authority
PIT	Passive integrated transponder
ppt	parts per thousand
Project	Sites Reservoir Project
PTM	Particle Tracking Model
QWEST	Net flow on the San Joaquin River at Jersey Point
RBDD	Red Bluff Diversion Dam
RBFS	Red Bluff Fish Screen
RCS	Ridge Cut Slough
RD22	Road 22
Reclamation	United States Bureau of Reclamation
rkm	River kilometer
RM	River Mile

RST	Rotary Screw Trap
salvage facilities	John E. Skinner Delta Fish Protective Facility and Tracy Fish Collection Facility
SDD	Stage Dependent Diversion
SFE	San Francisco Estuary
SL	Standard length
SRLCM	spring-run life cycle model
STARS	Survival, Travel Time, and Routing Simulation
SWP	State Water Project
SWRCB	State Water Resources Control Board
TAF	thousand acre-feet
TCC	Tehama Colusa Canal
TCCA	Tehama Colusa Canal Authority
TRR	Terminal Regulating Reservoir
TL	Total length
Toe Drain	Yolo Bypass Toe Drain Canal
UC	University of California
USEPA	United States Environmental Protection Agency
USFWS	United States Fish and Wildlife Service
USRDOM	Upper Sacramento River Daily Operations Model
VIN	CDEC station for Vina
Water Year Type	Water year types were classified using the Sacramento Valley Index and noted as Wet (W), Above Normal (AN), Below Normal (BN), Dry (D), and Critical (C).
White Sturgeon - WS	SFE White Sturgeon Distinct Population Segment (*Acipenser transmontanus*)
WLK	CDEC station for Wilkins Slough
WRLCM	Winter Run Life Cycle Model
WSE	Water surface elevation
WUA	Weighted Usable Area
WWFCF	Wallace Weir Fish Collection Facility
WY	Water year
X2	The two ppt isohaline location in km from the Golden Gate Bridge
YOY	young-of-year

1. INTRODUCTION

In response to the Sites Project Authority's (Sites Authority) request for authorization for the incidental take of winter-run Chinook Salmon (*Oncorhynchus tshawytscha*, CHNWR), spring-run Chinook Salmon (*O. tshawytscha*, CHNSR), Longfin Smelt (*Spirinchus thaleichthys,* LFS), Delta Smelt (*Hypomesus transpacificus,* DS), and the San Francisco Estuary (SFE) White Sturgeon Distinct Population Segment (*Acipenser transmontanus,* WS) under the California Endangered Species Act (CESA) for future operations of the Sites Reservoir Project (Project), the California Department of Fish and Wildlife (CDFW) has conducted analyses to evaluate the incidental take anticipated due to Project operations, and to inform Conditions of Approval for the Incidental Take Permit (ITP) that will minimize incidental take and impacts of the taking.

2. BACKGROUND

In this Effects Analysis, California Department of Fish and Wildlife (CDFW) considers Project operations to be consistent with the project description, analyses, and modeling provided in the Sites Reservoir Project Incidental Take Permit Application for Operations, Exhibit 1 Supplemental Information for the Sites Reservoir Project Incidental Take Permit Application for Operations, and additional transmittals from Sites during consultation with CDFW (collectively, ITP Application; Sites Authority 2023). A description of the project and details about CDFW's analytical approach are provided below (See ITP No. 2081-2023-051-00 for full Project Description).

2.1. Project Description

Note: This abridged Project Description, including key project facilities and summary descriptions of operations that are relevant to Covered Species, is included here for the readers' convenience. Please see ITP No. 2081-2023-051-00 for a complete Project Description.

Project related activities include: (1) Diversion of upper Sacramento River water from the Bureau of Reclamation's (Reclamation) Red Bluff Pumping Plant (RBPP) and the Glenn Colusa Irrigation District's (GCID) Hamilton City Pump Station (HCPS) to divert a combined total of up to 986 thousand acre-feet (TAF) annually; (2) Water exchanges with Oroville Reservoir of up to 136 TAF annually; (3) Water exchanges with Shasta Reservoir of up to 188 TAF annually; (4) Real-time exchanges and transfers between participants of up to 160 TAF annually; (5) Releases of up to 139 TAF annually for north-of-Delta participants and wildlife refuges north-of-Delta; (6) Releases of up to 637 TAF annually for downstream and south-of-Delta participants into (lower) Sacramento River and releases to the Yolo Bypass through Wallace Weir; and (7) Limited fish screen maintenance activities associated with Project diversions at the RBPP and HCPS diversion facilities.

2.1.1. Key Project Facilities

Red Bluff Pumping Plant – an existing diversion facility owned by the Bureau of Reclamation (Reclamation) and operated by the Tehama Colusa Canal Authority (TCCA), the RBPP consists of a 1,118-foot-long flat plate fish screen with 1.75-millimeter (mm) slot sizing, diversion channel, and pumping plant to divert water from the Sacramento River into the Tehama Colusa Canal.

Hamilton City Pump Station – an existing facility owned and operated by the GCID, the HCPS consists of a 1,100-foot-long flat plate fish screen on an oxbow of the Sacramento River (Hamilton City Oxbow), a flow control weir, and a pumping plant to divert water from the Sacramento River into the GCID Main Canal.

Tehama Colusa Canal – The Tehama Colusa Canal is a 110-mile-long concrete-lined canal that will convey water from the Sacramento River at the RBPP to Sites Reservoir, and from Sites Reservoir for downstream participants.

Glenn Colusa Irrigation District Main Canal – The GCID Main Canal is a 65-mile-long earthen canal that will convey water from the Sacramento River at HCPS to Sites Reservoir, and from Sites for downstream participants.

Sites Reservoir – A new 1.5 MAF reservoir, Sites Reservoir will impound water by the Golden Gate Dam on Funks Creek and the Sites Dam on Stone Corral Creek.

Colusa Basin Drain – an existing 70-mile earthen channel, CBD is gravity fed and will convey water from Sites Reservoir for downstream participants, along with agricultural runoff from the surrounding area, into the Sacramento River and the Yolo Bypass.

Knights Landing Outfall Gates – an existing DWR facility at the terminal end of the CBD, KLOG are operated to allow water from the CBD to enter the Sacramento River and to prevent backwater flooding into the CBD from the Sacramento River. The Project proposes to release water from the CBD to the Sacramento River at KLOG.

Knights Landing Ridge Cut – an existing channel that conveys flows from the CBD into the Yolo Bypass downstream of the Fremont Weir through the Wallace Weir Facility. The Project proposes to release water from the CBD into the Yolo Bypass through the Knights Landing Ridge Cut.

2.1.2. Project Operations Summary

Sites Authority will use existing infrastructure to divert flow from the Sacramento River at RBPP and HCPS diversion facilities to convey water to, and release water from, the new off-stream Sites Reservoir. The Project will divert a maximum annual total of 986 thousand acre-feet (TAF) per year from the Sacramento River from September 1 to June 14. At RBPP, maximum annual diversion will be 660 TAF per year, and the maximum instantaneous diversion rate will be 2,120 cfs. At HCPS, the maximum annual diversion will be 421 TAF per year, and the maximum instantaneous diversion rate will be 2,070 cfs. Sites Reservoir will release a maximum of 776 TAF per year to local participants and downstream participants via the GCID Main Canal, TCC and Sacramento River via the CBD and KLRC through the WW. Sites Reservoir will exchange up to 188 TAF per year with the CVP's Shasta Reservoir[4] and up to 136 TAF per year with the SWP's Oroville Reservoir. In addition, Sites Authority may facilitate annual exchanges of up to 160 TAF for real-time exchanges or transfers with participants.

2.1.2.1. Coordination with CVP and SWP, Exchanges, and Transfers

For the purposes of this ITP, the Sites Authority has made assumptions regarding Reclamation's actions to implement CVP operational flexibility with its storage in Sites Reservoir, associated with its 16% investment. Sites Authority has also made assumptions regarding the degree of real-time exchanges and transfers that participants will implement and the degree to which exchanges with Shasta and Oroville reservoirs will occur. It is expected that further clarification on the degree to which exchanges will be implemented and how Reclamation will implement CVP operational flexibility will be known after operational agreements with Reclamation and DWR are executed.

2.1.2.2. Releases from Sites Reservoir

Releases from Sites Reservoir may be made in any water year type through five separate operations: (1) releases along the Tehama Colusa Canal and GCID Main Canal; (2) releases along the CBD, Yolo Bypass, Sacramento River downstream of Knights Landing, and North Bay Aqueduct via direct release through the DP; (3) releases for participants along the Sacramento River via exchange with Sacramento River at HCPS or RBPS by replacing CVP diversions at these locations with releases from Sites; (4) Shasta exchanges; and (5) Oroville exchanges.

2.2. Analytical Approach for Effects Analysis

Note: Each effect analyzed in this document includes an introductory paragraph, formatted like this paragraph, describing why take or impacts of the taking could be reasonably expected to occur as a result of Project operations. This is intended to provide the reader with an understanding of why CDFW is evaluating the potential effect in plain language.

CDFW identified and analyzed the potential effects of the Project using best available science, including: (1) Information provided by Sites in the ITP Application and during Project consultation; (2) Visualization and analysis of Sites' model results completed by CDFW; (3) Additional analyses and modeling conducted by CDFW to evaluate Project effects; (4) Peer-reviewed scientific literature relevant to understanding Project impacts on listed species; and (5) Technical reports, regulatory documents, and input from subject matter experts.

For transparency, each analysis in this document describes the specific data sources, models, assumptions, and calculations used to analyze take or impacts of the taking as a result of Project operations. When CDFW's analysis or conclusion differ from what was provided in the ITP Application (Sites Authority 2023), the reasoning is clearly described.

Uncertainty is identified where it exists and, whenever possible, quantified. As operational agreements are not yet in place with Shasta and Oroville reservoirs, CDFW analyzed effects for three different operational scenarios (see Section 2.2.1). CDFW's approach for addressing operational, biological, environmental, and project uncertainty is described in Section 2.2.2.

2.2.1. Sites Project Alternatives and Exchange Scenarios

To understand potential impacts of the Project without certainty in the timing, magnitude, and details of operational exchanges, CDFW analyzed the effects of three operational scenarios that represent alternative implementations of exchanges with other large reservoirs in the Sacramento River basin.

No Action Alternative (NAA): The NAA was modeled and analyzed under the regulatory environment as of November 2021 under 2035 Central Tendency (CT) climate conditions and 15 cm sea level rise.

Alternative 3B (Alt3B): In addition to the regulatory environment and climate change assumptions for the NAA, Alt3B assumes United States Bureau of Reclamation (Reclamation) investment of up to 16% and 230 TAF of storage in the Sites Reservoir for use as Central Valley Project (CVP) operational flexibility. Alt3B also includes real-time exchanges or transfers, exchanges with Shasta, and exchanges with Oroville. The details of these exchange mechanisms are as follows:

CVP Operational Flexibility: assumes up to 230 TAF are preserved in Shasta during drier years through augmenting its conservation pool, and the Sites Authority would release water for Reclamation. This action was modeled in the ITP Application assuming if preserved Shasta storage is not spilled during the winter, Shasta enters the temperature management period with greater storage, improving cold-water pool and release volumes in drier years. If additional storage remains at the end of the temperature management period, storage releases may occur to increase the duration of Fall flow stability releases. In practice, it will be at Reclamation's discretion as to how the water will be used under CVP operational flexibility.

Real-Time Exchanges and Transfers: assumes maximum annual exchanges or transfers of up to 160 TAF with local storage participants. This type of exchange or transfer is most likely to occur with GCID but could also occur with other Sacramento River Settlement Contractors and Reclamation. Instead of diverting all or a portion of its water from the Sacramento River, the local storage participant would receive a portion of its water from Sites Reservoir. A portion of the local agencies' supply would be left in the Sacramento River (i.e., not diverted by that contractor or agency) and used for other storage participants.

Oroville Exchange: assumes maximum annual exchanges of up to 136 TAF per year with the State Water Project (SWP) Oroville Reservoir in Below Normal, Dry, and Critically Dry Water Years. Under an Oroville exchange, water would be released from Sites Reservoir in June and July to meet SWP purposes. In August through November, during the transfer window, California Department of Water Resources (DWR) would release an equivalent amount of water from Lake Oroville for storage participants. No exchanged water would be carried over from year to year. Exchanges with Lake Oroville are expected to happen more frequently than Shasta Lake exchanges. Releases of exchanged water shall not result in an exceedance of the maximum Feather River fall stability flow requirements.

Shasta Exchange: assumes maximum annual exchanges of up to 188 TAF per year with Shasta Reservoir in Dry and Critically Dry Water Years. These exchanges would use storage participants' share of Sites Reservoir storage, not including the use of Reclamation's share of the storage, in a manner to meet CVP deliveries and obligations as much as possible via Sites Reservoir to preserve water stored in Shasta Lake. Exchanges with Shasta Reservoir are also a primary mechanism for Project water deliveries to south-of-Delta participants due to the 1,000 cubic feet per second (cfs) limitation of Dunnigan pipeline (Sites Authority 2023). In the spring of Shasta Exchange years, Sites would release water for CVP uses in lieu of Shasta. As Sites Reservoir is releasing water for CVP uses, Shasta Lake releases would be reduced, preserving Shasta Lake storage and its cold-water pool through the spring (April–June). The volume of delivered water by Sites is equivalent to the exchange volume preserved in Shasta Reservoir. In late summer and fall (August–November), the preserved volume is released to Sites participants. At the end of the contract year (February), excess volume preserved in Shasta will be spilled.

No Shasta Exchanges (NoSha): In addition to the regulatory environment and climate change assumptions for the NAA, NoSha assumes the Project operates without a 16% Reclamation investment and without Shasta exchanges, but it includes Oroville exchanges and real-time exchanges or transfers.

No Shasta No Oroville Exchange (NoShaOro): In addition to the regulatory environment and climate change assumptions for the NAA, NoShaOro assumes the Project operates without a 16% Reclamation investment and without Shasta and Oroville exchanges, but it includes real-time exchanges and transfers.

2.2.2. Flow Models of Operations for Analyzing Effects

California Water Resources Simulation Model II (CalSim II) is the base model for all other hydrological, hydraulic, temperature, and biological modeling provided in the ITP Application (Sites Authority 2023). Modeling assumptions, including when and how exchanges would occur between Sites and Shasta and Oroville reservoirs, for CalSim II, Delta Simulation Model II (DSM2), HEC5Q, and Reclamation Temperature Model simulations of the Project are described in detail in Appendix 4A of the ITP Application (Sites Authority 2023). Modeling of the Alt3B operational scenario includes a representation of exchanges with Shasta and Oroville reservoirs, CVP operational flexibility based on Reclamation's investment in Sites, and real-time exchanges and transfers with participants. Appendix 4Q of the ITP Application (Sites Authority 2023), Water Exchange Criteria describes the criteria for the anticipated exchanges with the CVP and SWP that were modeled for this analysis and includes the associated trend reporting sheets and exchange volume timeseries.

2.2.2.1. California Water Resources Simulation Model II (CalSim II)

CalSim II is a hydrologic and water operations model developed jointly by the DWR and Reclamation. It operates on a monthly timestep and has a simulation period of 82 years (1922–2003), with some components (e.g., weir spills) calculated with daily shaping. CalSim II is primarily designed to represent planning-level decision making, particularly those impacting reservoir levels, coordinated operations between SWP and CVP, and monthly average conditions in the Sacramento- San Joaquin Delta (Delta), and is therefore an important tool for the Project to evaluate interactions with their participants and other water users in the system.

In practice, exchanges with Shasta Reservoir would occur at the discretion of Sites Authority and Reclamation; however, CalSim II modeling assumptions for these exchanges include:

In October through February, modeling of Shasta exchange operations assumes releases for fall flow stability when: (1) end of May Sites Reservoir storage is greater than 80% of total active capacity, (2) Shasta Reservoir storage was greater than 3.2 million acre feet (MAF) in the previous month, and (3) fall flow stability is already active. If exchange volume is not available in Shasta, releases are considered CVP credits in Sites. For fall flow stability, credited water cannot exceed 100 TAF in a given month, and total credited volume cannot exceed 200 TAF. Credited water is returned via exchange (temperature management in April through June, or spring pulse/fall flow stability in July through September) or is considered returned when Shasta spills (i.e., the volume of spill is the volume of return).

Modeling of Shasta exchange operations assumes a release for spring pulse flows in May when: (1) end of April Sites Reservoir storage is greater than 80% of total active capacity, and (2) end of April Shasta Reservoir storage (not including CVP operational flexibility) is greater than 4.1 MAF. If exchange volume is not available in Shasta Reservoir, releases are considered CVP credits in Sites. For spring pulses, credited water cannot exceed 75 TAF. Credited water is returned via exchange (temperature management in April through June, or spring pulse/fall flow stability in July through September) or is considered returned when Shasta Reservoir spills (i.e., the volume of spill is the volume of return).

2.2.2.2. Upper Sacramento River Daily Operations Model (USRDOM)

The Upper Sacramento River Daily Operations Model (USRDOM) is a daily timestep HEC-5 model developed by Reclamation and used as a daily CalSim II post-processor for the ITP Application (Sites Authority 2023). USRDOM includes hydrologic routing, which attenuates flows (i.e., reduced peak, longer duration) as they move downstream. USRDOM uses monthly averaged Project diversions from CalSim II, which limits its utility for some analyses. The ITP Application (Sites Authority 2023) primarily uses USRDOM to analyze spills over Tisdale Weir into Sutter Bypass, and CDFW uses USRDOM for some additional analyses in this Effects Analysis.

2.2.2.3. Sites Authority Reservoir Daily Divertible Flow Tool (DDFT)

The Daily Divertible Flow Tool (DDFT) is a spreadsheet simulation of potential Project diversions on a daily timestep provided in the ITP Application (Sites Authority 2023). DDFT uses historical hydrology to determine the timing and magnitude of diversions that would have been available based on the proposed diversion criteria for the Project. Because the tool does not include any hydrologic routing, diversions are assumed to reduce streamflow fully and immediately at downstream locations. DDFT looks only at diversions and does not include any reservoir operations or exchanges; it only estimates the maximum daily diversion that would have occurred under historical conditions.

2.2.2.4. Diversion Routing Analysis Tool (DRAT)

To analyze the effects impacts of Project diversions at downstream locations on the Sacramento River, including Yolo and Sutter bypasses, CDFW developed a new spreadsheet tool called the Diversion Routing Analysis Tool (DRAT), which combines the detail from multiple tools provided in the ITP Application (Sites Authority 2023). The approach for DRAT is similar to that of DDFT, as it uses historical hydrology and designation of "excess,"[1] as well as proposed diversion criteria, to determine the maximum daily water volume that could be diverted for the Project. DRAT then applies the hydrologic routing parameters from USRDOM to estimate the effect of Project diversions on downstream observed hydrographs.

The following components have been included in DRAT:

- Historical Hydrology (Water Years 1997–2023)
- Historical Excess Conditions (January 1, 2000, through September 30, 2019)
- Hydrologic routing parameters from USRDOM for the Sacramento River and Sutter Bypass
- Physical limitations on Red Bluff and Hamilton City Diversions
- Historical Diversions at Red Bluff and Hamilton City
- Bend Bridge Pulse Protection Criterion
- Wilkins Bypass Criterion (with/without forecasting)
- Flow Dependent Diversions Framework
- Tisdale Weir Rehabilitation and Fish Passage Project (on/off)
- Fremont Weir Big Notch Project (on/off)
- Spills at Ord Ferry, Moulton Weir, Colusa Weir, Tisdale Weir, and Fremont Weir on the Sutter Bypass

The outputs of DRAT are historical flows with and without maximum Project diversions, at various locations down the Sacramento River. DRAT also roughly estimates the 5-way intersection of flow

[1] Delta conditions are in "excess conditions" if water is available for export in excess of the flow required to meet Water Right Decision 1641 (D-1641; SWRCB 2000) flow and salinity requirements as well as other applicable regulations. Excess water conditions are periods when it is mutually agreed between Reclamation and DWR that releases from upstream reservoirs plus unregulated flows are greater than Sacramento Valley in-basin uses plus Delta exports.

at Verona/Fremont Weir, and it then calculates routed Yolo Bypass flow and routed Sacramento River flow at I Street Bridge, which can be used as inputs to DSM2.

Because DRAT estimates the maximum possible diversion and does not consider reservoir capacity and other constraints, CDFW considers the results to be an estimate of maximum downstream impacts of Project diversions. For this reason, DRAT is most useful for comparing different alternatives and informing actions to minimize near-field and downstream impacts of Project diversions.

2.2.2.5. Delta Simulation Model II (DSM2)

DSM2 is a one-dimensional mathematical model that simulates hydrodynamics (including tidal influence), water quality (e.g., salinity, temperature, dissolved oxygen (DO), and particle tracking. It is a daily time-step model, but the boundary condition river flows are based on a monthly time series from CalSim II (Sites Authority 2023, Appendix 4A). Results from DSM2 are used to analyze Project effects on conditions in the Delta that affect habitat and are also used as input for other models (e.g., routing and survival of Chinook Salmon).

2.2.3. CDFW's Approach to Uncertainty

CDFW acknowledges that it is not possible to predict the future, and that there is uncertainty in hydrology and water management, in ecological and biological responses, and in how the interaction between these is represented in computational modeling. In this Effects Analysis, CDFW uses the best scientific and technical information currently available. Analyses include descriptions of model limitations and uncertainty to provide transparency about knowledge gaps and to explain the reasoning behind the ITP's protective measures. The uncertainty does not prevent CDFW from fulfilling its obligations under CESA to minimize and fully mitigate the impacts of the Project to Covered Species. Where uncertainty exists, CDFW applied protective measures that reflected the level of uncertainty.

2.2.3.1. Operational Uncertainty

Without operational agreements in place that specify how Reclamation will use their investment in the Project, or how the lower Colusa Basin Drain (CBD) will be operated, there is uncertainty around the potential direct and indirect impacts and benefits to listed fish species as a result of Project operations. Exchanges with Shasta or Oroville reservoirs could be implemented in ways that are either beneficial or harmful to Covered Species. Benefits to CHNWR from increased cold-water pool volume in Shasta Reservoir may or may not occur. Transfers and exchanges of water among Sites participants are assumed to occur in all three operational scenarios modeled, and may facilitate changes in pumping and exports at the diversion facilities in the Delta that cannot be quantified separately from other Project operations. Additionally, the water quality of Project releases to the Sacramento River is dependent on the quality of other water in the CBD and operations of facilities in the CBD from the Dunnigan Pipeline to Knights Landing Ridge Cut and Knights Landing Outfall Gates (KLOG). To accommodate operational uncertainty during ITP development, CDFW took the approach of: (1) evaluating the effects of operational scenarios with and without exchanges with Shasta and Oroville reservoirs; (2) evaluating the effects of a range of release volumes through the CBD and KLOG to the Sacramento River; (3) determining where and when effects differ among operational scenarios; and (4) including measures requiring the Project to further examine these potential effects and demonstrate, through scientific studies and modeling, that Project operations will avoid or minimize impacts.

CDFW has found that this operational uncertainty creates the greatest uncertainty in impacts to listed fish species for certain locations and life stages. These include: (1) changes in egg-to-fry survival of CHNWR due to exchanges with Shasta Reservoir (Section 4.1.4), (2) changes in flow and temperature in the Sacramento River due to exchanges with Shasta and Oroville reservoirs (Sections 4.1.2.1 and 4.4.4.1), (3) water quality, temperature, and quantity of releases to the Sacramento River and Yolo Bypass, (Sections 4.1.2.2 and 4.4.4.2), (4) the effects of the Project on survival, production, and escapement (i.e., the number of returning spawners) of CHNWR (Section 4.1.10) and CHNSR (Section 4.1.11); and (5) water quality and temperature of releases to the Sacramento River (Section 4.1.3) and Yolo Bypass (Sections 4.1.2.2 and 4.3.1)

2.2.3.2. Biological Uncertainty

Even with focused scientific research on the effects of changes in flow on listed fish species in the Sacramento and San Joaquin rivers and Delta, remaining knowledge gaps exist regarding the degree of impacts to Covered Species across their life history. This Effects Analysis identifies those areas of biological uncertainty and, when possible, identifies science actions to assist in filling those gaps. For effects with high biological uncertainty, CDFW took the approach of: (1) quantifying uncertainty to the greatest extent possible based on the best available scientific information; (2) including measures that minimize and fully mitigate for those effects; (3) including science actions to validate or further CDFW's understanding of the effects of Project operations on species. CDFW found the greatest biological uncertainty around the following impacts and included science actions and advancements to address them: (1) direct and indirect effects to CHNSR, CHNWR, and WS near the diversion facilities; (2) timing and spatial distribution of WS spawning and larval/juvenile presence; (3) effects of changes in Delta outflow on recruitment of LFS; (4) hydrology and floodplain habitat availability and use in Sutter Bypass; and (5) rearing behavior and survival of smaller and earlier migrating CHNWR and CHNSR juveniles.

2.2.3.3. Modeling Uncertainty

A third category of uncertainty that CDFW considered is related to how the Project is represented in modeling supporting the ITP Application (Sites Authority 2023) and this Effects Analysis. Modeling uncertainty for specific mathematical and computational models used in this Effects Analysis is described, and, where possible, quantified, in the sections describing those modeling analyses. For example, the section analyzing water temperature describes uncertainty in the CE-QUAL water temperature model (Section 4.1.2.2), and the section describing the results of Chinook Salmon life cycle models describes the uncertainty and limitations of the Winter-run Life Cycle Model (WRLCM; Section 4.1.10.3).

Modeling assumptions, limitations, and uncertainty in the base hydrologic models, including CalSim II and DSM2, convey those same assumptions, limitations, and uncertainties to downstream models in ways that are not obvious or quantifiable. Some limitations of CalSim II include:

- CalSim II operates on a monthly time-step, which averages out variability and can mask effects that occur on daily or finer time scales. Even when CalSim II results are interpolated to daily values for input to a model with finer resolution, it does not capture extremes or variability, which is important for understanding effects on species.
- The CalSim II simulation period is 1922–2003 (82 years), ending more than 20 years ago. Climate change is considered by applying 2035 Central Tendency (CT) climate conditions and 15 cm sea level rise, but it assumes the water year type frequency and sequence from 1922–2003. Climate change is expected to result in more extremes, including longer and more extreme droughts; therefore, this year range may not represent future conditions well.
- CalSim II is an uncalibrated planning model and is not intended to be predictive of future operations. Results from CalSim II are intended to be used to compare scenarios against each other. While this can be useful for assessing changes in the CVP and SWP system operations and resulting incremental effects, CalSim II is limited in its ability to capture absolute conditions or conditions on a sub-monthly time step.
- CalSim II lacks detail in CBD, which is needed to capture changes in outflows that may be associated with the Project. In the model, there is no inflow into Sites, nor outflow out of Sites reservoir into Funks and Stone Corral creeks. CalSim II has a simplified and static representation of agricultural deliveries and return flows which will change with the Project. There is also no groundwater representation in CalSim II.

Even with these limitations, CalSim and these other base hydrologic models represent the best technical tools currently available to model Project operations and potential effects to Covered Species. To be computationally manageable, these models are simplified representations of a complex hydrologic and water resource management system. With knowledge of the above limitations of base hydrologic models, CDFW interprets the results of these models in relation to other modeled scenarios rather than as absolutes. When possible, this Effects Analysis also compares the results of modeled analyses to historical data to check for reasonableness. Collectively and generally, these limitations of the base hydrologic models lead CDFW to have more certainty in the direction of change between modeled scenarios than in the exact magnitude of that change. These analyses, including their limitations and results, are described in detail in Sections 4.1 through 4.4.

3. COVERED SPECIES LIFE HISTORY

The ITP Application (Sites Authority 2023) requests take authorization for the Project for the following CESA-listed species: Sacramento River winter-run Chinook Salmon (CHNWR; Endangered), Central Valley spring-run Chinook Salmon (CHNSR; Threatened), Longfin Smelt (LFS; Threatened), (Delta Smelt (DS, Endangered), and White Sturgeon (WS; Candidate for Listing). This section describes the life history, habitat, range and distribution, and population trends for each species to inform the analyses of effects in Section 4 of this Effects Analysis.

3.1. Winter-run Chinook Salmon (CHNWR)

Chinook Salmon are one of nine *Oncorhynchus* species distributed around the North Pacific Rim. The genus is found within the Family *Salmonidae* (salmon, trout, and char) in the Class Actinopterygii (ray-finned fish). Chinook Salmon, like all species within the genus, are anadromous. Adults spawn in freshwater and juveniles emigrate to the ocean where they grow to adulthood. Upon their return to freshwater, adults spawn and then die. In the Central Valley of California (Central Valley), there are four runs of Chinook Salmon. CHNWR are differentiated from other Central Valley Chinook Salmon by the timing of spawning migration, the degree of maturity of adult fish entering freshwater, their spawning areas, and emigration timing of juveniles. CHNWR are recognized as an Evolutionarily Significant Unit (ESU) of Chinook Salmon (Moyle 2002), and they maintain their genetic integrity by being temporally isolated from other runs in the Sacramento River system.

3.1.1. Species Life History

The life history of CHNWR, which return to freshwater from the ocean in winter but delay spawning until summer, is unique within the range of Chinook Salmon (Hallock and Fisher 1985; Moyle 2002). Adult CHNWR leave the ocean to begin their upstream spawning migration beginning in December, continuing upstream through July (Moyle 2002). Spawning and egg incubation occur during the warmest time of the year and require gravel-bedded stream reaches with cold, clean water to support developing embryos from April through October (NMFS 2014). Females lay approximately 5,000 eggs in shallow gravel nests called redds (WR PWT 2022), where they incubate for 40 to 60 days prior to emerging (NMFS 2014).

Juveniles migrate downstream from July through March, many rearing in side-channels, backwater areas, or tributaries to the Sacramento River or other non-natal habitats (Maslin et al. 1996; Silva 2014; Phillis et al. 2018), reaching the Delta from December through May (NMFS 2014). Residence time in the Delta is variable, and juveniles may spend one to four months rearing prior to entering San Francisco Bay on their way to the Pacific Ocean (del Rosario et al. 2013). CHNWR typically spend two years in the Pacific Ocean, where they travel in schools with other west coast salmon stocks and feed on smaller fish and amphipods and other crustaceans. Over 90 percent of CHNWR spawn at age three; however, some will return as two-year-old “grilse” or at age four or five (USFWS 2016; Satterthwaite et al. 2017).

3.1.2. Range and Distribution

CHNWR historically spawned in the upper reaches of Sacramento River, including the McCloud, Pit, and upper Sacramento rivers, and Battle Creek (Figure 3-1). Currently, the CHNWR ESU includes a single population that spawns in the mainstem Sacramento River below Keswick Dam (NMFS 2014) and an experimental population on Battle Creek. In the Pacific Ocean, CHNWR are generally further south than other Chinook Salmon runs, most found between Point Reyes and Point Sur in California (Satterthwaite et al. 2013).

Distribution and Migration Timing in the Sacramento River near Project Diversion Locations

CHNWR Adults and juveniles may be present near Project diversion locations at Red Bluff and Hamilton City from November through July and July through March, respectively (NMFS 2014). The majority of CHNWR juveniles migrate downstream past the diversion locations between September and the end of November (Figure 3-2), often moving in pulses during fall freshets (Poytress et al. 2014).

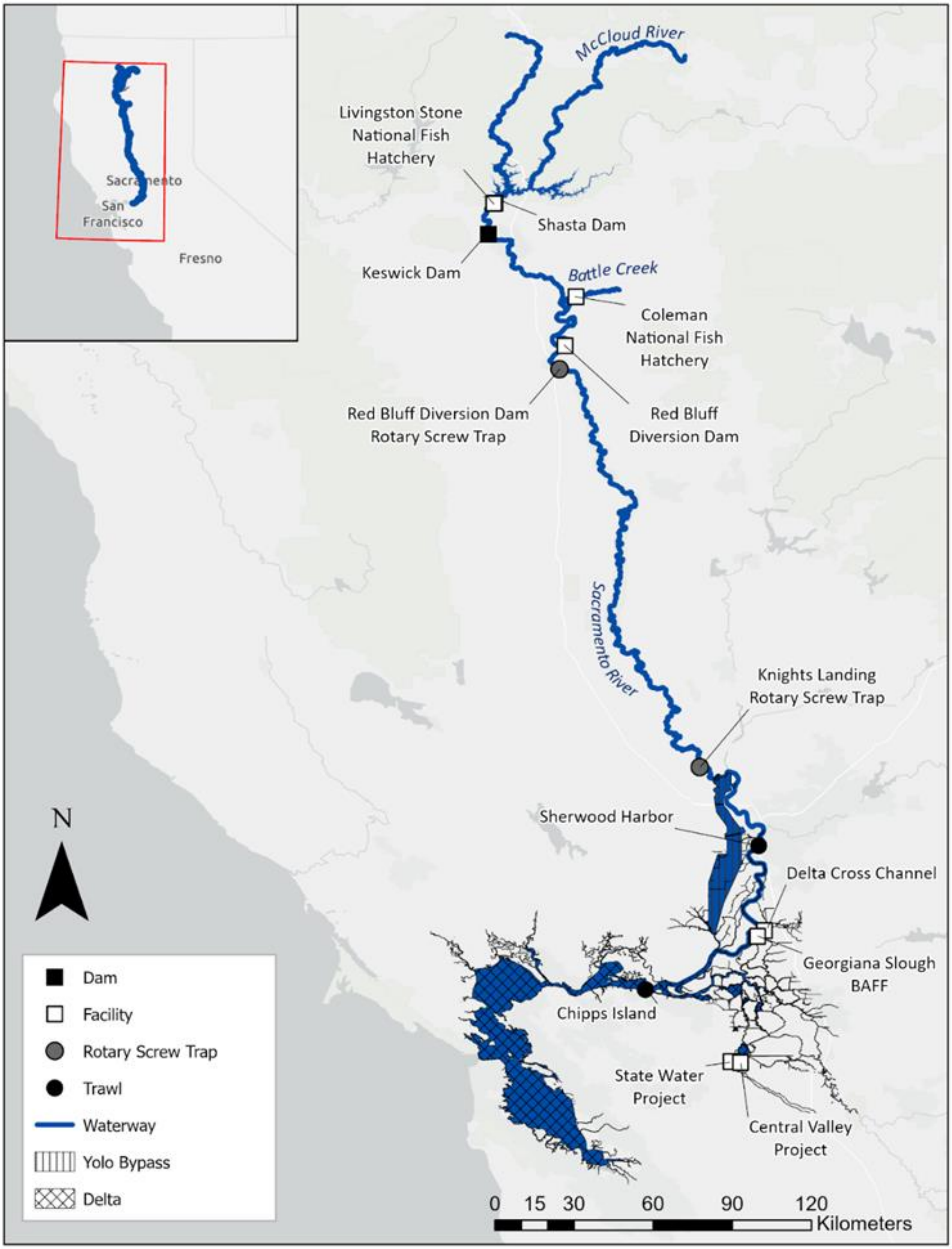

Figure 3-1. CHNWR distribution and relevant management related locations.

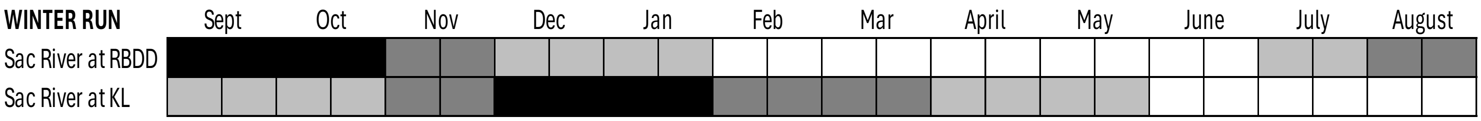

Figure 3-2. Winter-run Chinook Salmon juvenile migration timing at RBDD and Knights Landing. Darker colors represent higher abundance (Sources: CalFish 2024a, CalFish 2024b, Poytress et al. 2014, Williams et al. 2011)

Winter- run Chinook Salmon presence near Project Discharge Locations

CHNWR adults and juveniles are both present in the Delta and near the Project's discharge location between November and April. CHNWR sized juveniles are captured at the Knights Landing Rotary Screw Traps (RSTs), located approximately 4 km downstream of KLOG from late August through mid/late April (Columbia Basin Research 2024). Juvenile CHNWR may also utilize habitat in and around Knights Landing Ridge Cut immediately downstream of KLOG for rearing. CHNWR sized juveniles are also routinely captured by the United States Fish and Wildlife Service (USFWS) Delta Juvenile Fish Monitoring Program in beach seine sampling from October through March at the Knights Landing Boat Launch, approximately 0.2 km from KLOG (Figure 3-3; IEP et al. 2023a). Although juvenile CHNWR have not been captured in the limited beach seine sampling conducted in the Yolo Bypass by the DWR (IEP et al. 2023b), it is possible that they could enter the Yolo Bypass region via the Cache Slough Complex or at Fremont Weir.

Adults on their upstream spawning migration are present in the Sacramento River Basin from November through July (NMFS 2019), and genetically confirmed CHNWR adults have been captured in the Yolo Bypass region of the Delta from December through June (Figure 3-4). Adults may congregate immediately downstream of the KLOG if attracted by outflows at that location. In 2013, prior to construction of a fish barrier at KLOG, hundreds of CHNWR and CHNSR adults strayed into the CBD via KLOG and the Cache Slough Complex, perishing in upstream agricultural ditches (NMFS 2019, Kubo and Kilgour 2022). Thousands of fall-run Chinook Salmon (CHNFR) adults have also been observed to stray along these routes (NMFS 2019). The KLOG Fish Passage Barrier Project was constructed in 2015 to reduce Chinook Salmon adult straying and loss in the CBD (NMFS 2019). Currently, the fish barrier should prevent adult salmon from straying into the CBD via KLOG; however, outflows at KLOG may still attract adult salmon and delay their migration.

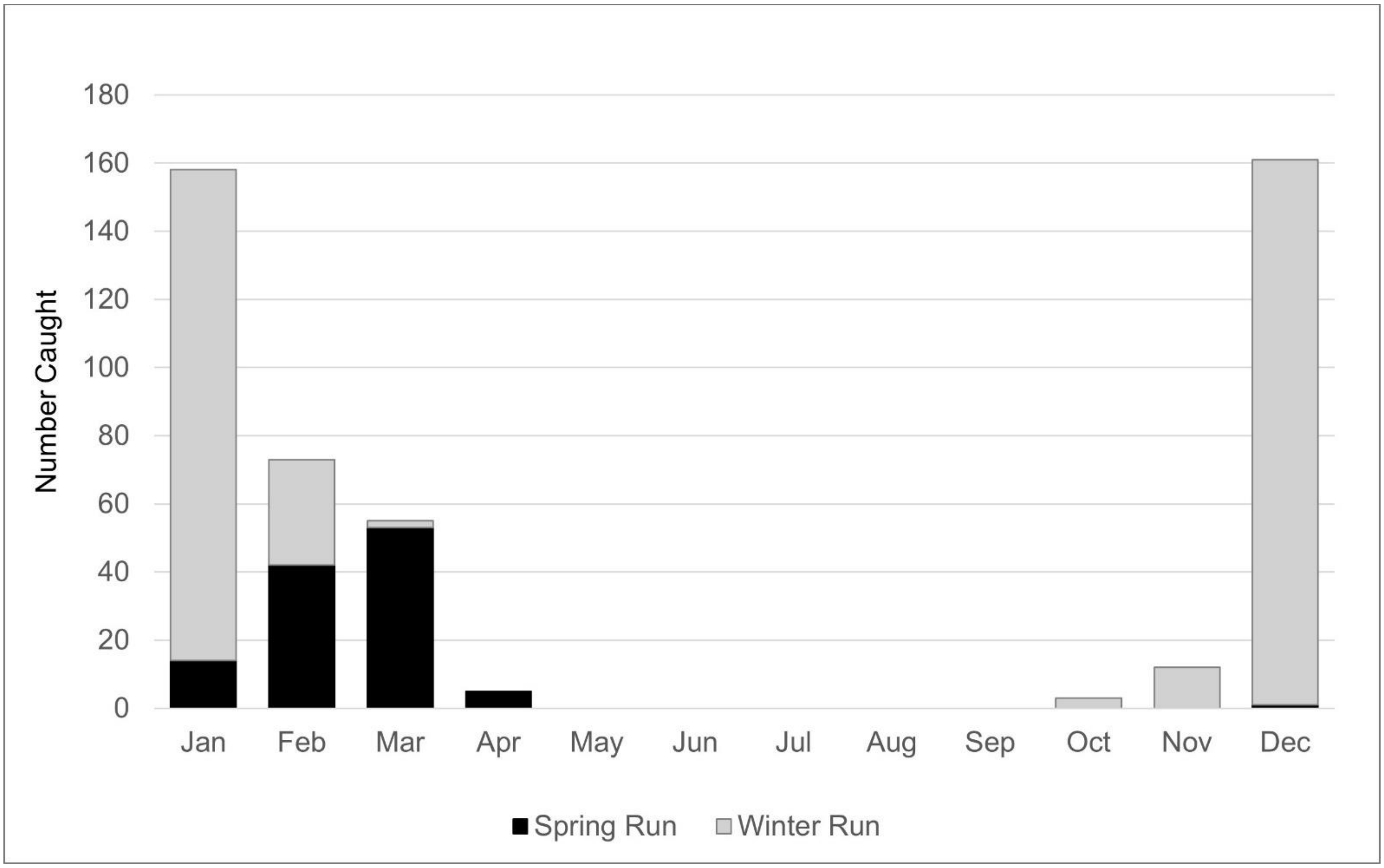

Figure 3-3. Juvenile spring-run and winter-run Chinook Salmon catch by month in the USFWS Delta Juvenile Fish Monitoring Program beach seine sampling at Knights Landing Boat Ramp, 2005–2017.

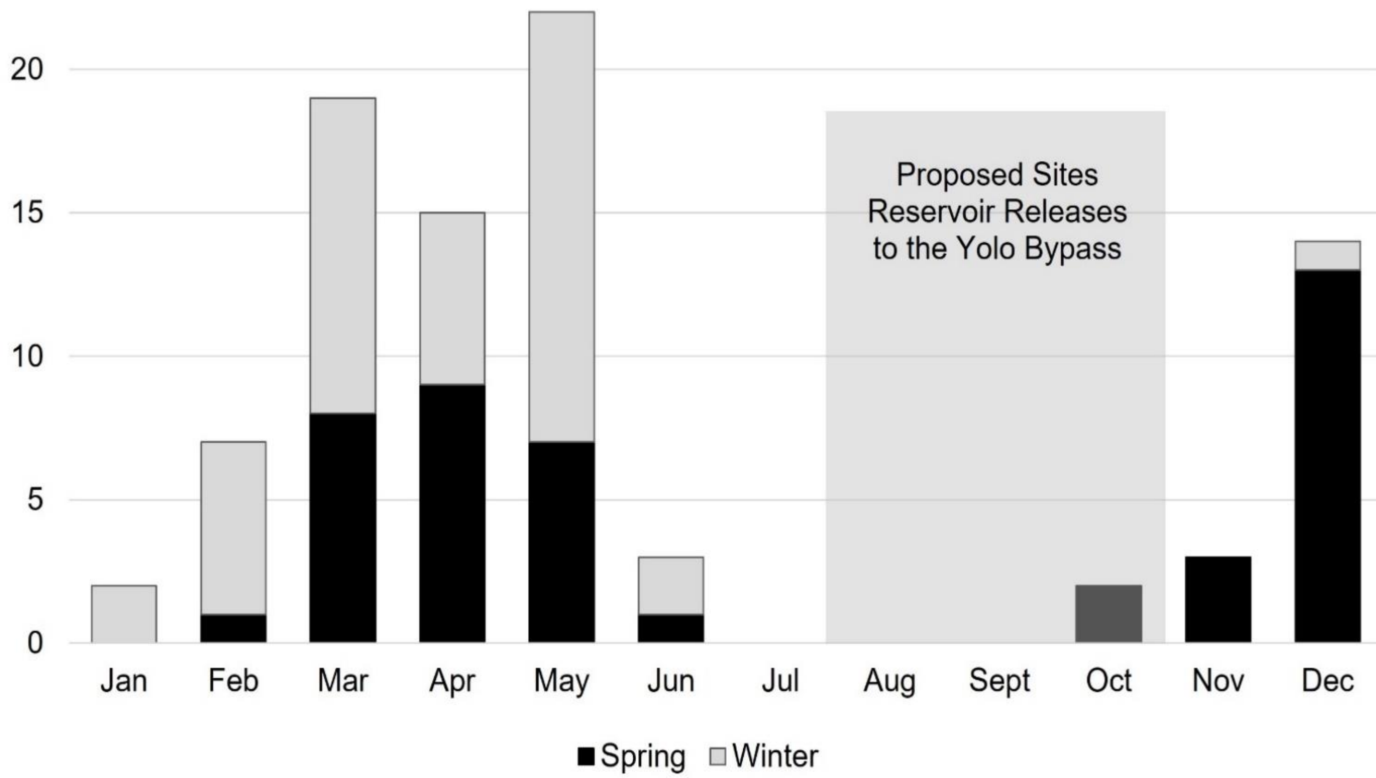

Figure 3-4. Genetically verified adult spring-run (black) and winter-run (gray) Chinook Salmon captured in the Colusa Basin Drain, Yolo Bypass Toe Drain, and at Wallace Weir Collection Facility, 2013-2023. Data from CDFW North Central Region.

3.1.3. Population Status and Trends

Annual CHNWR adult returns were as high as 120,000 fish in the 1960s, but by the 1990s had declined to fewer than 200 fish (NMFS 2019). From 1967 through 2000, CHNWR escapement estimates were based on counts of Chinook Salmon passing through one of three of RBDD fish ladders at approximately RM 243. From 1967 through 1986, Tehama-Colusa Canal Authority (TCCA), in coordination with Reclamation, typically operated RBDD throughout the entire CHNWR migration period, which allowed for a complete accounting of CHNWR escapement (Killam et al. 2016). In 1987, the operation of RBDD was modified to improve CHNWR migration, with dam gates raised from mid-September through mid-May of the following year to allow unimpeded upstream passage of most CHNWR adults (Killam et al. 2016). By 2011, National Marine Fisheries Service (NMFS) mandated that Reclamation to raise the gates out of the water year-round to provide for improved fish passage (NMFS 2009; Killam et al. 2016).

Beginning in 2001, CDFW shifted from using fish counts at RBDD for their formal escapement estimates to instead using mark-recapture estimates from carcass survey that were already being conducted on the Sacramento River by the USFWS, coupled with counting adult returns to Livingston Stone National Fish Hatchery (LSNFH), Coleman National Fish Hatchery (CNFH), Battle Creek, and Clear Creek, as the official means to obtain an annual CHNWR escapement estimate (Killam et al. 2016; CDFW 2023a).

Since 2001, the highest adult escapement (in-river and hatchery; Sacramento River system) occurred in 2005 and 2006 with an estimated total return of 15,839 and 17,296 adults, respectively (Figure 3-1; CDFW 2023a). Between 2001 and 2010, the average adult escapement was 7,639 adults; however, in the following decade (2011–2020) there was a precipitous decline in returns with an average of 3,676 adults observed. The lowest escapement since 2001 occurred in 2011 with an estimated return of 827 adults. The second largest return of adults, since 2006 (17,296 adults), occurred in 2021 with an estimate of 10,548 adults (CDFW 2023a). The 2021 escapement estimate was greater than the 2001 to 2010 average, but well below the 2006 estimate.

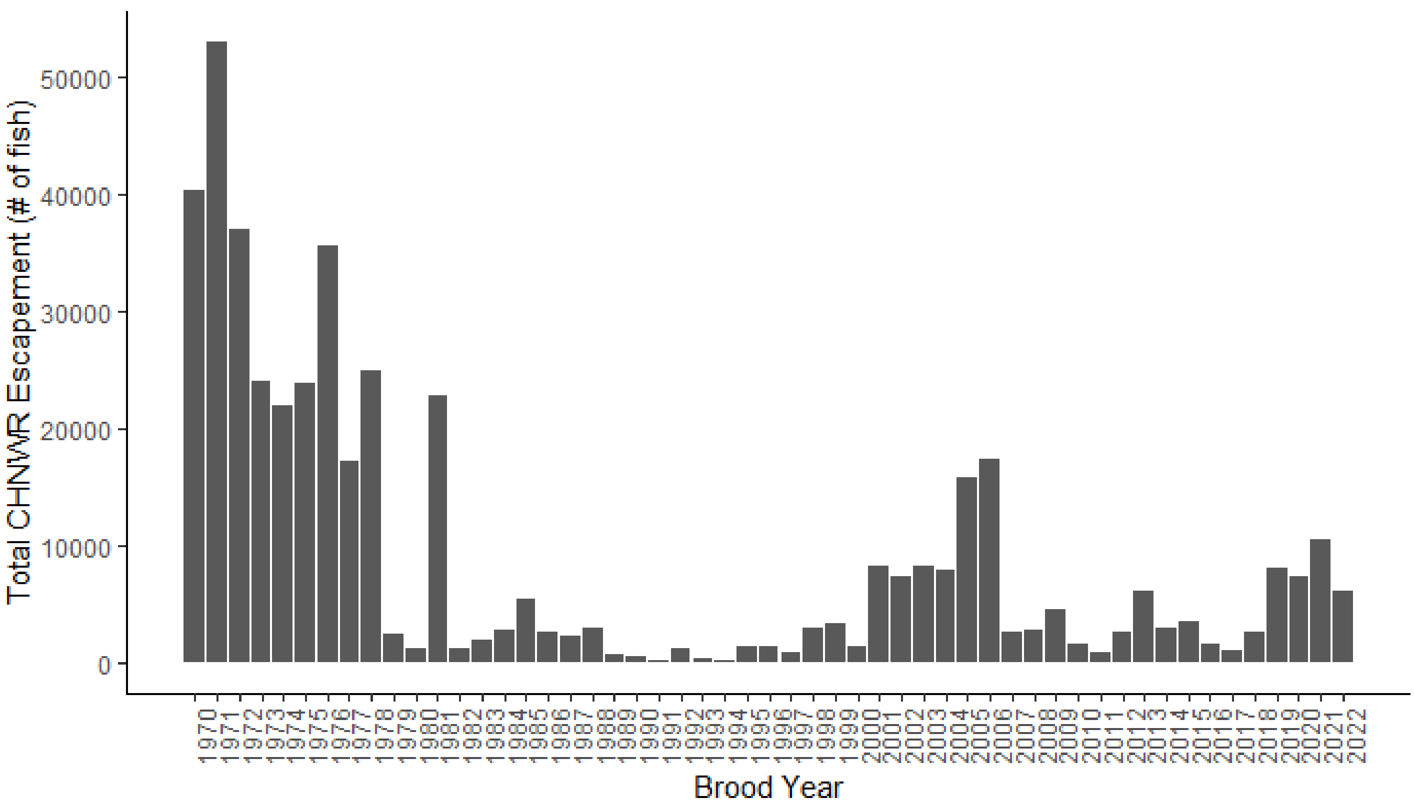

Figure 3-1. Total Sacramento River system annual natural- and hatchery-origin winter-run Chinook Salmon (CHNWR) escapement estimates for brood years 1970-2022 (CDFW 2023a). Escapement estimates include the number of adult CHNWR returning annually in the Sacramento River, Battle Creek, and Clear Creek and those propagated at the Livingston Stone National Fish Hatchery or Coleman National Fish Hatchery.

Adult escapement is not the only population metric to consider. The natural-origin CHNWR juvenile production estimate (JPE), an estimate of the number of juvenile CHNWR entering the Delta, is an important population forecast that accounts for annual fry counts and estimated survival at different life and migration stages (O'Farrell et al. 2018). While 2021 escapement was relatively high, the natural-origin CHNWR JPE was among the lowest on record, 124,521 individuals, caused by low egg-to-fry survival due to thiamine deficiency and temperature-dependent egg mortality (WR PWT 2022). Since brood year 2021, the JPE has continued to decrease. Brood year 2022 had the second lowest JPE since 1994, with an estimated 49,924 juveniles reaching the Delta (Figure 3-6).

Declining trends observed in CHNWR populations from 2007 through 2022 were likely due to a combination of factors such as poor ocean productivity, thiamine deficiency, extreme drought, and low in-river survival as a result of low flows and high-water temperatures (NMFS 2019, NMFS 2022a).

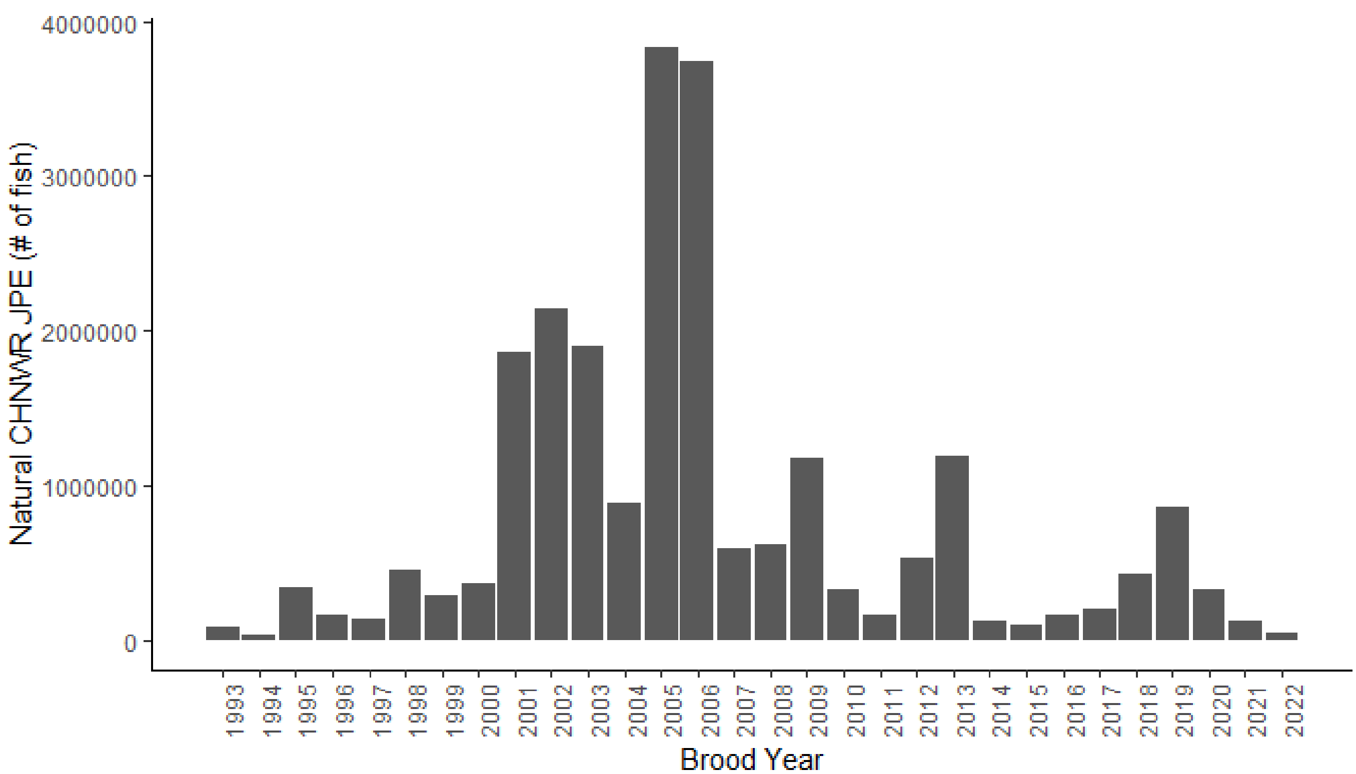

Figure 3-2. Natural-origin winter-run Chinook Salmon (CHNWR) juvenile production estimate (JPE) for brood years 1993-2022 (NMFS 2018, 2019b, 2020; CDFW 2020b; WR PWT 2021, 2022, 2023; corresponding to water years 1994-2023).

3.1.4. Listing History

On September 22, 1989, the California Fish and Game Commission (Commission) listed CHNWR as endangered under CESA (see Cal. Code Regs., tit. 14, § 670.5, subd. (a)(2)(M)). The Sacramento River CHNWR ESU, which includes CHNWR populations in the Sacramento River and its tributaries in California, was listed as threatened under the Endangered Species Act (ESA) on August 4, 1989 (54 Federal Registry (FR) 32085) and subsequently uplisted to endangered on January 4, 1994 (59 FR 440). CHNWR were reaffirmed as endangered under the ESA on June 28, 2005, and the ESU was extended to include CHNWR produced at the LSNFH (70 FR 37160). Sacramento CHNWR were reaffirmed as endangered again on August 15, 2011 (76 FR 50447). Critical habitat for CHNWR has been designated from Keswick Dam (RM 302) on the Sacramento River to the Golden Gate Bridge in San Francisco Bay (58 FR 33212).

3.1.5. Extinction Risk

The CHNWR ESU consists of a single spawning population in the Sacramento River below Keswick Dam and an experimental population on Battle Creek. The Sacramento River population has been completely displaced from its historical spawning habitat and persists in a section of the river where cold-water habitat is artificially maintained by releases from Shasta Reservoir (Williams et al. 2011). Due to limited supply of cold water in Shasta Reservoir, persistence of this population is precarious (NMFS 2014). NMFS's Recovery Plan for the Evolutionarily Significant Units of Sacramento River Winter-run Chinook Salmon and Central Valley Spring-run Chinook Salmon and the Distinct Population Segment of California Central Valley Steelhead (NMFS Recovery Plan) notes that the CHNWR ESU is extremely vulnerable to catastrophic events that could lead to its extinction (NMFS 2014). NMFS (2023) does not consider the CHNWR ESU a viable population because there is only one naturally spawning population, with spawning limited to outside the historical spawning range. To increase spatial diversity and abundance, efforts were initiated in 2017 to reintroduce a population of CHNWR in Battle Creek, which has shown some success with adults returning to spawn every year since 2019 (CDFW 2023a).

3.2. Spring-run Chinook Salmon (CHNSR)

CHNSR are differentiated from other Central Valley Chinook Salmon by the timing of spawning migration, the degree of maturity of adult fish entering freshwater, their spawning areas, and emigration timing of juveniles. CHNSR are recognized as an ESU of Chinook Salmon (Moyle 2002), and they maintain their genetic integrity by being temporally and/or spatially isolated from other runs in the Sacramento River system.

3.2.1. Species Life History

Adult CHNSR leave the ocean to begin their upstream spawning migration in late January to early February. Adults enter their natal tributaries from mid-February through July, with upstream migration peaking in May. CHNSR are sexually immature when they enter freshwater, and their gonads mature during the summer holding period (Marcotte 1984). Spawning occurs beginning in mid-August and continues through mid-October, when females lay approximately 4,200-5,000 eggs (CDFG 1998; Moyle 2002; Giovannetti and Brown 2008) in nests, or redds, in gravel stream beds. Eggs hatch into "alevin" that continue to live in the gravel until their yolk sac is absorbed.

The period of egg incubation is greatly influenced by water temperature, and juveniles ("fry") emerge beginning as early as November in warmer streams such as Butte Creek (McReynolds et al. 2006) or as late as March in colder streams such as Mill and Deer creeks (Johnson and Merrick 2012). CHNSR juveniles will spend from three to fifteen months in freshwater before emigrating to the ocean (Johnson and Merrick 2012). Some juveniles may rear in their natal habitat until they become "smolts," physiologically prepared for outmigration into saltwater. Others will emigrate from the spawning habitat as fry or parr and rear in downstream habitats. While most juveniles emigrate during the first winter and spring after their emergence, some will over-summer and out-migrate as yearlings the following fall, winter, or spring (CDFG 1998). Although relatively rare, this "yearling" outmigrant strategy results in a disproportionately larger fraction of returning adults during periods of drought (Cordoleani et al. 2021).

The timing of young-of-year (YOY) entry into the Delta is highly variable, ranging from December to June, and the timing and age at Delta entry appears to be influenced by the timing of winter high flow events (Williams 2006). CHNSR spend from one to five years in the ocean, where they travel in schools with other west coast salmon stocks and feed on smaller fish and amphipods and other crustaceans. The majority of Central Valley CHNSR return to spawn in freshwater at age three, with a smaller proportion leaving at age two and four, and, to a lesser extent, age five (NMFS 2000).

3.2.2. Range and Distribution

Historically, CHNSR were the second most abundant salmon run in the Central Valley, occurring in all major tributaries to the Delta including the San Joaquin, American, Yuba, Feather, Sacramento, McCloud, and Pit rivers (Figure 3-7). Over the past century, many of these independent populations have become extirpated due to the degradation and loss of spawning and rearing habitat resulting from hydropower operations, water diversions, and disconnection of rivers from their floodplains (Lindley et al. 2004; NMFS 2022a).

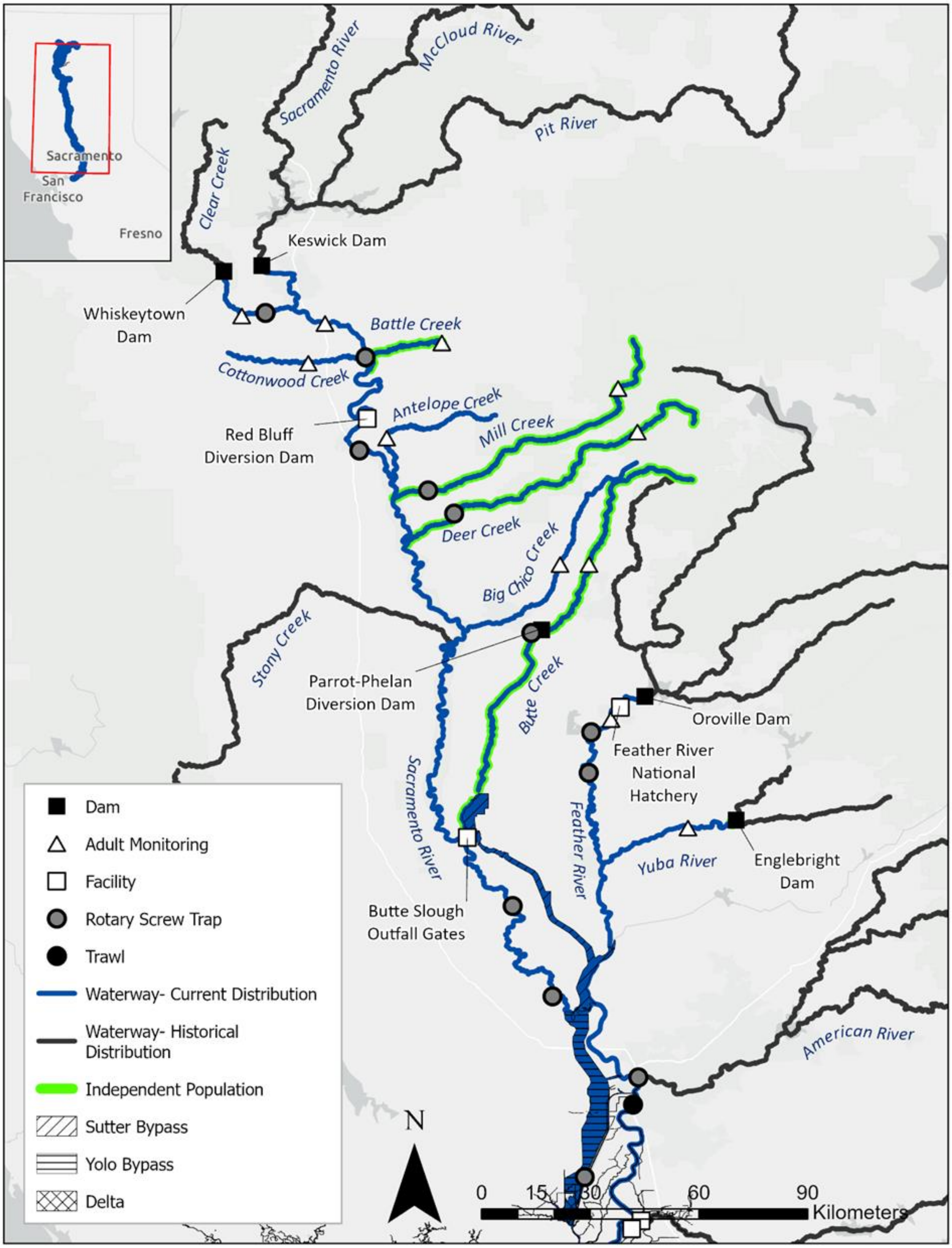

Figure 3-3. CHNSR current and historical distribution and relevant management related locations north of the Sacramento-San Joaquin Bay-Delta.

Of the 19 historically independent populations of CHNSR, 14 were in the Sacramento River Basin (Lindley et al. 2004; NMFS 2022a). Currently, self-sustaining populations are limited to Battle, Mill, Deer, and Butte creeks, with small populations found in the Feather and Yuba rivers as well as in Antelope, Clear, Big Chico, and Beegum (a tributary to Cottonwood Creek) creeks (CDFG 1990; CDFG 1998; Goertler et al. 2020). Hatchery sustained populations are present on the Feather River, via the Feather River Fish Hatchery (FRFH), and the San Joaquin River, via the Salmon Conservation and Research Facility (CDFW 2022).

Distribution and Migration Timing in the Sacramento River near Project Diversion Locations

The only existing CHNSR populations upstream of the Project diversion location at Red Bluff spawn in Battle Creek, Clear Creek, Beegum Creek, and the mainstem Sacramento River. Adults from these populations are likely present at either the Red Bluff or Hamilton City diversion locations from March through June, and juveniles are likely to be present from November through April, with juvenile migration peaking from November through January (Figure 3-8).

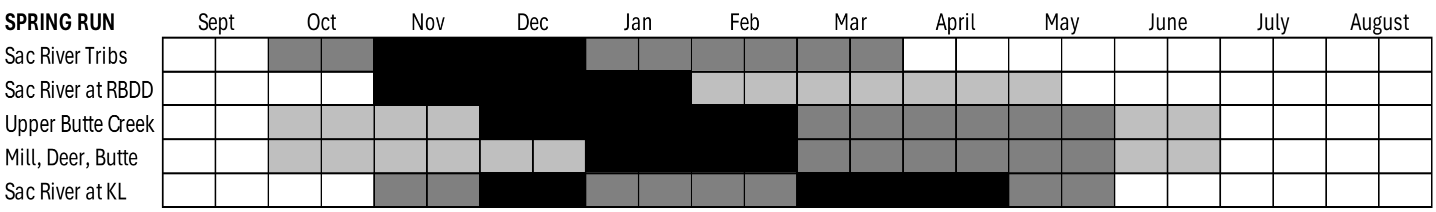

Figure 3-4. CHNSR juvenile migration timing at different locations in the Sacramento River Basin, including Sacramento River Tributaries, RBDD, Mill and Deer creeks, and Knights Landing. Darker colors represent higher abundance (Sources: CalFish 2024, Cordoleani et al. 2019, Johnson and Merrick 2012, NMFS 2014, Poytress et al. 2014, R. Revnak personal communication July 2024, T. McReynolds personal communication July 2024, Williams et al. 2011)

CHNSR populations in Mill Creek, Deer Creek, and Antelope Creek spawn upstream of Hamilton City, but these tributaries enter the Sacramento River downstream of Red Bluff. Like the populations further north, adults from these streams migrate past Hamilton City from February through June, sometimes as late as September (NMFS 2014). Juveniles in Mill and Deer creeks, however, tend to emerge later and grow more slowly than other populations (Johnson and Merrick 2012). Juvenile CHNSR within Deer and Mill creeks are unique in that they exhibit three distinct life-history strategies characterized by large variations in size, migration timing, and age during outmigration. One strategy is characterized by prolonged tributary rearing until smoltification, followed by rapid outmigration through the riverine and estuarine environments to the ocean in late spring (Johnson and Merrick 2012, Notch et al. 2020a). This delayed outmigration makes Mill and Deer creek smolts particularly vulnerable to low flows, elevated temperatures, and reduced turbidity in the in the late spring, all of which reduce survival.

An analysis of 16 years of data from Mill and Deer creeks RSTs found that CHNSR smolts (75 mm–120 mm fork length [FL]) outmigrating from March through June account for 30.31% of all juveniles captured (Johnson and Merrick 2012). Notch et al. (2020a) used acoustic telemetry to evaluate survival and migration rates of late-migrating Mill Creek CHNSR smolts from 2013 to 2017. All fish tagged during the study measured over 80 mm FL and were caught in the Mill Creek RST between early April through early June. Tagged smolts migrated downstream in Mill Creek at a rate of 8 to over 20 km per day, and up to 40 km–80 km per day once in the Sacramento River, and smolts migrating during higher flows had faster travel times and higher survival rates than those migrating under lower flows (Notch et al. 2020a).

Spring-run Chinook Salmon near Project Discharge Locations

CHNSR adults and juveniles are both present in the Delta and near the Project's discharge location at KLOG between April and November. CHNSR sized juveniles are captured at the Knights Landing RSTs located approximately 4 km downstream of KLOG from mid-October through late May (Columbia Basin Research 2024). Juvenile CHNSR may also utilize habitat in and around Knights Landing Ridge Cut immediately downstream of KLOG for rearing. They are routinely captured by the USFWS Delta Juvenile Fish Monitoring Program in beach seine sampling from December through April at the Knights Landing Boat Launch approximately 0.2 km from KLOG (IEP et al. 2023a; Figure 3-3).

Adults on their upstream spawning migration are present in the Sacramento River Basin from March through October (NMFS 2019), and genetically confirmed CHNSR adults have been captured in the Yolo Bypass region of the Delta from October through June, as well as in in the Yolo Bypass at the Wallace Weir Fish Collection Facility in KLRC (Figure 3-4). In 2013, prior to construction of a fish barrier at KLOG, hundreds of CHNWR and CHNSR adults strayed into the CBD via KLOG and the Cache Slough Complex, perishing in upstream agricultural ditches (NMFS 2016; Kubo and Kilgour 2022). Thousands of CHNFR adults have also been observed to stray along these routes (NMFS 2019). The construction of the Knights Landing Outfall Gates Fish Passage Barrier Project in 2015 was to reduce Chinook Salmon adult straying and getting trapped in the CBD (NMFS 2019). Currently, the fish barrier should prevent adult salmon from straying into the CBD; however, it is likely that outflows at KLOG may continue to attract adult salmon and delay their migration.

3.2.3. Population Status and Trends

The Central Valley of California is estimated to have supported CHNSR runs as large as 600,000 fish between the late 1880s and 1940s (CDFG 1998). Historically, CHNSR were the second most abundant salmon run in the Central Valley, occurring in all major tributaries to the Delta including the San Joaquin, American, Yuba, Feather, Sacramento, McCloud, and Pit rivers. Currently, self-sustaining populations are limited to Battle, Mill, Deer, and Butte creeks, with small populations found in the Feather and Yuba rivers as well as in Antelope, Clear, Big Chico, and Beegum creeks (tributary to Cottonwood Creek) (CDFG 1990; CDFG 1998; Goertler et al. 2020). Hatchery sustained populations are present on the Feather River, via the FRFH, and the San Joaquin River, via the Salmon Conservation and Research Facility (CDFW 2022).

Genetic analyses have shown that natural and hatchery-origin CHNSR within Mill, Deer, and Butte creeks retain their genetic integrity (Good et al. 2005; Garza et al. 2008). However, the Feather River CHNSR population has shown introgression with CHNFR due to overlaps in spatial and temporal run timing which are constrained by Oroville Dam (Good et al. 2005; Garza et al. 2008; DWR and CDFW 2023).

The NMFS (2022a) Viability Assessment for CHNSR indicated that population declines have been substantial for all independent populations and are close to qualifying as catastrophic declines (>90% decline). There has been a precipitous decline in adult returns in the recent decade for CHNSR in the Sacramento River, Feather River, Mill Creek, and Deer Creek, and some increases on Battle and Clear creeks (Table 3-1, Figure 3-9).

Table 3-1. CHNSR escapement trends as decadal averages across region (CDFW 2023a). Butte Creek carcass survey estimates are included in the Butte Creek and total escapement estimates and include prespawn mortality. Total escapement estimate includes the number of adult CHNSR returning annually in the Sacramento River system, including independent and dependent populations, and those propagated at the Feather River Fish Hatchery. Ranges included in parentheses.

Average Timeframe (Decades)	Sac River	Battle Creek	Clear Creek	Mill Creek	Deer Creek	Butte Creek	Feather River Fish Hatchery	Total Escapement
2001-2010	152 (0-621)	170 (73-291)	87 (0-200)	929 (237-1,594)	1331 (140-2,759)	10,977 (1,991-18,670)	3,118 (989-8,662)	16,218 (4,446-30,697)
2011-2020	61 (0-414)	256 (30-799)	121 (8-659)	343 (80-768)	420 (90-830)	6,837 (515-16,782)	2,589 (532-4,294)	10,685 (1,591-23,810)

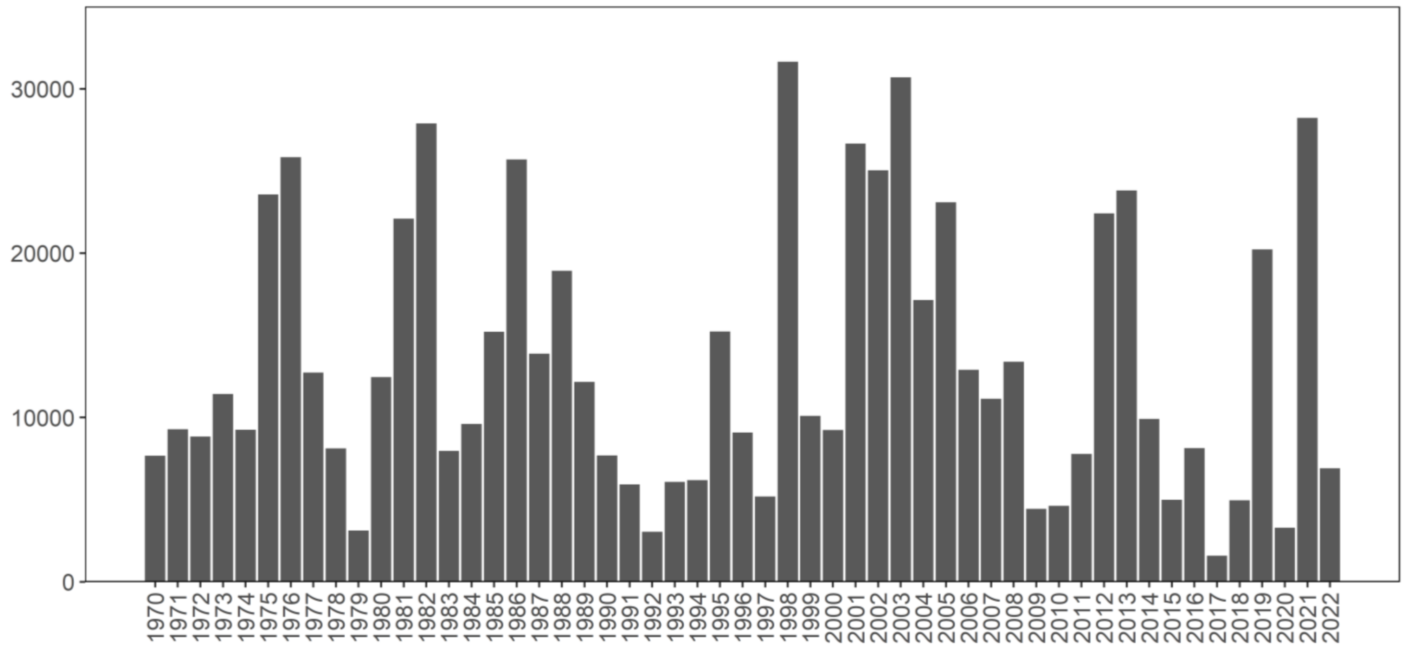

Figure 3-5. Total Sacramento River system annual CHNSR escapement estimates for brood years 1970-2022 (CDFW 2023a). Escapement estimates include the number of adult CHNSR returning annually in the Sacramento River system, including independent and dependent populations, and those propagated at the Feather River Fish Hatchery. Butte Creek carcass survey estimates are included in total escapement estimates and include prespawn mortality. In 2021, an estimated 19,773 of 21,580 CHNSR died in Butte Creek prior to spawning.

3.2.4. Listing History

On February 5, 1999, the Commission listed CHNSR of the Sacramento River drainage as threatened under CESA (see Cal. Code Regs., tit. 14, § 670.5, subd. (b)(2)(c)). The Central Valley CHNSR ESU, which includes CHNSR populations in the Sacramento River and its tributaries including the Feather River, was proposed for listing as endangered by NMFS on March 9, 1998 (63 FR 11482) following CHNSR extirpation from the San Joaquin River Basin. During the listing review, data showed that a large run of CHNSR on Butte Creek in 1998 was produced naturally rather than the result of straying from the FRFH. Subsequently, NMFS listed CHNSR as threatened under the ESA on September 16, 1999 (64 FR 50394) and reaffirmed the listing status on June 28, 2005 and the ESU was extended to include CHNSR produced at the FRFH (70 FR 37160). Critical habitat for CHNSR includes the Sacramento River Basin and the Yolo Bypass (70 FR 52488).

3.2.5. Extinction Risk

In the Candidate Species Status Report, CDFW (1998) cited habitat loss, low diversity, restricted range, and low abundance as major factors contributing to the state listing of CHNSR. The NMFS

Recovery Plan for CHNSR identified ongoing threats to the federal ESU as small population sizes, loss of habitat, water operations, climate variation, and limited spatial distribution within the Central Valley, described as lack of diversity groups within the ESU (NMFS 2014). These threats have contributed to declining abundances as well as limited resilience, or the ability of populations to recover after disturbance and environmental change. This loss of resilience further increases extinction risk for individual populations and the ESU.

The few remaining populations of CHNSR are small, isolated, and lack spatial diversity. The four demographically independent populations of CHNSR, in Battle, Deer, Mill, and Butte creeks, have seen declining trends in abundance. Dependent populations in other tributaries to the Sacramento River support few spawners, which appear to be primarily strays from independent populations and the FRFH. A viability assessment by NMFS (2023) determined that independent CHNSR populations in Battle, Deer, Mill, and Butte creeks showed substantially lower total population sizes and mean escapement than in the previous assessment in 2015 and elevated the ESU to a moderate to high risk of extinction. Since the NMFS (2023) assessment, CHNSR escapement numbers have indicated that populations are continuing to decline.

3.3. Longfin Smelt (LFS)

3.3.1. Life History and Population Status

LFS in California is a small (up to 150 mm total length [TL]), presumably semelparous, anadromous member of the “true smelt” family *Osmeridae* (Moyle 2002). It exhibits a predominantly two-year life history (Moyle 2002, Rosenfield and Baxter 2007) though the potential to spawn at the end of their first and third years of life has been detected (CDFG 2009a). The abundance of LFS has been in decline for decades (Kimmerer and Gross 2022; Nobriga and Rosenfield 2016; Rosenfield and Baxter 2007; Sommer et al. 2007), except during short periods of high spring outflow and consequent population increase (Thomson et al. 2010). Increasing spring X2 (i.e., reduced outflow) and, to a lesser degree, water clarity have had negative effects on LFS abundance over the long-term (Thomson et al. 2010). Changes in its feeding environment after the introduction of the overbite clam, *Potamocorbula amurensis*, are believed to have caused the first of two known step declines in abundance beginning in 1988 (Baxter et al. 2010; Feyrer et al. 2003; Kimmerer 2002a). The second step decline occurred in the early 2000s (Kimmerer et al. 2009) and is associated with the Pelagic Organism Decline (Sommer et al. 2007; Baxter et al. 2010), of which the cause remains unknown (Mac Nally et al. 2010; Thomson et al. 2010). LFS abundance has since declined to record lows (Hobbs et al. 2017; Kimerer and Gross 2022). LFS abundance (i.e., year-class strength) continues to be positively related to freshwater outflow during its winter-spring spawning and early rearing periods (Jassby et al. 1995; Kimmerer 2002b; Kimmerer and Gross 2022; Rosenfield and Baxter 2007; Sommer et al. 2007; Stevens and Miller 1983; Tamburello et al. 2019; Thomson et al. 2010), and there is strong evidence that adult stock size also influences the outflow abundance relationship (Nobriga and Rosenfield 2016).

3.3.2. Spawning

In the SFE, spawning mostly occurs from December through March but periodically extends from November through April (CDFG 2009a, USFWS 2022). Maturing and immature LFS move toward freshwater sources in late fall and winter as water cools. They stage in low salinity habitat around X2, with densities decreasing with increasing distance and decreasing salinity upstream (CDFG 2009a; J. Hobbs personal communication 2019; Lewis et al. 2019, USFWS 2022). This results in LFS moving farther into the Delta during dry years when X2 is farther upstream in the Delta, increasing their vulnerability to entrainment into the south Delta (CDFG 2009b, USFWS 2022). Spawning is inferred to occur in some marshes, particularly within Suisun Bay and the western Delta (Grimaldo et al. 2017). Due to prevailing oceanic currents, there is little interaction between the LFS population in SFE and populations to the north (Saglam et al. 2021).

Adhesive eggs are not believed to be particularly vulnerable to direct entrainment; however, they are known to be captured by drift nets in Lake Washington tributaries at times (Martz et al. 1996), thus eggs can presumably drift under strong currents. Eggs spawned in brackish water or near the downstream limit of freshwater in the Bay-Delta may be affected by increases in salinity due to declining outflow related to natural runoff and export operations in the south Delta. At hatching, larvae are buoyant and become predominantly surface oriented until they grow to 10 mm TL, when air bladder development begins, facilitating vertical movement and allowing fish to better maintain position or move within the estuary (Bennet et al. 2002; Wang 2007). Larvae are initially dispersed by tidal currents and net flows and are therefore susceptible to entrainment into the south Delta when hatched in the central or south Delta (CDFG 2009b). LFS larvae develop fully formed fin rays and have an associated increase in volitional movement at approximately 20 mm TL (Wang 2007).

3.3.3. Larval and Juvenile Dispersal

As larvae and juveniles develop, they disperse downstream from spawning habitat and into brackish water and eventually marine habitats (Baxter et al. 1999; Kimmerer and Gross 2022, USFWS 2022). Both larvae and early juveniles are initially distributed around the location of X2; however, the population size index in relation to X2 seems to be strongest after early larval development (Dege and Brown 2004; Kimmerer and Gross 2022; Parker et al. 2017). For this reason, hatch location, net channel currents, and the position of X2 influence the risk of entrainment for these early life stages. Early rearing in the LSZ, particularly in the 1 ppt–4 ppt range, has produced the highest recruitment in previous years (Hobbs et al. 2010), though larvae and small juveniles have been found in much higher salinities of 14 ppt–18 ppt (Kimmerer et al. 2013; Parker et al. 2017). The volume and surface area of the LSZ varies with X2, reaching its maxima when X2 is in Suisun Bay at about 68 km and when X2 is in San Pablo Bay at about 40 km (Kimmerer et al. 2013). The larger embayments of San Pablo and Suisun bays are typically more turbid than other areas of the estuary due to wind driven and tidal mixing (Durand 2014; Nobriga et al. 2008; Ruhl and Schoellhamer 2004). The increase in volume and surface area, combined with turbidity, could provide additional foraging opportunities and reduce predation risk, enhancing larval growth and survival.

Interestingly, laboratory experiments have found LFS yolk sac larvae to have the best performance, in terms of growth and survival, at salinity ranges higher than X2 (Yanagitsuru et al. 2022). These experiments show an increase in fitness in terms of osmoregulation and ion regulation for individuals reared in 5 ppt–10 ppt. This suggests that increases in whole body sodium ions in response to higher salinity treatments may be a positive adaptation as opposed to a failure to regulate ionic content within the body (Yanagitsuru et al. 2022). Future study is needed to better understand the relationship between salinity and growth, survival, and recruitment to adult life stages.

Many juvenile LFS disperse into marine salinities by summer; however, an unknown but likely small segment of the juvenile population rear in intermediate salinities in San Pablo Bay during summer and fall (Baxter et al. 2010; Baxter 1999). After the introduction of the overbite clam, LFS exhibited a distribution shift toward higher salinities (Fish et al. 2009), and LFS larvae and juveniles that do not migrate downstream from freshwater habitats no longer contribute significantly to the adult population (Hobbs et al. 2019a). Actions to improve habitat and productivity of Suisun Bay in spring, summer, and fall could provide benefits to rearing juvenile LFS and, if successful, may over time increase LFS use of this region. During high flow years, LFS recruitment is heavily influenced by conditions in the San Francisco Bay, suggesting that restoration efforts there may also confer benefits to the species (Grimaldo et al. 2020).

3.3.4. Food sources

The LSZ, whether in San Pablo Bay, Suisun Bay, or farther upstream, also contains important LFS food sources, including calanoid copepods and mysid shrimp. Larval LFS prey selection is associated with larva size. Larvae smaller than 25 mm TL feed primarily on copepods, while larvae larger than 25 mm TL almost exclusively target mysids (Barros et al. 2022). In addition to dietary biases related to size, LFS diets show some biases in prey species selection. Particularly, LFS positively select for the calanoid copepod *Eurytemora affinis* and the mysid shrimp *Neomysis mercedis* (Barros et al. 2022; Rosenfield and Baxter 2007). Historically, *E. affinis* was abundant and available for much of the year, regardless of flow conditions. Since the invasion of the overbite clam (and possibly the introduction of other copepods such as *Pseudodiaptomus forbesi*), *E. affinis* is only abundant for one or two months in spring, and its abundance is positively correlated with spring outflow (Hennessy and Burris 2017; Kimmerer 2002a). Similarly, the once-abundant *N. mercedis* has dramatically declined in population size, with the smaller, nonnative mysid *Hyperacanthomysis longirostrus* largely replacing *N. mercedis* (Avila and Hartman 2020; Kimmerer 2002a; Kimmerer and Orsi 1996; Orsi and Mecum 1996).

Mac Nally et al. (2010) developed strong evidence that low outflow (reported as high X2) significantly reduced calanoid copepod biomass in spring and mysid biomass in summer within the LSZ (see also Hennessy and Burris 2017). The introduced calanoid copepod *P. forbesi* and introduced mysids (primarily *H. longirostrus*) now provide important LFS diet components from late spring through fall (Barros et al. 2022; Baxter et al. 2010). The abundance of *P. forbesi* in the LSZ during summer and fall is subsidized from upstream and influenced by freshwater outflow (Durand 2010; Hennessy and Burris 2017; Kimmerer et al. 2018). This food subsidy to Suisun Bay replaces some of the local zooplankton production lost to the overbite clam, but it decreases as outflow decreases (reported as X2 advancing upstream; see also Mac Nally et al. (2010)). Decreased outflow also shifts the *P. forbesi* population farther east, where it is at greater risk of entrainment and loss to south Delta and in-Delta water exports (Kimmerer et al. 2018).

3.3.5. Listing History

On April 5, 2009, the Commission listed LFS as threatened under CESA (see Cal. Code Regs., tit. 14, § 670.5, subd. (b)(2)(e)). The San Francisco Bay-Delta distinct population segment of LFS was proposed for listing under the Federal ESA by USFWS on October 7, 2022 (87 FR 60957) and listed as endangered under the ESA on August 29, 2024 (89 FR 61029). Critical habitat rule for LFS will be published in a future edition of the Federal Registry.

3.4. Delta Smelt (DS)

3.4.1. Life History and Population Status

The DS is a small (≤ 120 mm TL), euryhaline, member of the "true smelt" family *Osmeridae* that is endemic to the upper SFE, primarily Suisun Bay and the Delta (Moyle 2002; Sweetnam 1999). In recent years, few adults have exceed 90 mm FL (Bennett 2005; Sweetnam 1999). Most DS have a one-year life history (Moyle 2002) though a few adults survive after spawning (Baxter 1999) and may contribute to subsequent spawning periods (Bennett 2005). In the benign environment of artificial culture, two-year-old fish survive and remain viable for spawning (Lindberg et al. 2013). DS abundance suffered a step decline in the early 1980s followed by an unexplained sharp drop in the early 2000s (Sommer et al. 2007; Thomson et al. 2010). Its abundance has since dropped to record lows (Hobbs et al. 2017). DS abundance does not exhibit a linear relationship to outflow (IEP-MAST 2015; Tamburello et al. 2019), as does LFS abundance (Kimmerer 2002b, Kimmerer and Gross 2022; Sommer et al. 2007; Rosenfield and Baxter 2007). Instead, DS abundance peaks are associated with intermediate levels of outflow, specifically those that position X2 and the LSZ (0.5-6.0 psu, Kimmerer (2004)) in Suisun Bay, where habitat quality reaches a local maximum (Feyrer et al. 2007; Feyrer et al. 2011; Kimmerer et al. 2013). Such an orientation aligns the preferred salinity range of DS with shallower, more turbid, and potentially cooler water in Suisun Bay when compared to points upstream.

The DS population has undergone a protracted abundance decline influenced by changes in hydrology, Delta hydrodynamics, and the upper estuary pelagic food web; changes in contaminant loads and predator numbers may also be involved (Baxter et al. 2008; Baxter et al. 2010; IEP-MAST 2015; Sommer et al. 2007). No single factor has been identified as responsible for the decline of DS (IEP-MAST 2015). During high outflow years, larvae presumably benefit from increased transport and dispersal downstream, increased food production, reduced predation through increased turbidity, and reduced loss to entrainment due to a reduced influence of negative San Joaquin River flows on DS spawning habitat (IEP-MAST 2015). Conversely, during low outflow years, negative effects of reduced transport and dispersal, reduced turbidity and potentially increased loss of larvae to predation and increased loss at the export facilities result in lower young-of-year recruitment. Analyses to separate effects of these multiple factors are ongoing (e.g., Mac Nally et al. 2010; Thompson et al. 2010).

3.4.2. Habitat and Contingents

During much of its lifecycle, a large contingent of the DS population inhabits the LSZ (Dege and Brown 2004; Feyrer et al. 2007; Feyrer et al. 2011; Sommer et al. 2011), the location of which is indexed by X2 (Kimmerer 2004). During its juvenile and sub-adult stages in summer and fall, the distribution of DS in the estuary is strongly related to freshwater outflow and the location of the LSZ (Sweetnam 1999; Moyle 2002; Dege and Brown 2004). When the LSZ is in Suisun Bay, it overlaps with other important habitat characteristics, principally regions of higher turbidity and potentially lower water temperatures relative to upstream habitats (Feyrer et al. 2007; Feyrer et al. 2011; IEP-MAST 2015; Wagner et al. 2011).

The LSZ is not the only summer and fall habitat for DS. Otolith chemistry analyses indicate three predominant life history phenotypes: 1) a freshwater resident contingent (23% of the population; mean across 7 years examined); 2) a brackish water resident contingent (7% of the population; mean across 7 years examined); and 3) a migratory contingent that moves to freshwater to mature and spawn, and subsequent larvae and young rear in freshwater prior to dispersing/migrating to brackish water in the LSZ to rear during summer and fall (70% of the population; mean across 7 years examined) (Bush 2017; Hobbs et al. 2019b). The freshwater contingent uses tidal freshwater regions in the lower Sacramento River adjacent to and directly upstream of Sherman Lake and the north Delta, including Cache Slough and the Sacramento Deepwater Ship Channel, the latter when summer and fall temperatures allow. Such a migratory schedule, particularly for juvenile DS in late summer or fall, may provide food benefits for migrants, specifically improved freshwater foraging in summer and in brackish water in fall and winter (Hammock et al. 2017). If temperatures approach or exceed about 25 °C in the north Delta, DS can move downstream toward cooler water; if water temperatures do not approach the 25 °C limit, a contingent of DS may remain in the north Delta through summer and fall (Bush 2017; Hobbs et al. 2019b). DS have lost summer and fall use of the lower San Joaquin River due to decreased turbidity and increased water temperature (Nobriga et al. 2008).

Although DS inhabit pelagic waters, typically away from shore and structure, there is evidence that they also use tidal habitats. Tidal marsh habitats, such as the Cache Slough Complex, may have been a refuge to DS during poor habitat conditions during the 2012-2016 drought (Mahardja et al. 2019). Additionally, a recent investigation found that DS proximity to tidal marshes resulted in greater stomach fullness (Hammock et al. 2019). Tidal marsh habitats may provide food benefits in the form of larval fish and zooplankton, particularly during winter, for DS preparing to spawn and recovering from spawning (Hammock et al. 2019). However, it is uncertain to what extent, both in terms of space and abundance, tidal wetlands may subsidize pelagic food webs within the Delta (Hartman et al. 2022).

3.4.3. Spawning

During the period from December through February, the migratory contingent inhabiting the LSZ use periods of increased turbidity to move upstream into freshwater habitats (Bennett and Burau 2015; Grimaldo et al. 2009; Sommer et al. 2011) where they stage, continue to forage and eventually spawn. If no such period of increased turbidity occurs, this migratory contingent will disperse into freshwater habitats in the Spring, just prior to spawning. During this migratory period, DS can become vulnerable to entrainment into the south Delta and the export facilities, particularly when San Joaquin Old and Middle River (OMR) flows are strongly negative (Grimaldo et al. 2009).

Spawning appears to be controlled by temperature, beginning at about 12 °C as early as February and continuing into May or June or until water temperatures surpass 18 °C (Baskerville-Bridges et al. 2005; Bennett 2005). Within the spawning period, female DS can spawn more than one batch of eggs—potentially up to three batches—depending on the duration of the spawning window (Damon et al. 2016; Nagel et al. 2015). Spawning likely takes place in both freshwater and slightly brackish water (Hobbs et al. 2019b), but exact spawning locations and substrates are not known. Those spawned in brackish water may be affected by increases in salinity due to export operations or natural outflow fluctuations. Although adhesive eggs are not believed to be vulnerable to direct entrainment, egg retention is influenced by the substrate type (Wang 2007, Lindberg et al. 2019). DS release small adhesive eggs that form a stalk to hold the egg above the substrate (Wang 2007), suggesting that eggs retention is lower in substrates that are more susceptible to displacement. Investigations using wild DS and a selection of natural substrates assorted in experimental tanks found that pebbles and sand were the dominant choices for spawning substrates, especially in higher velocities (Lindberg et al. 2019). Lindberg et al. 2019 also found that egg retention was significantly lower in sand than all other tested substrates under the high velocities.

3.4.4. Larval and Juvenile Dispersal

The duration of egg incubation is inversely related to water temperature and typically takes one to two weeks (Mager et al. 2004; Baskerville-Bridges et al. 2004; Baskerville-Bridges et al. 2005). Larvae are positively phototactic for the first 4 to 6 days post-hatch, making them vulnerable to transport by tidal and net currents (Baskerville-Bridges et al. 2005, Bennett 2005). Swim bladder development occurs between 14 mm and 20 mm TL (Bennett 2005) and allows larvae to better maintain vertical distribution and move in the water column using tidal currents to change or maintain their position in the estuary (Bennett et al. 2002). Larvae and small juveniles in the water column are initially dispersed by tidal currents and net flows, which makes them susceptible to entrainment. Larvae and juveniles in or near the central Delta are at risk of entrainment in the south Delta, and those in the south Delta are at risk of entrainment into the export facilities.

Both larval and early juvenile DS are initially distributed primarily upstream of the location of X2 (Dege and Brown 2004), and therefore X2 position influences their risk of entrainment. Even though larvae are primarily distributed above X2, post-larvae (60 to 64 days post hatch) are tolerant of salinities up to that of full sea water (Komoroske et al. 2014), perhaps providing this life stage some leeway to survive, develop, and reposition themselves to lower salinity habitat even if dispersed by flows. DS at this stage are the most tolerant of high water temperatures (Komoroske et al. 2014), which allows time for air bladder and fin development to aid in downstream dispersal prior to seasonal temperature exceeding their thermal maximum. With time and development, larvae and juveniles disperse downstream from spawning habitat (Baxter 1999; Dege and Brown

2004) and away from warming temperatures. Many juvenile DS disperse into Suisun Bay and the LSZ by summer, while others rear in freshwater habitats as long as temperatures remain below their thermal maximum (Dege and Brown 2004, Bush 2017, Hobbs et al. 2019b). Juveniles and adults are successively less temperature tolerant (Komoroske et al. 2014). Initial temperature tolerance experiments found that small juveniles are sensitive to water temperatures approaching and above 25 °C (Swanson et al. 2000), so they are believed to move downstream to cooler conditions in early summer as water temperatures approach 25 °C. Although subsequent investigations showed increased temperature tolerance, few juvenile DS have been caught at temperatures exceeding 25 °C (Komoroske et al. 2014).

Few juvenile and adult fish in the LSZ will venture into more saline water, although DS have occasionally been caught in the wild at 18 ppt (Bennett 2005) and can tolerate higher salinities in laboratory settings (Komoroske et al. 2014; Swanson et al. 2000). DS juveniles and adults appear to tolerate salinities in the 18 ppt range without change to body condition or survival, but appear not to do so frequently, probably due to other limiting factors such as food (Komoroske et al. 2016). As previously mentioned, there are potential foraging benefits to rearing in freshwater during summer and then migrating to the LSZ in fall and remaining for winter (Hammock et al. 2017).

3.4.5. Food Sources

Food is an important factor in DS population dynamics (Sommer et al. 2007, Baxter et al. 2010, Mac Nally et al. 2010, IEP-MAST 2015). However, DS food resources have been declining since the late 1980s (Kimmerer and Orsi 1996; Orsi and Mecum 1996; Winder and Jassby 2011). Overgrazing the overbite clam, which was introduced to the Delta in the 1980s, has likely led to lower food abundance and thus smaller-sized adult DS (Sweetnam 1999). Both adult size and egg production are important factors in modeled DS population dynamics because larger DS produce more eggs (Rose et al. 2013a; Rose et al. 2013b).

The quality of food available to DS has also declined since the 1980s, contributing further to food limitation on the species. The location of the LSZ has moved eastward in recent decades, relative to unimpaired and earlier impaired conditions (Fleenor et al. 2010). Historically, the LSZ provided habitat for important DS food sources, including *E. affinis* and *N. mercedis* (Moyle et al. 1992, Kimmerer and Orsi 1996, Orsi and Mecum 1996, Winder and Jassby 2011). However, these species have been largely replaced within the Delta by recent invaders of the system (see Section 3.3.4). Since their introduction, the copepods *P. forbesi*, *Sinocalanus doerrii*, *Acartiella sinensis*, *Tortanus dextrilobatus*, *Limnoithona tetraspina*, and the mysid *H. longirostrus* have also become important food sources for DS and now constitute a majority of the DS diet in summer and fall

(Moyle et al. 1992; Slater and Baxter 2014). Seasonal shifts in timing of peaks in key prey species, including *E. affinis* and *P. forbesi*, in low salinity habitats no longer coincides with peak use of this habitat by DS, potentially creating another source of food limitation to DS (Merz et al. 2016; Slater and Baxter 2014).

Historically, *E. affinis* was abundant and available for much of the year regardless of flow conditions, and its abundance was not correlated with flow. After the invasion of the overbite clam (and possibly the introduction of other copepods such as *P. forbesi*), *E. affinis* is only abundant for one or two months in spring and its abundance is positively correlated with spring outflow (Hennessy and Burris 2017; Kimmerer 2002a). Similarly, the once abundant *N. mercedis* has dramatically declined in abundance, with the smaller, nonnative *mysid H. longirostrus* largely replacing *N. mercedis* (Avila and Hartman 2020; Kimmerer 2002a; Kimmerer and Orsi 1996; Orsi and Mecum 1996). Mac Nally et al. (2010) developed strong evidence that low outflow (represented by X2) significantly reduced calanoid copepod biomass in spring and mysid biomass in summer, both within the LSZ (see also Hennessy and Burris 2017).

The abundance of *P. forbesi* in the LSZ during summer and fall is subsidized from upstream and influenced by freshwater outflow (Durand 2010; Hennessy and Burris 2017; Kimmerer et al. 2018). This food subsidy into Suisun Bay replaces some of the local zooplankton production lost to feeding by the overbite clam (Kimmerer et al. 2018). The authors note that this subsidy decreases as outflow decreases (reported as X2 advancing upstream; see also Mac Nally et al. (2010)) and decreased outflow also shifts the *P. forbesi* population farther east, where it is at greater risk of entrainment and loss to south Delta and in-Delta water exports (Kimmerer et al. 2018). To counteract losses in secondary productivity due to decreased upstream subsidies and potentially increased entrainment, modest flow actions in the north Delta for spring, summer and fall have been proposed and implemented to improve habitat and productivity downstream and into Suisun Bay for the benefit of DS (CNRA 2016).

3.4.6. Listing History

On January 20, 2010, the Commission updated the listing of DS from threatened to endangered under CESA (see Cal. Code Regs., tit. 14, § 670.5, subd. (a)(2)(O)). USFWS listed DS as threatened on April 5, 1993 (58 FR 12854). Critical habitat for DS include the Delta, Suisun Marsh, Suisun Bay, and Carquinez Strait (59 FR 65256).

3.5. White Sturgeon (WS)

3.5.1. Species Life History

WS are the largest fish that can be found in freshwater in North America. There are historical records of fish as large as 610 cm (20 ft) TL, although it is now rare to encounter fish larger than 200 cm (6.5 ft) TL in Californian waters. The average WS captured in the Delta in recent years is approximately 109 cm (3.6 ft) TL. As with all Acipenseriformes, WS are long-lived. The oldest fish on record was 103 years old at the time of capture, but most fish in the Delta are now believed to be less than 20 years old. WS typically reach sexual maturity at between 10 and 20 years old (Blackburn et al. 2019), with males maturing earlier and at a smaller size than females (Heublein et al. 2017). WS in California spawn every 1-2 years for males and every 2-4 years for females. Adults migrate from the estuary into the river starting in December, spawn from February to June, and return to the Delta after spawning. It has been hypothesized that this increase in river flow is a requirement for successful reproduction of the species (Counihan and Chapman 2018), as WS spawning has been observed following an increase in river flow at Colusa (Schaffter 1997). Since the 1960s, more sturgeon larvae have been observed in the Delta in years with high Sacramento River flows (Stevens and Miller 1970).

WS are broadcast spawners, depositing eggs on gravel or cobble streambeds in areas of water depths from 1.5 to 10.5 m and velocities greater than 1.0 m/s (Schaffter 1997; Jackson et al. 2016). Fine substrates without interstitial spaces can decrease survival of WS eggs (Hildebrand et al. 2016) and may limit recruitment to the larval or juvenile life stage. Female WS can lay hundreds of thousands of eggs per year at maturity, as fecundity averages 5,648 eggs per kg of body weight (Heublein et al. 2017; Webb et al. 1999). Eggs are negatively buoyant and become adhesive upon fertilization (Moyle 2002; Israel et al. 2009; Hildebrand et al. 2016).

Development and survival of WS embryos are temperature-dependent, and optimal survival to hatching occurs between 14 °C (88.6% ± 2.2% survival) and 17 °C (83.6% ± 1.9% survival) (Wang et al. 1985). Embryo mortality increases as water temperatures increase to 20 °C (49.1% ± 3.2% survival), and water temperatures greater than 20 °C are lethal to developing embryos (Wang et al. 1985). Time until WS eggs hatch is also temperature-dependent, with warmer water resulting in shorter incubation duration (Wang et al. 1985; Deng et al. 2002). Development time for eggs incubating at 15.7 ± 0.2 °C averages 176 hours (Deng et al. 2002).

WS yolk-sac larvae are 10 mm–11 mm TL at emergence, and the yolk sac is completely absorbed approximately 20–23 days post-fertilization (Wang et al. 1985). Larvae are negatively phototactic upon hatching and swim near the bottom of rivers (Kynard and Parker 2005). Small (<17 mm TL)

WS larvae have been observed to seek out and use cover to avoid predation (Gadomski and Parsley 2005), but studies have observed that WS leave cover at the size where exogenous feeding begins.

Little is known about the timing of outmigration and rearing habitat of WS larvae in the Sacramento River system (Israel et al. 2009). However, juvenile WS are believed to initiate a secondary dispersal (the primary dispersal occurring at the larval stage) in spring by actively swimming downstream during the night (Kynard and Parker 2005). Dispersal duration is unknown, but observed swimming intensity and duration in laboratory studies indicate dispersal likely lasts several days and over many kilometers (Kynard and Parker 2005). Small juvenile WS are likely preyed upon by a variety of native and invasive piscivores (Hildebrand et al. 2016). A mark-recapture study involving juvenile hatchery-origin WS (approximately 200 mm FL) at the Tracy Fish Collection found juvenile WS in the stomachs of striped bass collected at the facility during the study (Karp and Bridges 2015). Juvenile WS increase their tolerance to salinity as they age, allowing WS to occupy a wider range of habitats within the Bay-Delta as they become young adults (Vaz et al. 2015). As adults, WS move throughout the SFE, occasionally making forays into coastal waters.

3.5.2. Range and Distribution

The SFE WS consists of a primary spawning population in the Sacramento River and a secondary spawning population on the San Joaquin River (Figure 3-10). These two populations have been displaced from their historical spawning habitat upstream of the Central Valley Rim dams and persist in a section of the river where suitable habitat is artificially maintained by releases from reservoirs (Moyle et al. 2015; Sellheim et al. 2022). A relic population that persisted in Shasta Reservoir after construction of Shasta Dam indicates that WS likely migrated and spawned upstream of the current damsite historically, including in major tributaries to the upper Sacramento River such as the Pit River (Moyle 2002; Moyle et al. 2015).

The absence of evidence for consistent spawning activity in the Central Valley outside of the mainstem Sacramento River and San Joaquin River may reflect a lack of systematic sampling in other Central Valley rivers (Jackson et al. 2016). Additionally, extensive levels of water development limit the frequency and spatial extent of successful WS spawning in the San Joaquin River (Jackson et al. 2016), and some Sacramento River tributaries. Low flow levels, construction and maintenance of the Stockton Deepwater Ship Channel, and high nutrient inputs to the San Joaquin River from agriculture upstream foster low DO conditions and frequent HABs (e.g., of the toxic cyanobacteria *Microcystis*) (Berg and Sutula 2015) in the lower San Joaquin River, both of which are likely to impair WS migrations to and from spawning grounds in the San Joaquin River and its tributaries (CBDA & CV RWQCB 2006; Moyle et al. 2015).

Telemetry data and observed aggregations of gravid WS have shown that WS likely spawn in the lower Feather River, though spawning has not been documented in recent years (Heublein et al. 2017). The frequency of flow and temperature conditions suitable for WS spawning and incubation in the Feather River are also likely to be far lower now than what occurred historically, due to construction and operations of Oroville Dam and the Thermalito water management infrastructure (Heublein et al. 2017).

Figure 3-6. Current and historic distribution of White Sturgeon (*Acipenser transmontanus*). The San Francisco Estuary (SFE) is the only known spawning population in California; detection of White Sturgeon in rivers north of the SFE is not believed to reflect presence of a current spawning population (CDFW 2023b).

Most documented WS spawning is in the Sacramento River between Knights Landing (RM 90) and Colusa (RM 144) (Miller et al. 2020) and above the mouth of the Feather River (Kohlhorst 1991). During the spawning season (January through June) adults may spend as few as three weeks to more than two months in the spawning reach before returning downstream to the Delta (Miller et al. 2020). Telemetry data of 259 tagged WS from 2010 to 2023 indicate that most adult detections at Colusa occur between March and April (Table 3-2; UC Davis PATH 2024).

Table 3-2. Percentage of detections of adult White Sturgeon within 20 km of the city of Colusa by month during spawning season (December–June). (Source: UC Davis PATH 2024).

Month	Percentage of Detections	Cumulative Percentage
December	1.09	1.09
January	6.37	7.46
February	12.1	19.56
March	32.6	52.16
April	39.0	91.16
May	6.68	97.84
June	2.17	100

Adult and juvenile WS have been detected much further upstream in some years, but monitoring data are insufficient to determine frequency and density of presence and spawning in the upper sections of the Sacramento River. Adult WS have been reported by anglers near the confluence of the Sacramento River and Deer Creek (RM 220) and observed during summer and early fall near Hamilton City (RM 206) (Heublein et al. 2017). Juvenile WS have also been collected in the RST at GCID and reported by anglers in the area (Heublein et al. 2017). Given these observations, WS presumably spawn upstream from the GCID oxbow in some years.

Adult WS have also been recorded spawning on the mainstem San Joaquin between RM 71–86 (Jackson et al. 2016). Fertilized WS eggs were collected downstream of Grayson (RM 86) in late April of 2012 and fertilized WS eggs were collected downstream of Vernalis (RM 71–87) from late March through mid-May of 2012 (Jackson et al. 2016).

WS larvae begin appearing south of the city of Sacramento in the 20-mm Survey and San Francisco Bay Study mainly between the months of March and May of any given water year (Table 3-3). During high outflow years, WS larvae can be observed as downstream as Suisun Bay (Stevens and Miller 1970). Miller et al. (2020) found that tagged juvenile WS were most often detected in Suisun Bay and the Delta, then followed by San Pablo Bay. Sub-adult WS were most frequently detected in San Pablo Bay, Suisun Bay, San Francisco Bay, and the Delta, while a small number of individuals venture out into coastal waters for a short period of time (Miller et al. 2020).

Table 3-3. Month of first detection of a White Sturgeon smaller than 100 mm in the 20-mm Survey and San Francisco Bay Study surveys.

Water Year	Month of first <100 mm White Sturgeon detection
1993	May
1994	April
1995	April
1996	April
1997	April
1998	April
1999	May
2000	March
2001	No catch
2002	No catch
2003	March
2004	April
2005	July
2006	April
2007	No catch
2008	No catch
2009	No catch
2010	No catch
2011	March
2012	May
2013	May

Water Year	Month of first <100 mm White Sturgeon detection
2014	No catch
2015	No catch
2016	March
2017	March
2018	March
2019	March
2020	No catch
2021	No catch
2022	No catch
2023	March
2024	May

3.5.3. Population Status and Trends

WS populations are declining (Figure 3-11; SWRCB 2017; Blackburn et al. 2019). Although longevity and fecundity may buffer populations through periods of low recruitment, delayed maturation, and the multi-year interval between egg clutches of individual females increase vulnerability of WS to sustained anthropogenic modification of river and estuarine flow regimes, overharvest, and sustained degradation of other habitat conditions (Blackburn et al. 2019). Population trends are discussed below in the context of four factors for which data are available: (1) The frequency high river flows that support juvenile recruitment; (2) Salvage at the water export facilities in the south Delta; (3) Estimates of WS abundance and harvest associated with the recreational fishery; and (4) Catastrophic mortality in response to harmful algal blooms (HABs).

Recruitment of juvenile WS is flow-dependent, and chronically low river flows and reductions in Delta outflow have contributed to the decline of WS (Jackson et al. 2016; SWRCB 2017). As a result, successful cohort formation is infrequent for WS, corresponding to years of high spring-summer river flows into and out of the Delta (Figure 3-11; Moyle 2002; Fish 2010; Kohlhorst et al. 1991; Schaffter and Kohlhorst 1999; SWRCB 2017). The SWRCB analyzed the relationship between average freshwater Delta outflow in March-July and recruitment of juvenile WS and found that recruitment of juvenile WS did not occur when March-July average flows were below certain thresholds (see Figures 3.6-2 and 3.6-3 of SWRCB 2017) and determined that monthly average Delta outflows >37,000 cfs during this period were sufficiently protective of WS. From 1980-1999, average March-July Delta outflows >37,000 cfs occurred 30% of the time (6 out of 20 years). Since 1999, flows of this magnitude have occurred only 17.4% of the time (4 out of 23 years). Juvenile recruitment during optimal conditions may also be constrained by declines in the spawning stock of adults (SWRCB 2017; Blackburn et al. 2019), adult fecundity, or both.

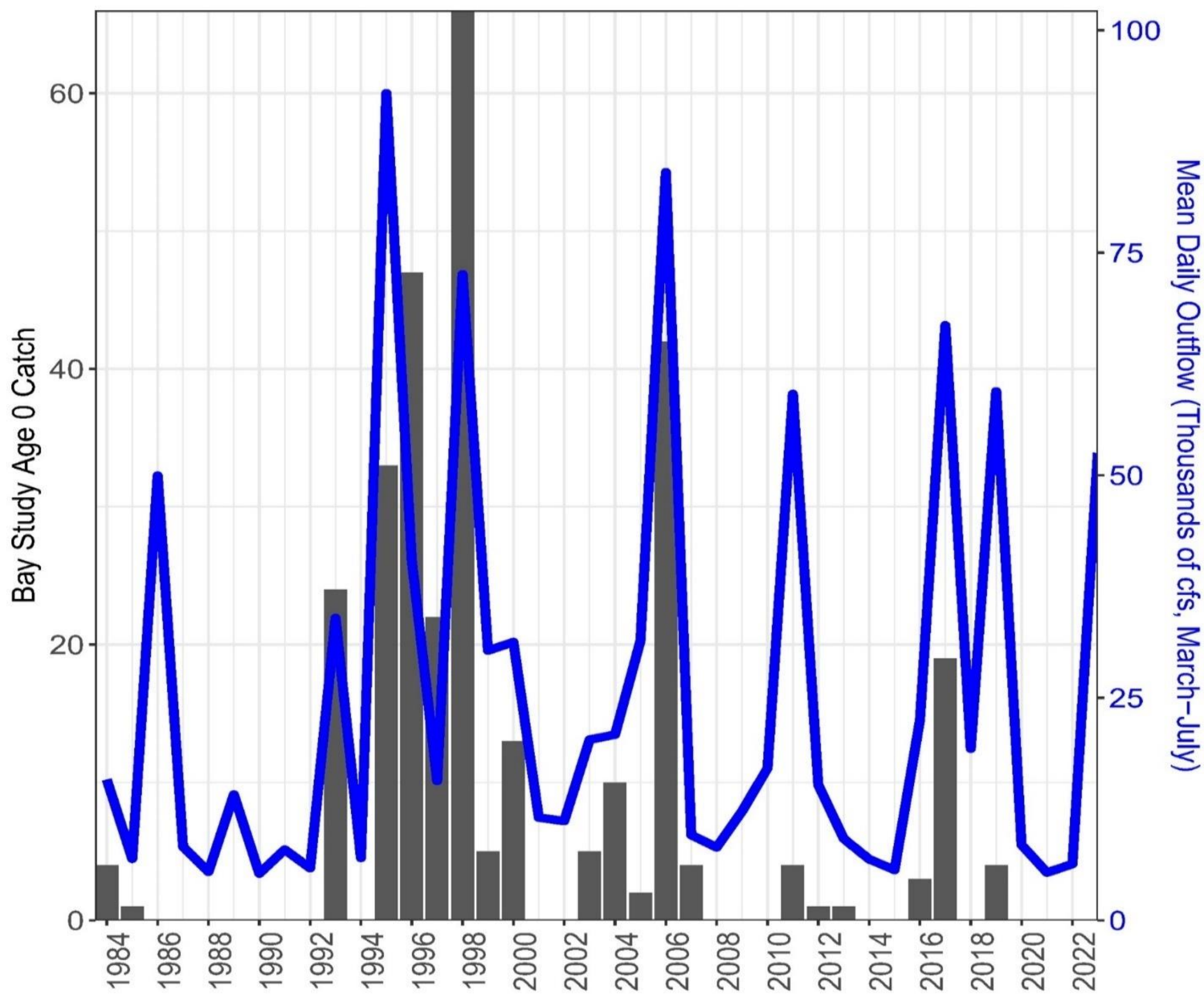

Figure 3-7. Relationship of spring-summer Delta outflow and White Sturgeon juvenile recruitment. Left axis: Bay Study index of Age 0 White Sturgeon caught in the San Francisco Estuary (source: CDFW). Right axis: Mean daily Delta outflow during March-July, in thousands of cfs (source: DWR (2024)). Abundance is strongly correlated with March–July Delta outflow.

Juvenile WS are entrained due to water exports from the Delta, and the number of WS salvaged at the facilities may provide an index of recruitment. Trends in WS salvage data indicate a significant declining trend in abundance, including zero fish detected in five of the last ten years (Figure 3-12).

High salvage in 2023 likely reflects a relatively large cohort of YOY WS produced following the record precipitation and runoff of that year.

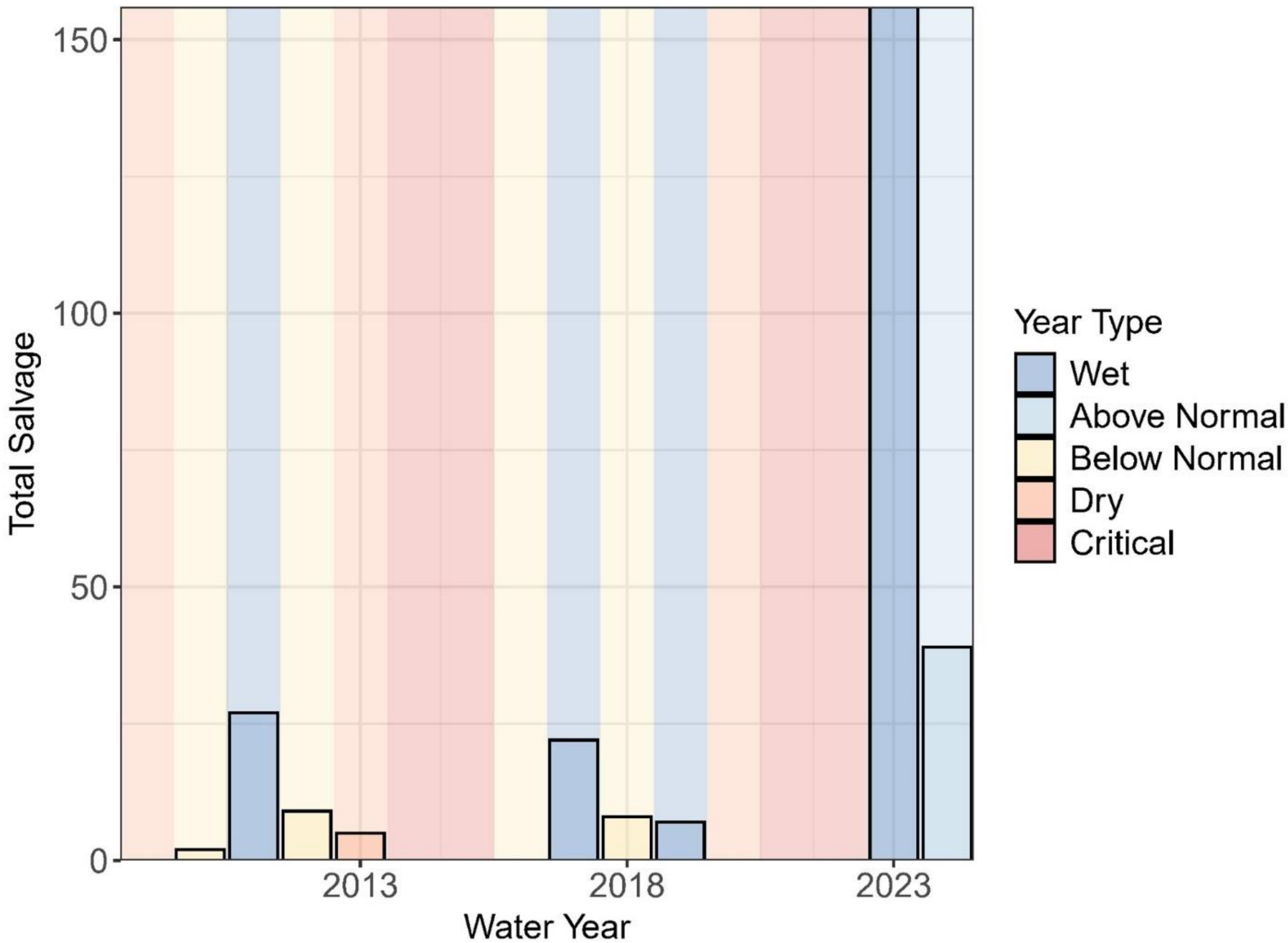

Figure 3-3-8. Annual combined salvage of White Sturgeon at the Central Valley Project and State Water Project facilities from water years 2009–2024, with each colored region representing Water Year Type based on the Sacramento Vally Index.

CDFW manages recreational harvest of adult WS using slot limits, which allows harvest of WS within a size range; WS that are larger or smaller than the length range must be released by anglers. CDFW estimates the abundance of the harvestable ("slot sized") population using mark recapture studies. Estimates of "slot sized" fish regularly exceeded 150,000 fish in the 1980s and returned to these levels in the late 1990s following an extended drought from 1987-1993 (Figure 3-13). By 2021, the estimated harvestable population had declined to a 5-year average of approximately 33,000 fish (CDFW 2023b). The sport fishery harvest rate for WS averaged 13.6% (range: 8-29.6%) between 2007 and 2015 (Blackburn et al. 2019), and 8.1% (range: 3.5-14.2%)

from 2016 through 2021 (CDFW 2023b), above those that the best available science indicates can be sustained (CDFW 2023b).

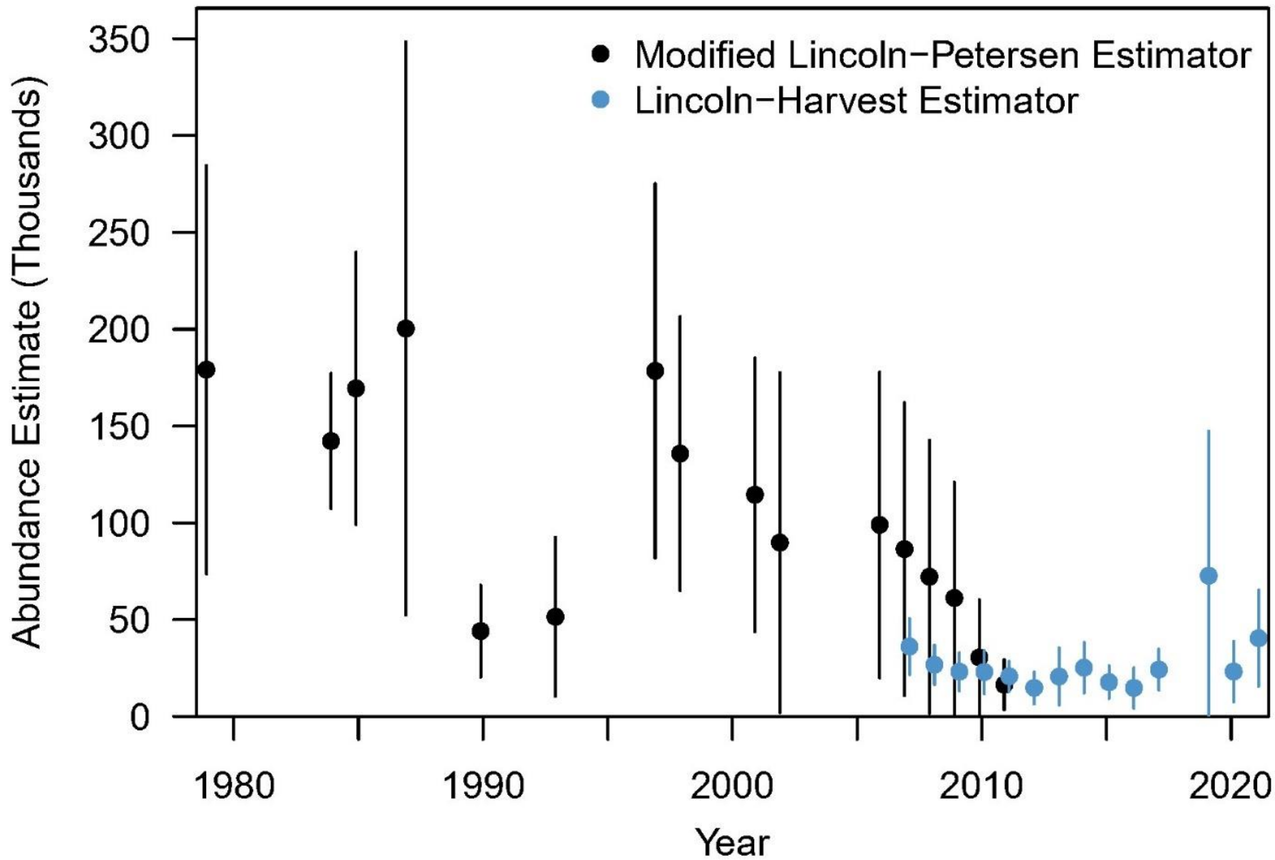

Figure 3-9. Estimated abundance of "slot-sized" White Sturgeon based on CDFW mark-recapture studies. Whiskers represent error bounds. The latest year of data (2021) precedes fish kills related to harmful algal blooms in 2022 and 2023. (CDFW 2023b).

In addition to the chronic drivers of declining abundance and harvest, the WS population is susceptible to widespread catastrophic loss from HABs in the San Francisco and San Pablo Bays and in the Delta. Red tide algal blooms caused by *H. akashiwo,* have been observed in the San Francisco Bay and San Pablo Bay and have also been linked to fish kills elsewhere in the world (CDFW 2023b). During July and August, 2022, the San Francisco Bay region experienced a major HAB of *H. akashiwo* that killed at least 850 sturgeon, primarily WS (CDFW 2023b). Of the 850 carcasses recovered, 86% were legal-sized (40 inches) or greater, representing mature, spawning broodstock (CDFW 2023b), and total mortality was likely much greater than the number of carcasses observed.

3.5.4. Listing History

On November 29, 2023, the Commission received a Petition from San Francisco Baykeeper, the Bay Institute, Restore the Delta, and California Sportfishing Protection Alliance to list WS as threatened under CESA (Rosenfield 2023). On December 6, 2023, the Commission referred the Petition to CDFW for evaluation. On June 19, 2024, the Commission voted to accept WS as candidate for threatened status under CESA (see Cal. Code Regs., tit. Fish & G. Code, §2074.2, subd. (e)(2)). Subsequently, CDFW is in the process of developing a peer-reviewed report using the best scientific information available to advise the Commission on whether the petitioned action is warranted (Fish & G. Code, § 2074.6), which the Commission will use to determine whether the petitioned action to list White Sturgeon as threatened is warranted (Fish & G. Code, § 2075.5). On November 29, 2023, pursuant to Section 4(b) of the ESA, 16. U.S.C. § 1533(b); Section 553(e) of the Administrative Procedure Act, 5. U.S.C. § 553(e); and 50 C.F.R. § 424.14(a), San Francisco Baykeeper, The Bay Institute, Restore the Delta, and California Sportfishing Protection Alliance provided notice in accordance with 50 C.F.R. § 424.14(b) and (c)(9) that they intended to petition the Secretary of Commerce, through NMFS, to list the San Francisco Estuary (SFE) White Sturgeon Distinct Population Segment as a threatened species. The petition was subsequently passed to the USFWS to maintain consistency with the listing of the Kootenai White Sturgeon population. On October 9, 2024, the USFWS posted their 90-Day Finding on the Federal Register with the decision that the petition presented substantial information that the SFE White Sturgeon population may be a listable entity (Federal Docket No. FWS-R8-ES-2024-0049). Critical habitat for White Sturgeon has been proposed from below all the Central Valley dams to the waters and fringing marshes of San Francisco Bay and its sub-embayments, along with the nearshore ocean off San Francisco Bay (Gulf of the Farallones) and nearby coastal embayments (e.g., Bodega Bay, Tomales Bay). The proposed critical habitat includes spawning sites on the San Joaquin and Sacramento rivers, as well as anticipated spawning and rearing habitats on the San Joaquin and Sacramento rivers major tributaries, including waterways used for migration to and from these spawning/rearing areas in and upstream of the Delta.

3.5.5. Extinction Risk

The low intrinsic population growth rate of WS means it is highly sensitive to overharvest (Blackburn et al. 2019; Ulaski et al. 2022) and catastrophic adult mortality events. Furthermore, because WS recruitment is heavily influenced by survival at early life stages (Kohlhorst et al. 1991, Hildebrand et al. 1999), less frequent high magnitude spring-summer river flows has increased the interval between successful cohorts, reducing the population’s resilience and viability during periods of poor recruitment or high levels of sub-adult or adult mortality.

4. TAKE AND IMPACTS OF TAKING ON COVERED SPECIES

Water storage and management in the Sacramento River Basin has immensely altered the natural hydrology, which affects the composition and health of aquatic ecosystems (Poff and Zimmerman 2010; Moyle and Mount 2007). Historically, the hydrologic regime included winter flood pulses and a long spring snowmelt that provided high flows and frequent floodplain inundation, which juvenile CHNSR, CHNWR, and WS depended on during rearing and outmigration (Mount et al. 2017). The current, highly managed system stores much of this water from the winter and spring, releasing it in the late spring and summer when it is needed for irrigation or other human needs (Figures 4-1 and 4-2). This water management reduces flow and flow variability during the spring and fall when CHNSR, CHNWR, and WS are typically migrating through the system.

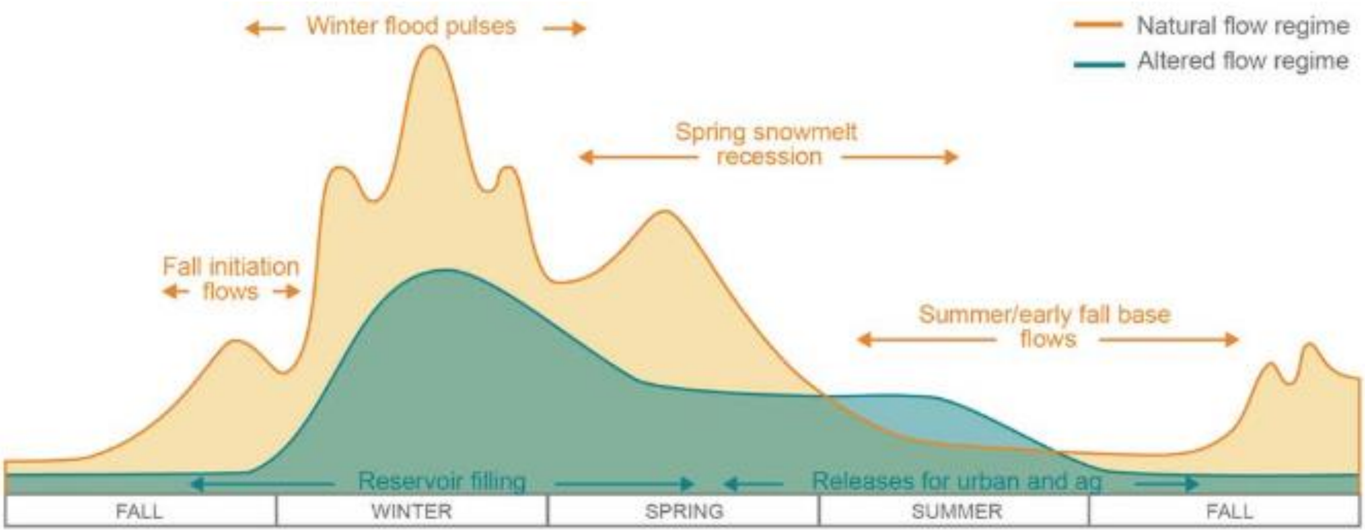

Figure 4-1. Comparison of a natural flow regime to a managed flow regime (from Mount et al. 2017)

Reducing river flows causes water to move downstream more slowly, and less water in the river means that water temperature is more affected by air temperature (i.e., reduced thermal mass) (Michel et al. 2023). Because water in the river is both heating up faster and moving more slowly, water temperatures in the Sacramento River increase more quickly and farther upstream than would happen under higher flows when air temperatures are warm. When increased water temperatures coincide with CHNSR, CHNWR, and WS migration, they reduce juvenile survival and can harm or block migration of adults (McCullough et al. 1999; Webb et al. 1999; Michel et al. 2023).

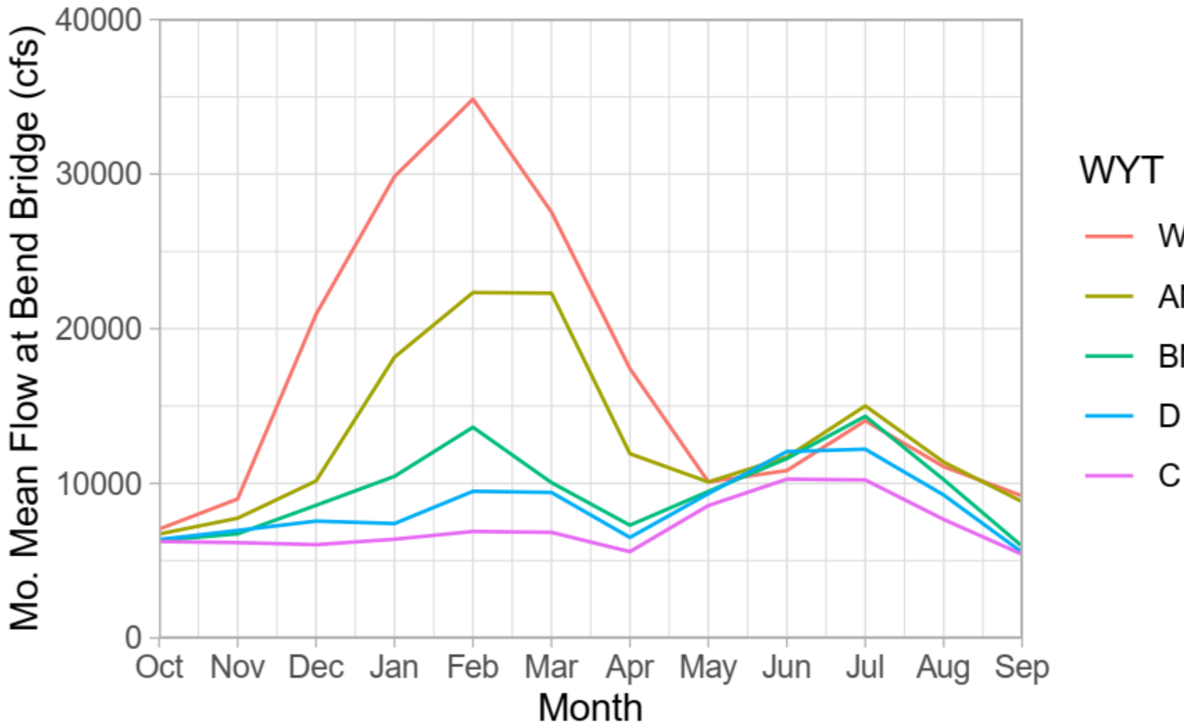

Figure 4-2. Daily flows at the Sacramento River at Bend Bridge for the No Action Alternative (NAA). Daily flows from Upper Sacramento River Daily Operational Model (USRDOM) were averaged by water year type to illustrate the current managed hydrologic regime in the Sacramento River. Water year types were classified using the Sacramento Valley Index as Wet (W), Above Normal (AN), Below Normal (BN), Dry (D), and Critical (C). Notably, average flows in the Sacramento River below Keswick Dam during summer months are consistently above 10,000 cfs for all water year types, but flows in winter and spring vary considerably (range from approximately 7,000 cfs to 35,000 cfs) by water year type. Average streamflow for February and March, typically the wettest months in this region, are lower than average streamflow in June and July, typically the driest months, for Dry and Critical years.

Effects of Project Diversions

The Project proposes to divert, convey, and store water from two existing diversion locations on the Sacramento River, Red Bluff and Hamilton City, annually between September 1 and June 14, when CHNWR, CHNSR, and WS juveniles are rearing and outmigrating from the Sacramento River and its tributaries (Figure 4-3). Diversions during this period may affect migrating juveniles due to near-field effects such as impingement or increased predation at diversion locations (see Sections 4.1.1, 4.4.1, and 4.4.2) or by decreasing streamflow in the Sacramento River downstream of the diversions and through the Delta.

Figures 4-4 and 4-5 show the timing and magnitude of proposed diversion at Red Bluff and Hamilton City for the NAA, Alt3B, NoSha, and NoShaOro modeled operational scenarios, as compared to migration timing of juvenile CHNSR and CHNWR passing the Sacramento River juvenile monitoring station at Knights Landing. Very few data are available for WS juvenile rearing and migration in the Sacramento River, but they could be present from Hamilton City to Verona and down through the Delta between January and June (Miller et al. 2020, CDFW 2023b).

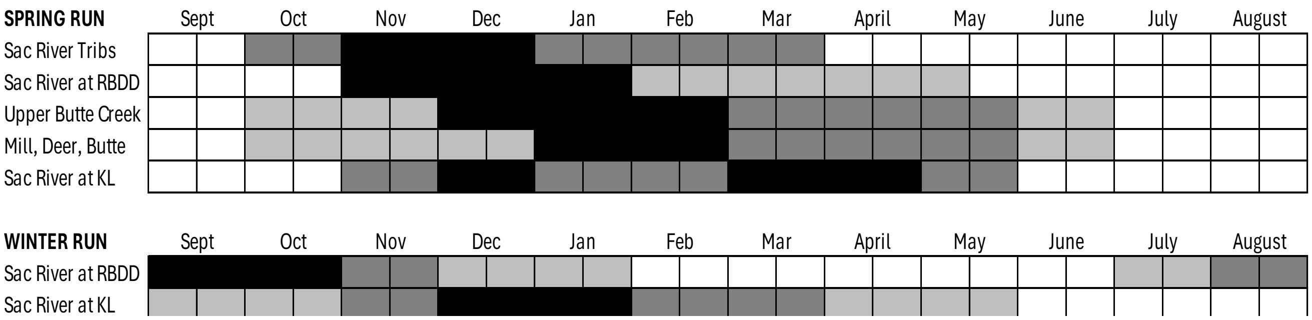

Figure 4-3. Spring-run Chinook Salmon and winter-run Chinook Salmon juvenile migration timing at different locations in the Sacramento River Basin. Darker colors represent higher abundance (Sources: W. Poytress personal communication July 2024, CalFish 2024, Cordoleani et al. 2019, Johnson and Merrick 2012, NMFS 2014, Poytress et al. 2014, R. Revnak personal communication July 2024, T. McReynolds personal communication July 2024, Williams et al. 2011)

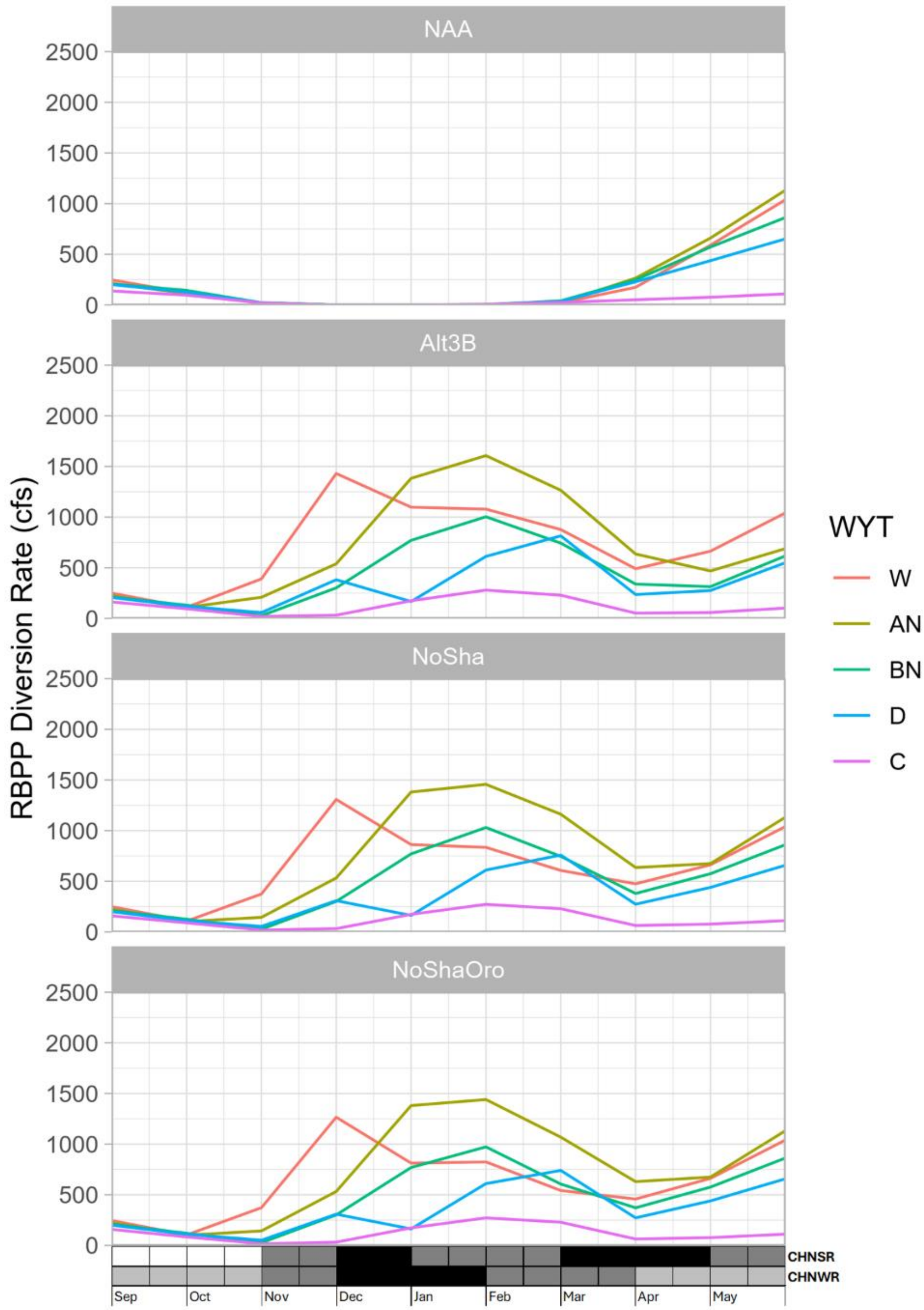

Figure 4-4. Diversion timing at Red Bluff Pumping Plant (RBPP), averaged by month and water year type for illustration (data from Upper Sacramento River Daily Operational Model (USRDOM) for No Action Alternative (NAA) and the Alt3B, NoSha, and NoShaOro operational scenarios, and migration timing of juvenile spring-run and winter-run Chinook Salmon passing Knights Landing. Water year types were classified using the Sacramento Valley Index and noted as Wet (W), Above Normal (AN), Below Normal (BN), Dry (D), and Critical (C). The grayscale bar below the figure shows relative presence of juvenile CHNWR and CHNSR downstream at Knights Landing, with darker colors representing higher presence.

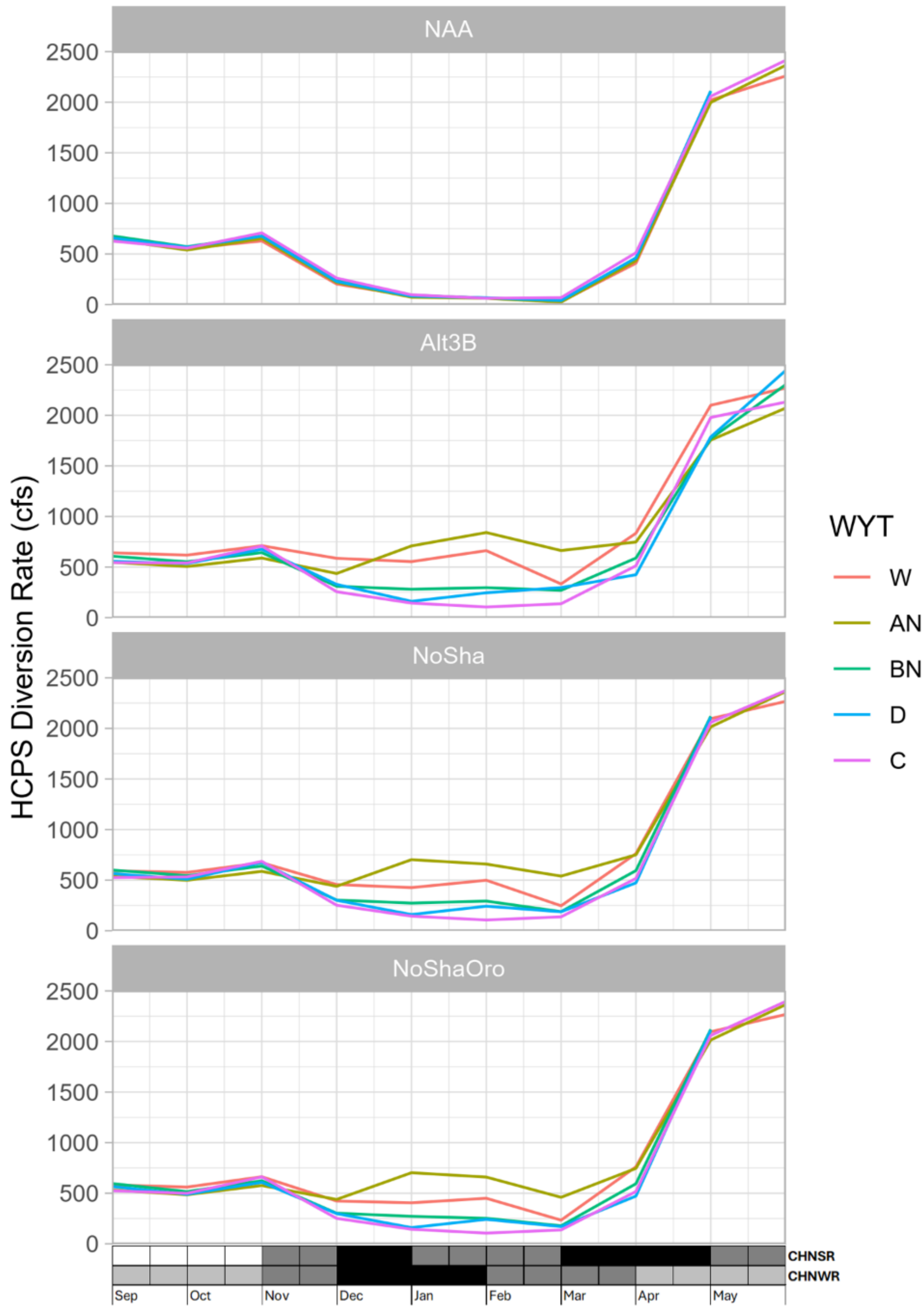

Figure 4-5. Diversion timing and magnitude at Hamilton City Pump Station (HCPS), averaged by month and water year type for illustration (data from Upper Sacramento River Daily Operations Model (USRDOM) for No Action Alternative (NAA) and the Alt3B, NoSha, and NoShaOro operational scenarios, and migration timing of juvenile spring-run and winter-run Chinook Salmon passing Knights Landing. Water year types were classified using the Sacramento Valley Index as Wet (W), Above Normal (AN), Below Normal (BN), Dry (D), and Critical (C). The grayscale bar below the figure shows relative presence of juvenile CHNWR and CHNSR downstream at Knights Landing, with darker colors representing higher presence.

Effects of Project Deliveries and Exchanges

The timing and locations of water delivery from Sites Reservoir, including CVP operational flexibility and exchanges, may also have effects on listed fish species. Sites participants would receive water from Sites Reservoir one of four ways (Figure 4-6). Depending on delivery method, Sites Reservoir delivery operations might not affect river flow directly (e.g., Figure 4-6, A and C), or may increase Sacramento River flows in some reaches at certain times during the summer and fall (e.g., Figure 4-6, B and D). Because the farthest downstream diversion location for the Project (Hamilton City, RM 205) is approximately 115 miles upstream of the reservoir release location (Knights Landing Outfall, RM 90), the river reach between can be expected to experience decreases in streamflow during the diversion season, during the delivery season, and annually, on average as a result of Project operations.

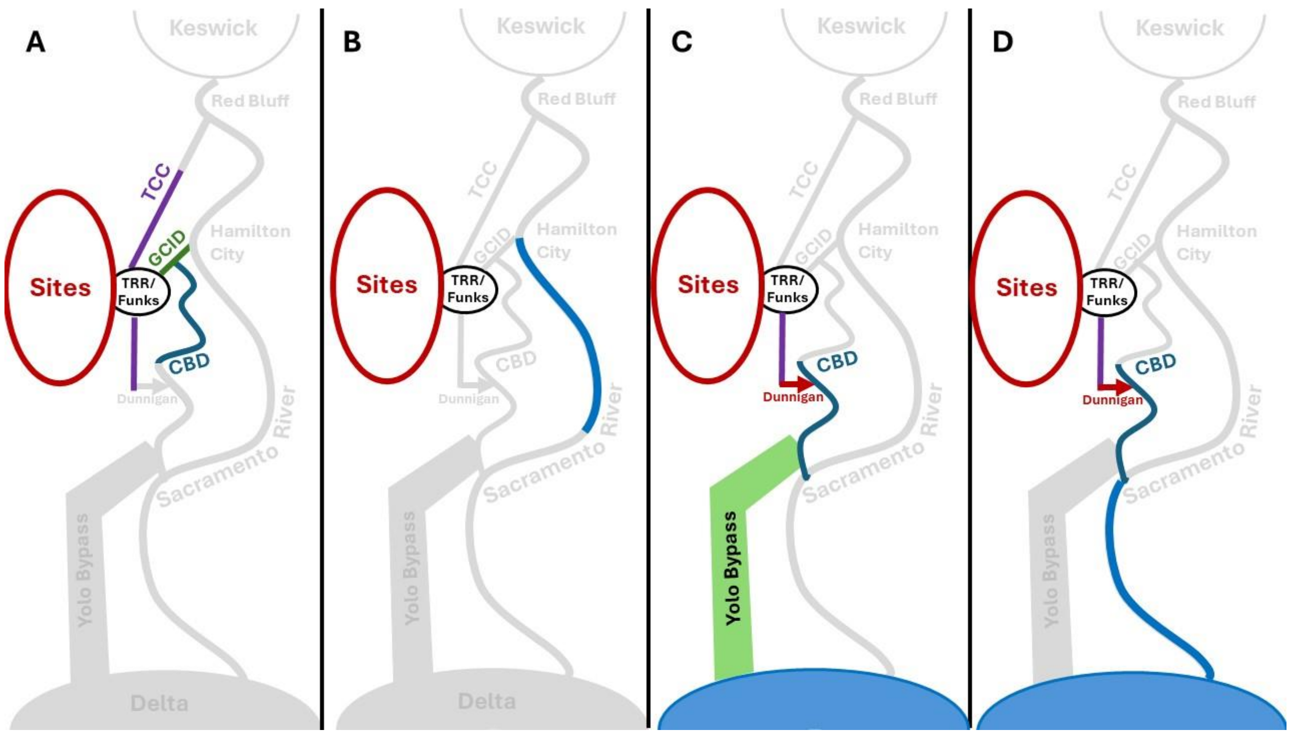

Figure 4-6. Four options for water delivery from Sites Reservoir (figure created using information in Sites Authority 2023): (A) Releases from Sites for storage participants along the Tehama Colusa Canal (TCC) and Glenn Colusa Irrigation District (GCID) Main Canal (shown in dark green) between the Hamilton City diversion and Colusa Basin Drain (CBD). Once those flows were diverted from the Sacramento River, they would not be returned. (B) Releases for storage participants along the Sacramento River would be made by exchanges, as there is no conveyance to convey water directly from Sites into the Sacramento River. Flows may increase in the Sacramento River between GCID and the location of diversion, then decrease between the point of diversion downstream. (C) Releases for storage participants along the CBD and Yolo Bypass would be made from Funks or the Terminal Regulating Reservoir (TRR) and conveyed down the TCC to the Dunnigan Pipeline through the CBD and Knights Landing Ridge Cut (D) Releases for south-of-Delta storage participants, including refuge water supply, would be made from Funks Reservoir, through the TCC and Dunnigan Pipeline, into the CBD and to the Sacramento River through the Knights Landing Outfall Gates.

CDFW compared monthly Sacramento River flows from the ITP Application CalSIM II model (Sites Authority 2023) for the NAA and the Alt 3B, NoSha, and NoShaOro operational scenarios to better understand the Project's effects due to CVP operational flexibility, real-time exchanges, and exchanges with Shasta and Oroville reservoirs. For all three operational scenarios for the Project, Sacramento River flows would be, on average, lower in late spring (March-May) and higher in summer (July-August). CDFW found that these effects are most pronounced in the reach between Hamilton City and KLOG during Critical, Dry, and Below Normal years. Figures 4-7 and 4-8 show the percent change in flow at the Sacramento River at Tisdale Weir (Tisdale) (RM 119, approximately one mile upstream of Wilkins Slough) compared to the NAA for the three operational scenarios for April and May of Critical, Dry, and Below Normal water years.

Changes in April (Figure 4-7) and May (Figure 4-8) Sacramento River flow differ considerably among the three operational scenarios, often by as much as 10% and 1,000 cfs at Tisdale, and the Alt3B operational scenario generally had the largest reductions in flow (see also Appendix B). Significant changes in streamflow are likely to have implications for water temperatures and survival for CHNWR, CHNSR, and WS present in those months (see Sections 4.1.2.1, 4.1.5, 4.1.10, and 4.4.4). These large relative differences in modeled streamflow between alternatives, and the potential biological impacts of these differences, highlight the need to further understand operations and potential flow and temperature impacts of the Project once operations agreements are in place and the timing, magnitude, and effects of CVP operational flexibility and exchanges are better understood.

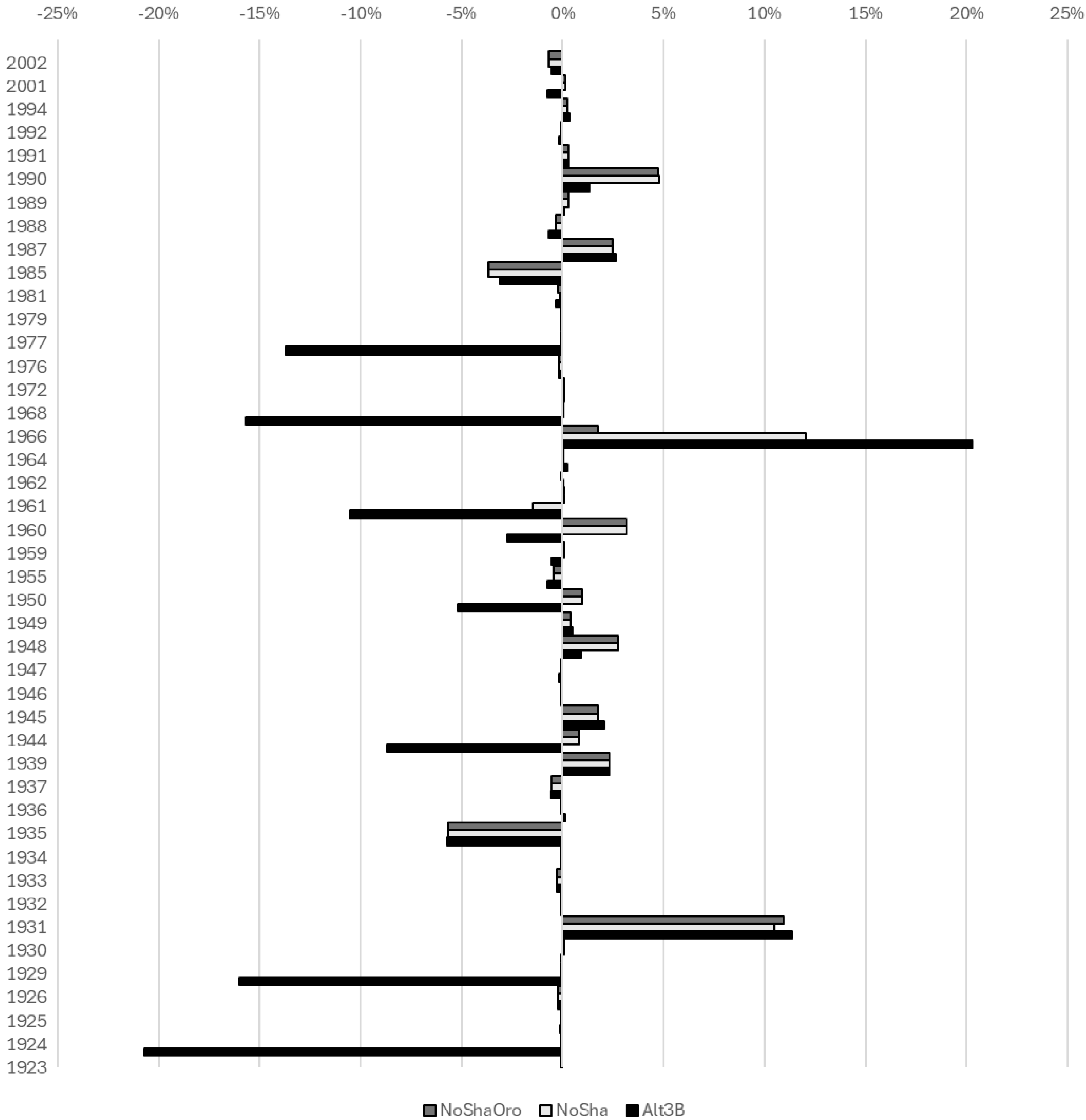

Figure 4-7. Percent change in monthly average streamflow at Tisdale Weir in April of Critical, Dry, and Below Normal years, compared to the No Action Alternative (NAA). Data from HEC-5Q model provided by Sites Authority (2023). "Alt3B" = Alternative 3B. "NoSha" = No exchanges with Shasta Reservoir. "NoShaOro" = No Exchanges with Shasta or Oroville reservoirs. Bars are not visible when there was no difference from NAA.

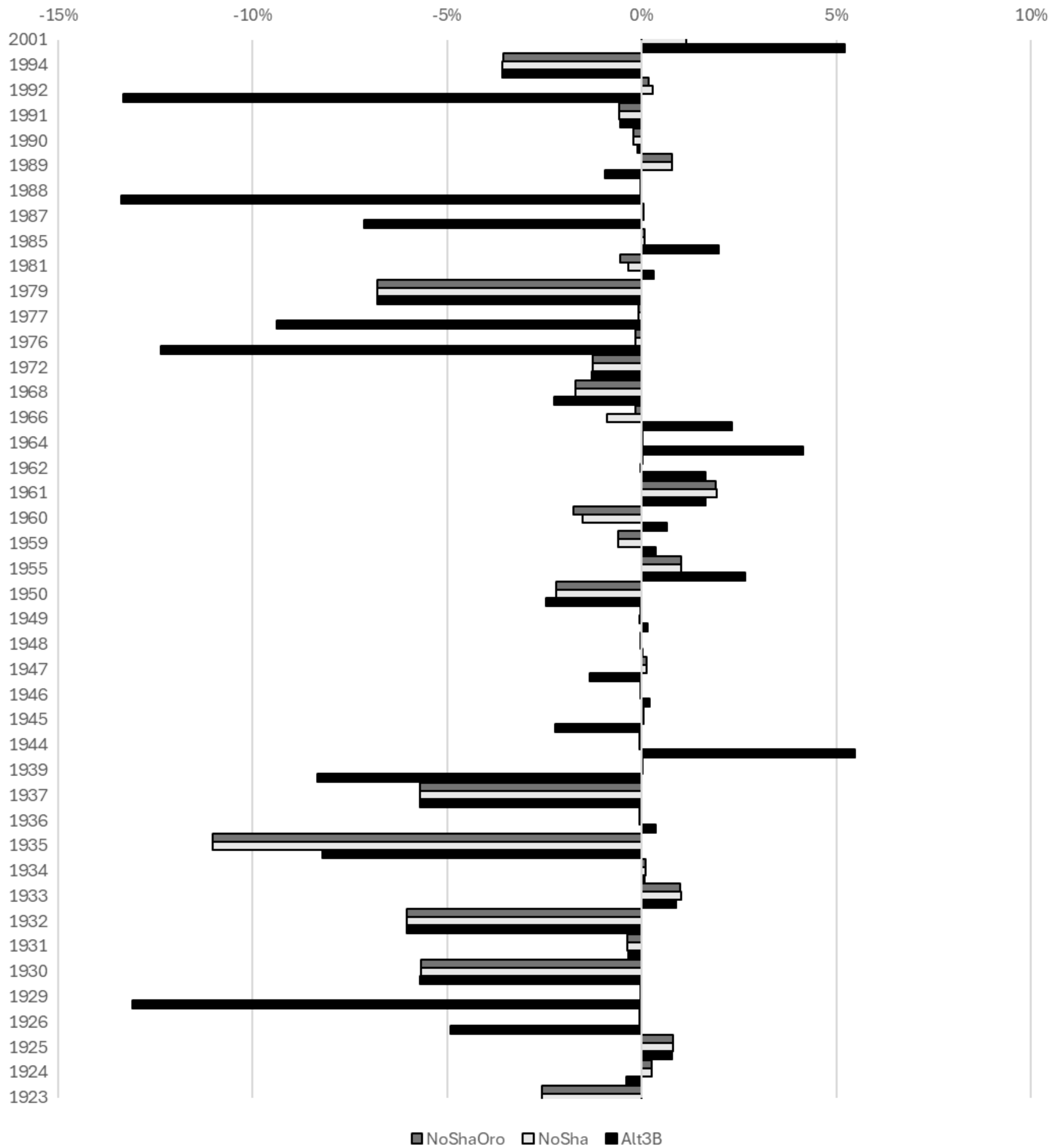

Figure 4-8. Percent change in monthly average streamflow at Tisdale in May of Critical, Dry, and Below Normal years, compared to the No Action Alternative (NAA). Data from HEC-5Q model provided by Sites Authority (2023). “NoSha” = No exchanges with Shasta Reservoir. “NoShaOro” = No Exchanges with Shasta or Oroville reservoirs. “Alt3B” = Project with exchanges. Bars are not visible when there was no difference from NAA.

Effects of the Project on South Delta Exports

Operations of the Project would result in changes in south Delta exports at CVP's Jones and SWP's Banks pumping plants as water is moved from Sites Reservoir or through exchanges to Sites participants that are south of the Delta. Based on CalSIM II modeling provided in the ITP Application (Sites Authority 2023), South Delta exports would increase by a long-term average of approximately 35 TAF per year in wet years to approximately 250 TAF per year in Dry Years (Figure 4-9). Increased exports would primarily occur at the SWP's Banks Pumping Plant, where average exports in Dry years under the Project (Alt3B, NoSha, and NoShaOro operational scenarios) would be 13–14% higher than under the NAA (Sites Authority 2023). Changes in exports resulting from Project operations would occur in all months, but most frequently in July through November (Figure 4-10), coinciding with the transfer period.

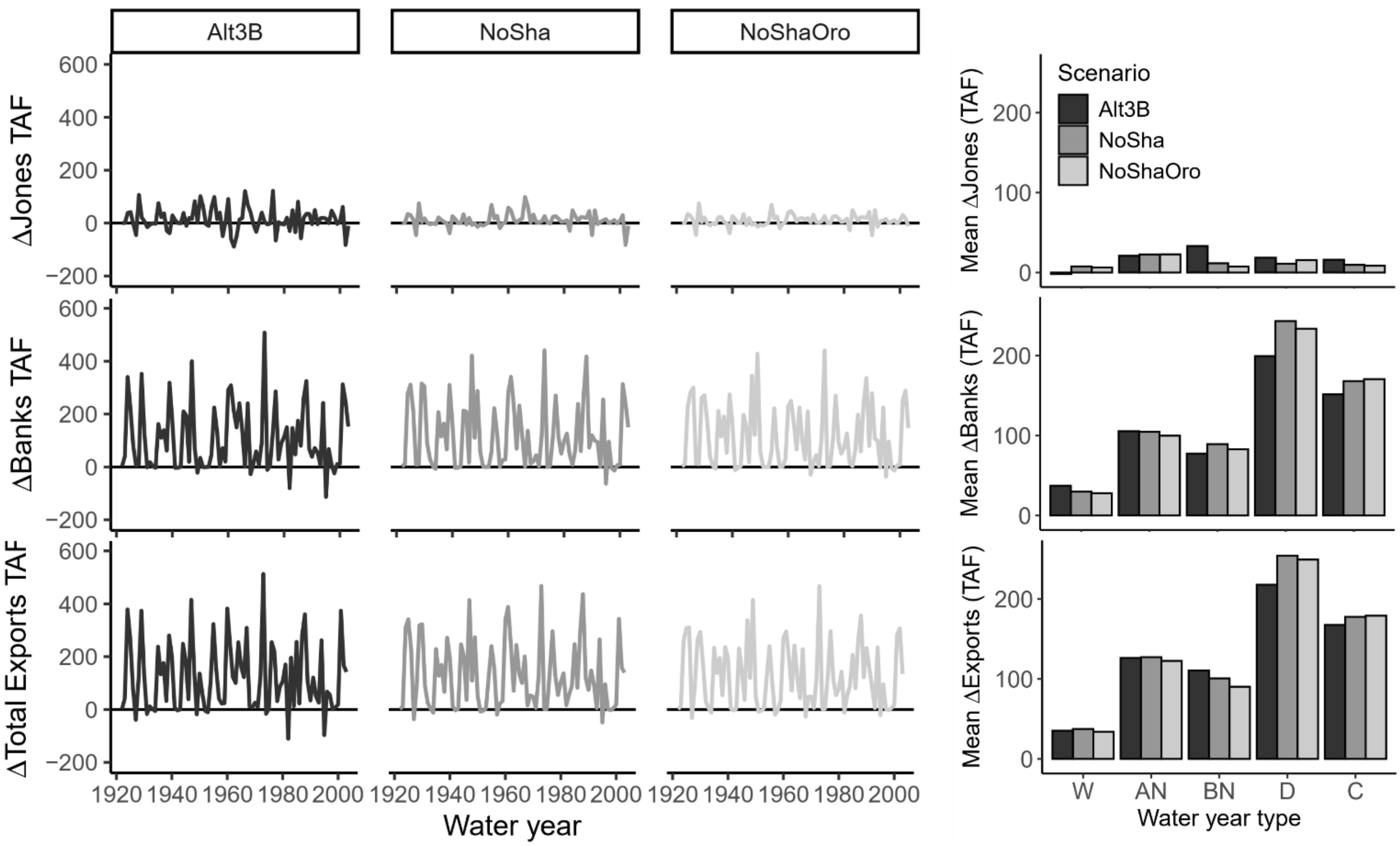

Figure 4-9. (left) Mean change annual exports (TAF) at Jones Pumping Plant (top), Banks Pumping Plant (middle) and Jones and Banks (bottom) water export facilities in the south Delta under Alt3B (black), NoSha (dark gray) and NoShaOro (light gray), relative to the NAA. (right) Mean change in exports by water year type at Jones (top), Banks (middle) and Jones + Banks (bottom) water export facilities in the South Delta. Shades are as in righthand panels. Water year types are wet (W), Above Normal (AN), Below Normal (BN), Dry (D) and Critical (C). Note that axis scales on left and right differ.

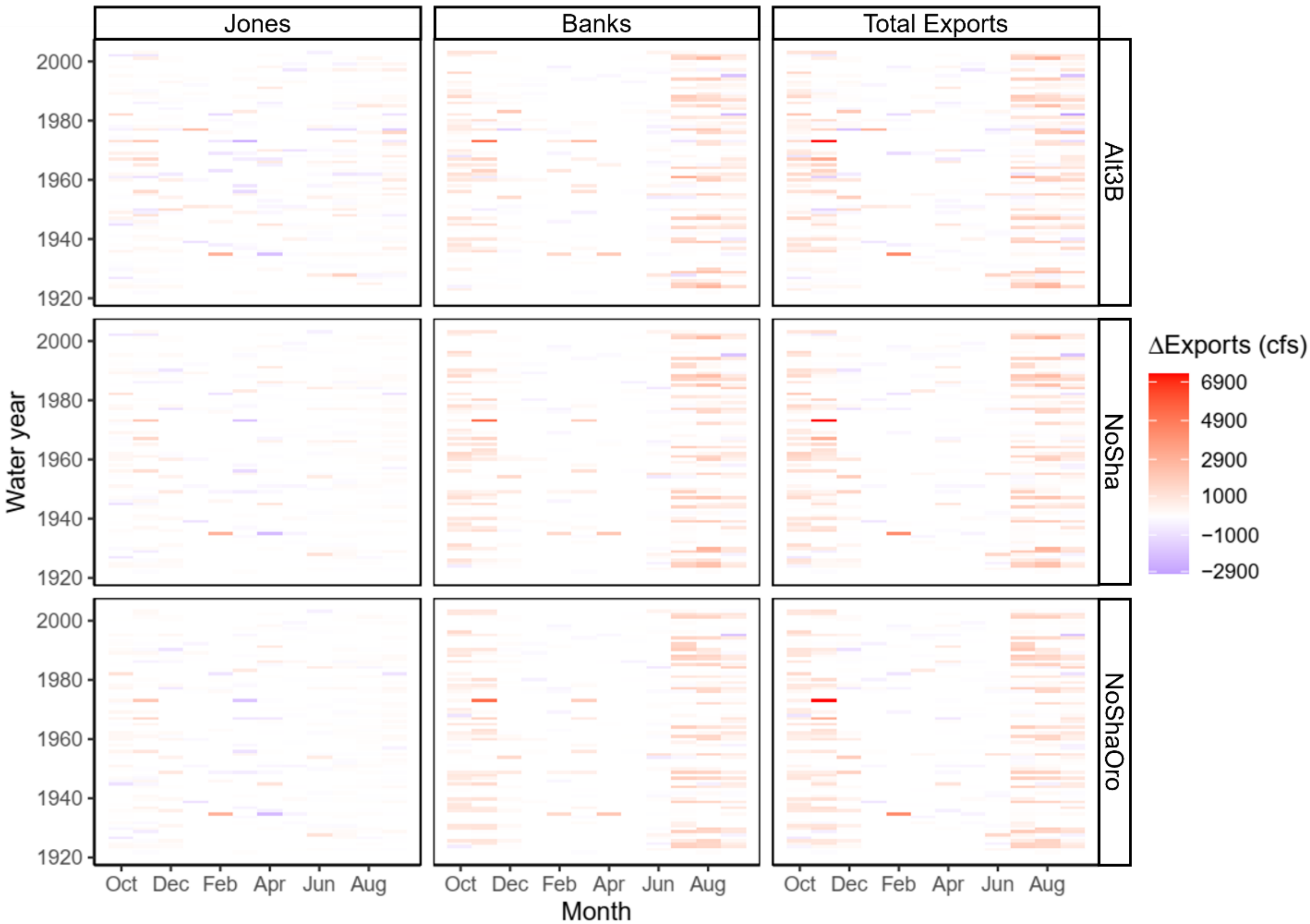

Figure 4-10. Monthly mean change in exports (cfs) by month (x-axis) and water year (y-axis) at Jones (left), Banks (middle) and Jones and Banks (right) in the south Delta under Alt3B (top), NoSha (middle) and NoShaOro (bottom), relative to the NAA. Red shades indicate an increase in exports; violet shades indicate a decrease in exports.

Effects of the Project on Conditions in the Delta

Although Project diversions will occur far upstream of the Delta, Project operations will affect hydrology in the Delta by changing the timing and magnitude of inflow, exports, and outflow to and from the Delta. Changing Delta inflow and outflow affects local hydrodynamics in the Delta, including the position of the LSZ and the flow of water in the lower San Joaquin River past Jersey Point (Qwest), which in turn affects fish species in the Delta and the quality and quantity of their habitat.

The LSZ is a dynamic area that moves upstream and downstream, its location and volume depending in large part on the net freshwater outflow from the Delta (Q_{out}) (Kimmerer et al. 2013). X2, the position in km from the Golden Gate Bridge of the 2 ppt isohaline (Jassby et al. 1995), roughly corresponds to the middle of the LSZ (Kimmerer et al. 2013) and is negatively associated with Q_{out} (Hutton et al. 2016), as greater freshwater outflow drives X2 downstream toward San Pablo and San Francisco bays (Figure 4-11). The volume of the LSZ also depends on the location of X2 (Kimmerer et al. 2013). The LSZ is largest during periods of very high Q_{out}, when X2 is less than 50 km and the LSZ includes a portion of San Pablo Bay. If X2 is between 60 km (just upstream of Carquinez Strait) and 81 km (near the confluence of the Sacramento and San Joaquin rivers) the LSZ includes portions of Honker, Grizzly, and Suisun bays. However, if X2 is greater than 81 km, the LSZ habitat extends into the lower Sacramento and San Joaquin rivers and its volume is significantly contracted (Kimmerer et al. 2013). As Q_{out} decreases and X2 moves upstream, X2's sensitivity to changes in Q_{out} increases; thus, the degree to which X2 will change in response to a change in outflow is greater when X2 is above 81 km than when it is below 81 km. An X2 of 81 km corresponds to Q_{out} of approximately 7,900 cfs, on average (Figure 4-11).

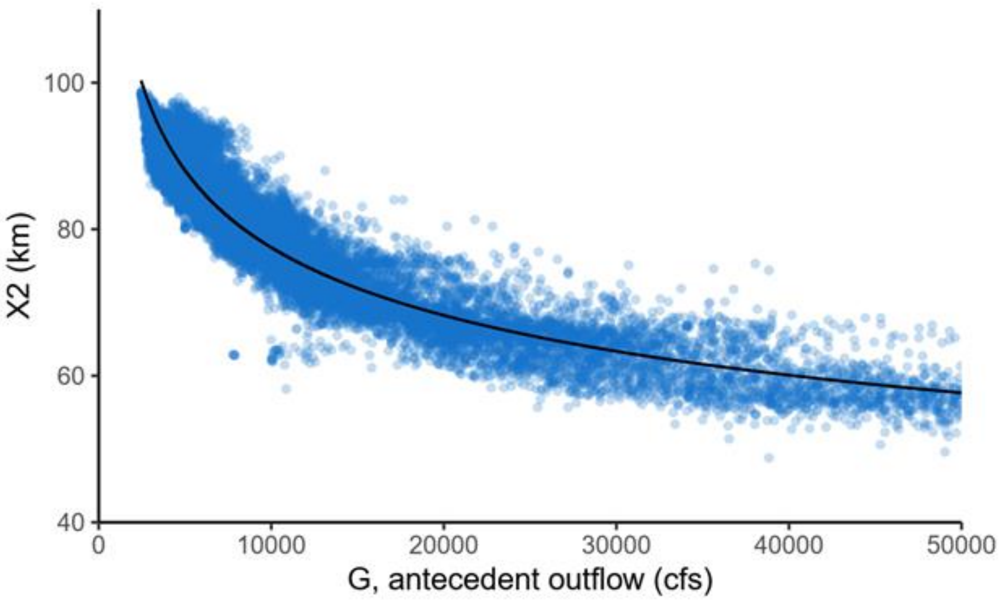

Figure 4-11. X2 plotted against Q_{out}. X2 is calculated using the autoregressive Equation 3 from Hutton et al. (2016). G ("antecedent outflow") is autoregressive outflow, calculated by substituting the 15-day rolling average flow at Martinez into Equation 5 of Denton and Sullivan (1993). The fitted curve is a least-squares fit of Hutton et al. (2016), Equation 4, which is the steady-state solution to their Equation 3.

The ITP Application (Sites Authority 2023) modeled daily Q_{out} and X2 under the NAA, Alt3B, NoSha and NoShaOro operational scenarios using the DSM2, which takes CalSIM II-simulated Sacramento River flow as one of its inputs. Based on this DSM2 modeling, CDFW created exceedance plots and monthly Q_{out} figures to show how Q_{out} under the three operational scenarios (Alt3B, No Sha, NoShaOro) would differ from Q_{out} under the NAA by less than or equal to 4,000 cfs 99.9% of the time and by less than or equal to 2,000 cfs 99.0% to 99.7% of the time (Figure 4-12). CDFW also created exceedance plots and monthly X2 figures illustrating that X2 under the Alt3B, NoSha and NoShaOro operational scenarios would differ from X2 under the NAA by less than or equal to 2 km 99.2% of the time, and by less than or equal to 1 km 96.4%–96.9% of the time (Figures 4-12 through 4-14). There are rare cases, however, in which differences in Q_{out} and X2 between the operational scenarios and the NAA are much greater; these cases bear close examination.

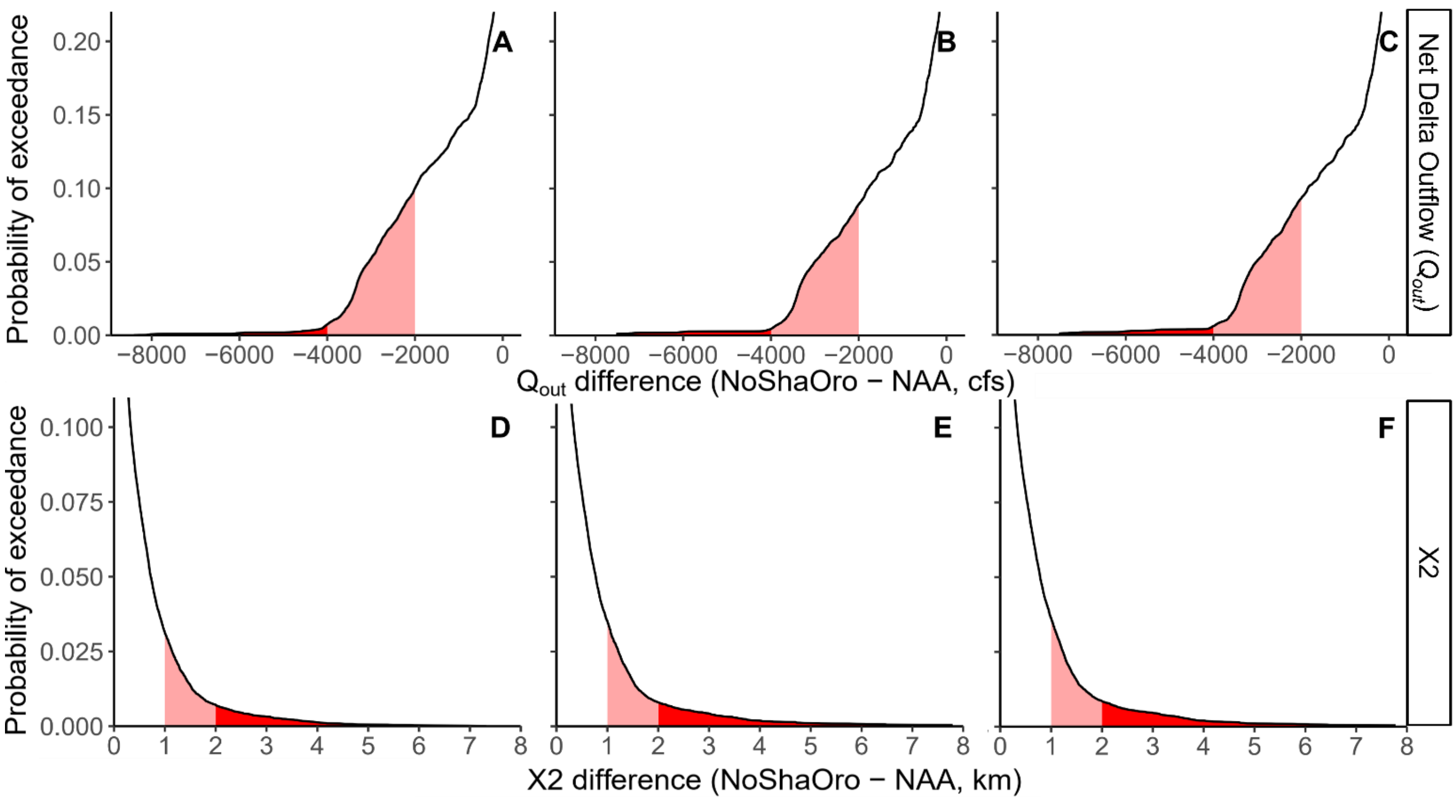

Figure 4-12. Probability of exceedance of Q_{out} (top row) and X2 (bottom row) under the Alt3B (A,D), NoSha (B,E) and NoShaOro (C,F) operational scenarios. Shaded regions in top panels indicate the probability of change in Q_{out} of at least -2,000 cfs (light red) or at least -4,000 cfs (dark red). Shaded regions in bottom panels indicate a change in X2 of at least 1 km (light red) or at least 2 km (dark red). Light red and dark red areas overlap. Note that x-axis and y-axis scales differ between top and bottom. DSM2 simulated output provided by Sites Authority (2023b).

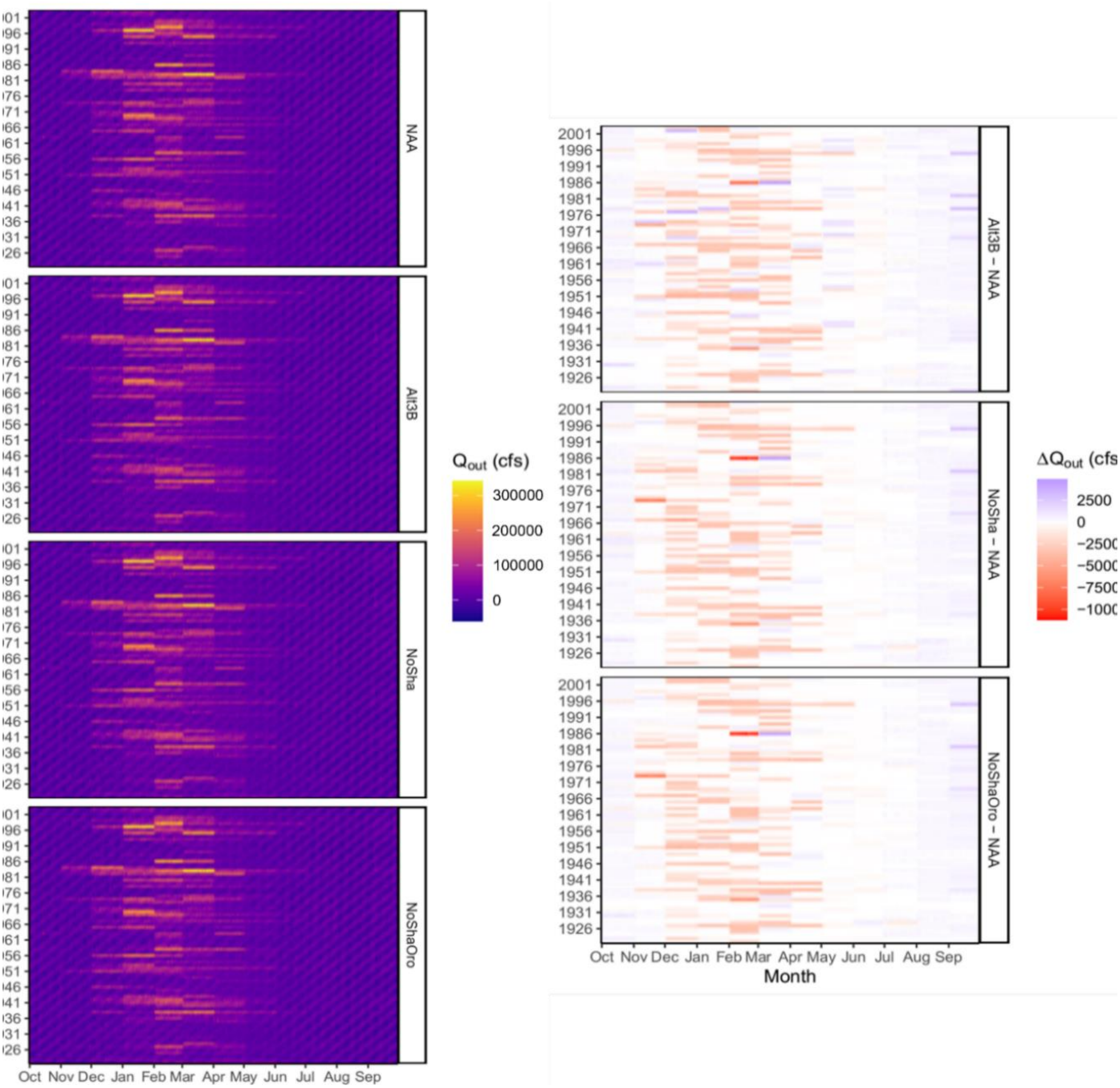

Figure 4-13. (left) Simulated Q_{out} (cfs) under the No-Action Alternative (NAA, top), and the Alt3B (second), NoSha (third) and NoShaOro (bottom) operational scenarios; (right) Difference in Q_{out} (cfs) between the three Project operational scenarios and the NAA by month and water year. DSM2 simulated output provided by Sites Authority (2023b).

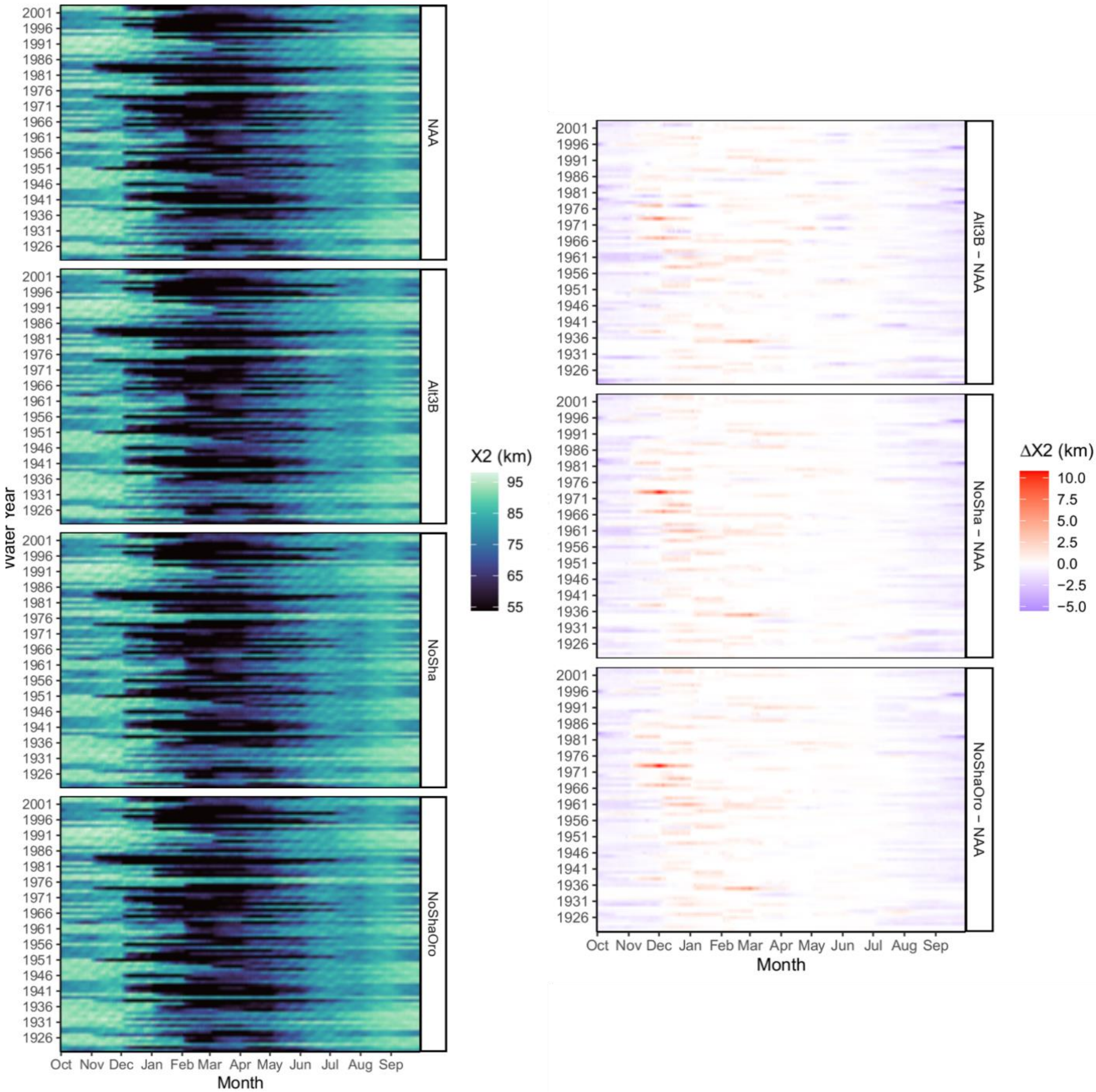

Figure 4-14. (left) Simulated X2 (km) under the No-Action Alternative (NAA, top), Alternative 3B (Alt3B, second), No Shasta Exchanges (NoSha, third) and No Shasta or Oroville Exchanges (NoShaOro, bottom); (right) Difference in X2 (km) between the three Project Alternatives and the NAA by month and water year. DSM2 simulated output provided by Sites Authority (2023).

CDFW used DSM2 simulations from the ITP Application (Sites Authority 2023) to assess the effects of Project operations on the frequency with which Project operations caused X2 to exceed 81 km (Figures 4-15 through 4-17). Days when the modeled NAA (baseline) X2 was greater than 81 km are shown in orange and days when the NAA X2 was less than or equal to 81 km in blue. Also shown, in red, are the days on which Project operations under Alt3B would cause X2 to cross 81 km, moving upstream.

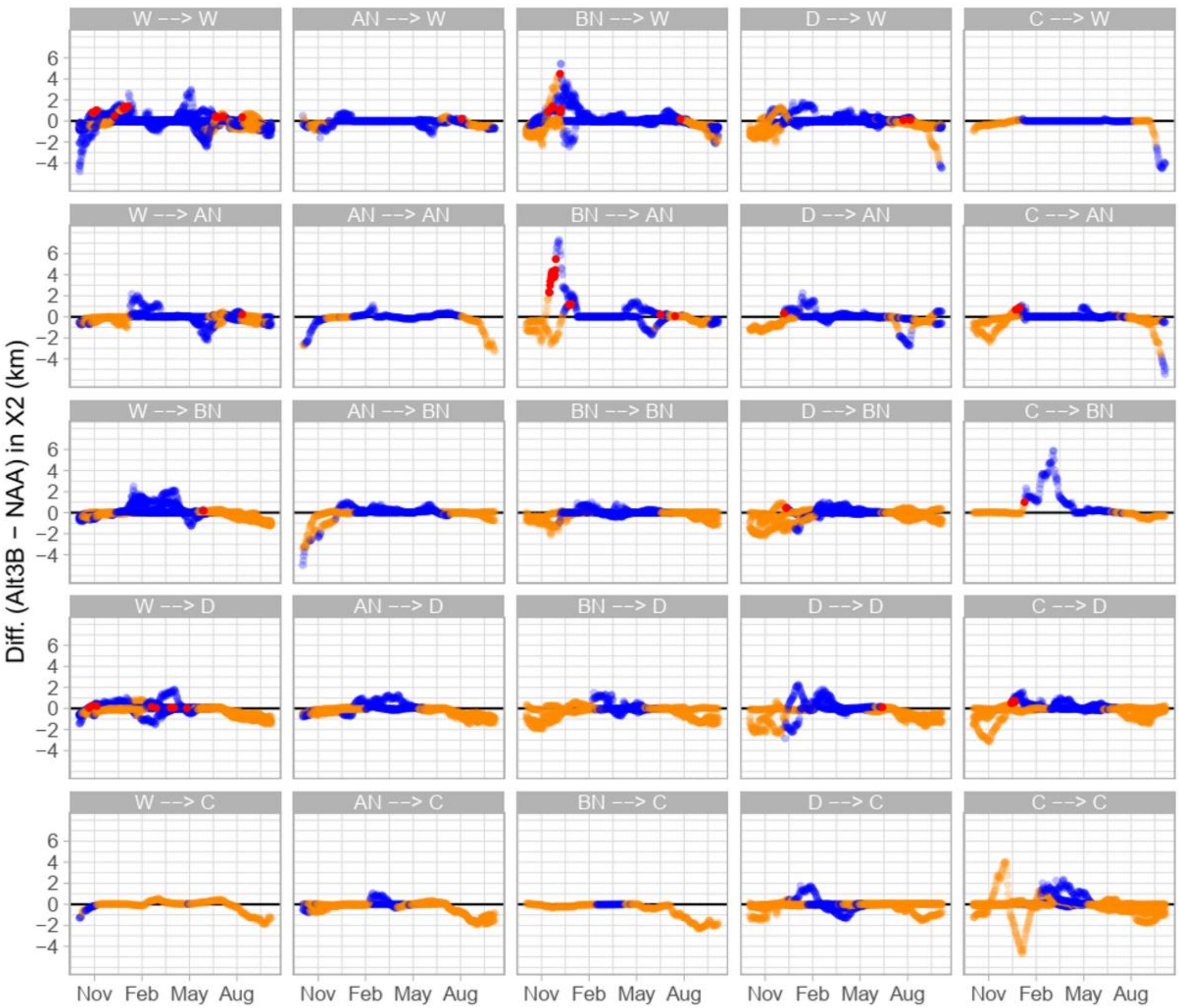

Figure 4-15. Difference in DSM2-simulated X2 (km) between the Alternative 3B (Alt3B) operational scenario and the No Action Alternative (NAA). Letters in headers preceding the arrow indicate the previous water year type, while letters following the arrow indicate the current water year type. Water year types were classified using the Sacramento Valley Index and noted as Wet (W), Above Normal (AN), Below Normal (BN), Dry (D), and Critical (C). Blue points are less than 80 km, and orange points are greater than 80 km. Red points indicate days on which Project operations would cause X2 to move from <81 km to >81 km. DSM2 data provided by Sites Authority (2023).

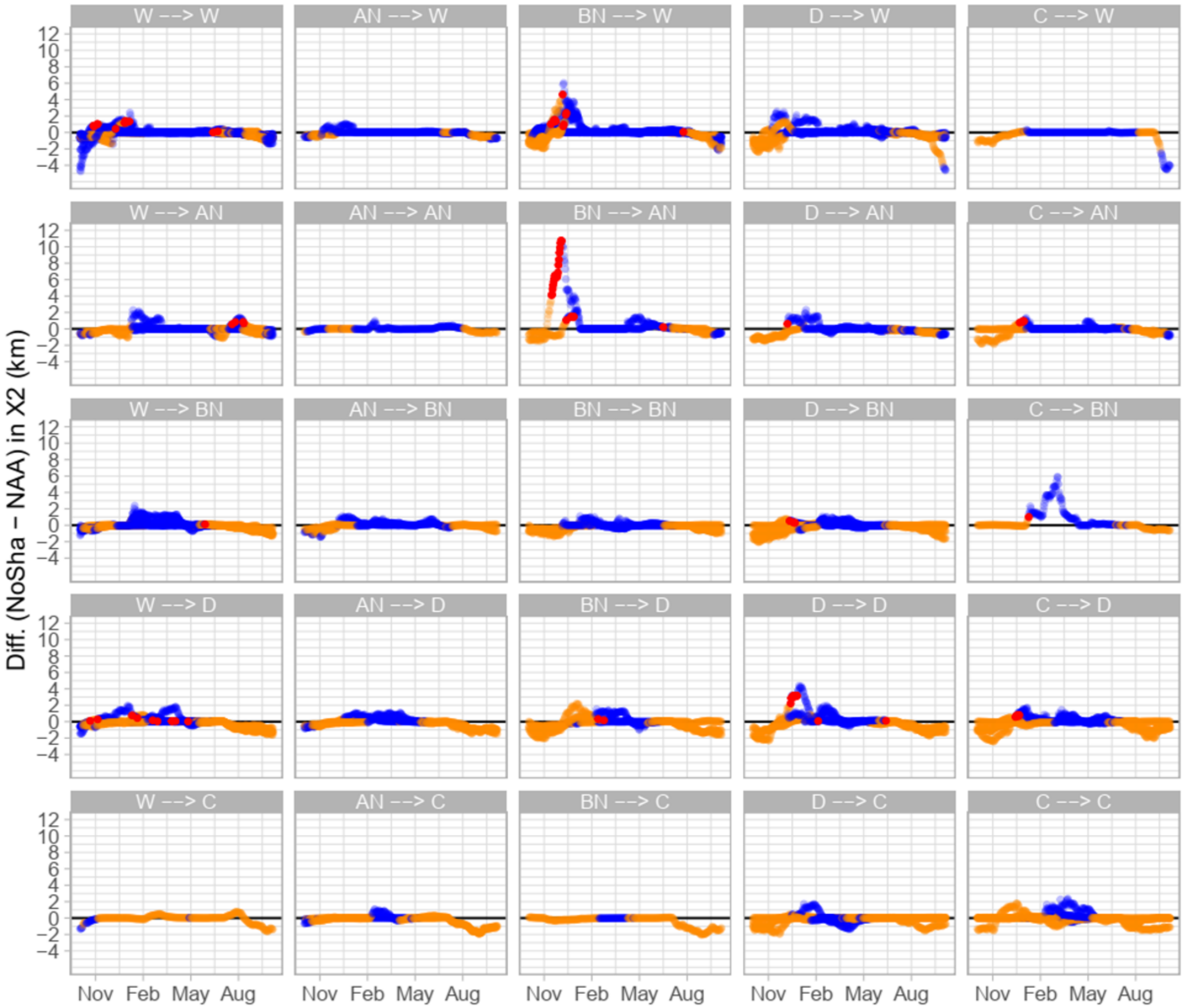

Figure 4-16. Difference in DSM2-simulated X2 (km) between the No Shasta Exchanges (NoSha) operational scenario and the No Action Alternative (NAA). Letters in headers preceding the arrow indicate the previous water year type, while letters following the arrow indicate the current water year type. Water year types were classified using the Sacramento Valley Index and noted as Wet (W), Above Normal (AN), Below Normal (BN), Dry (D), and Critical (C). Blue points are less than 80 km, and orange points are greater than 80 km. Red points indicate days on which Project operations would cause X2 to move from <81 km to >81 km. DSM2 data provided by Sites Authority (2023).

Early in the water year (October through December), Q_{out} and X2 may depend more on the previous water year type than on the current water year type. Although the water year begins on October 1, water year type is often determined by precipitation in January through March. Q_{out} and X2 in October through December may thus depend to a large degree on the amount of water stored in the previous water year. Thus, large changes in Q_{out} in October through December may produce sizable changes in X2 and LFS recruitment, even in wet water years, if the previous water year was drier and Q_{out} is low. For example, the ITP Application (Sites Authority 2023) DSM2 modeling indicates increases in X2 of greater than 6 km in November of an above-normal water year (water year 1973) following a below-normal water year under Alt3B (Figure 4-15) and increases of more than 10 km in the same water year under the NoSha and NoShaOro operational scenarios. DSM2 simulations indicate that the largest increases in X2 occur during January through May of below-normal water years and in October through December of water years following below-normal and critical water years (Figures 4-16 and 4-17).

In the ITP Application (Sites Authority 2023) DSM2 simulations, Project operations caused X2 to exceed 81 km in November or December in seven years of the 82-year DSM2 simulation under Alt3B and 10 years under the NoSha and NoShaOro operational scenarios (Figure 4-18). Project modeling showed that the largest and longest-lasting exceedances occurred in 1973, an above-normal water year following a below-normal water year (Figure 4-18). In 1973, X2 was 83–86 km for nine days under Alt3B and 84.5–91.0 km for 18 days under the NoSha and NoShaOro operational scenarios. In all water years except 1973, modeling showed that exceedances were by less than 2.5 km, lasted four days or less, and occurred in all water year types except below-normal (Sites Authority 2023). Notably, a large number of exceedance days occurred in wet years following wet years; however, these exceedances were small, with X2 shifted approximately 1 km or less upstream of 81 km (Figure 4-18).

The flow of water past Jersey Point in the lower San Joaquin River (Qwest) determines whether water is flowing downstream in the lower San Joaquin River towards the confluence and Suisun Bay (positive Qwest) or whether water is flowing upstream in the lower San Joaquin River towards the central and south Delta (negative Qwest). Positive Qwest indicates that passive particles like zooplankton and larval fish are being pushed downstream, away from the zone of entrainment in the south Delta. Negative Qwest indicates that these particles are being pulled upstream closer to the zone of entrainment in the south Delta. DSM2 modeling provided in the ITP Application (Sites Authority 2023) indicates that the Project will reduce Qwest at times (Figures 4-19 through 4-21), most notably in November and December of above-normal water years and February and March of below-normal water years. Under Project scenario Alt3B, which includes exchanges, modeled Qwest is slightly more negative in October through February in dry and critical years (Figure 4-19) than under the NoSha (Figure 4-20) and the NoShaOro scenarios (Figure 4-21).

DSM2 modeling simulations provided in the ITP Application (2023) indicate that Project operations will have some, usually small, effects on Delta outflow, X2, and Qwest, which could affect fish habitat extent and quality in the Delta. Section 4.2 and 4.3 analyze these potential effects on LFS and DS, respectively.

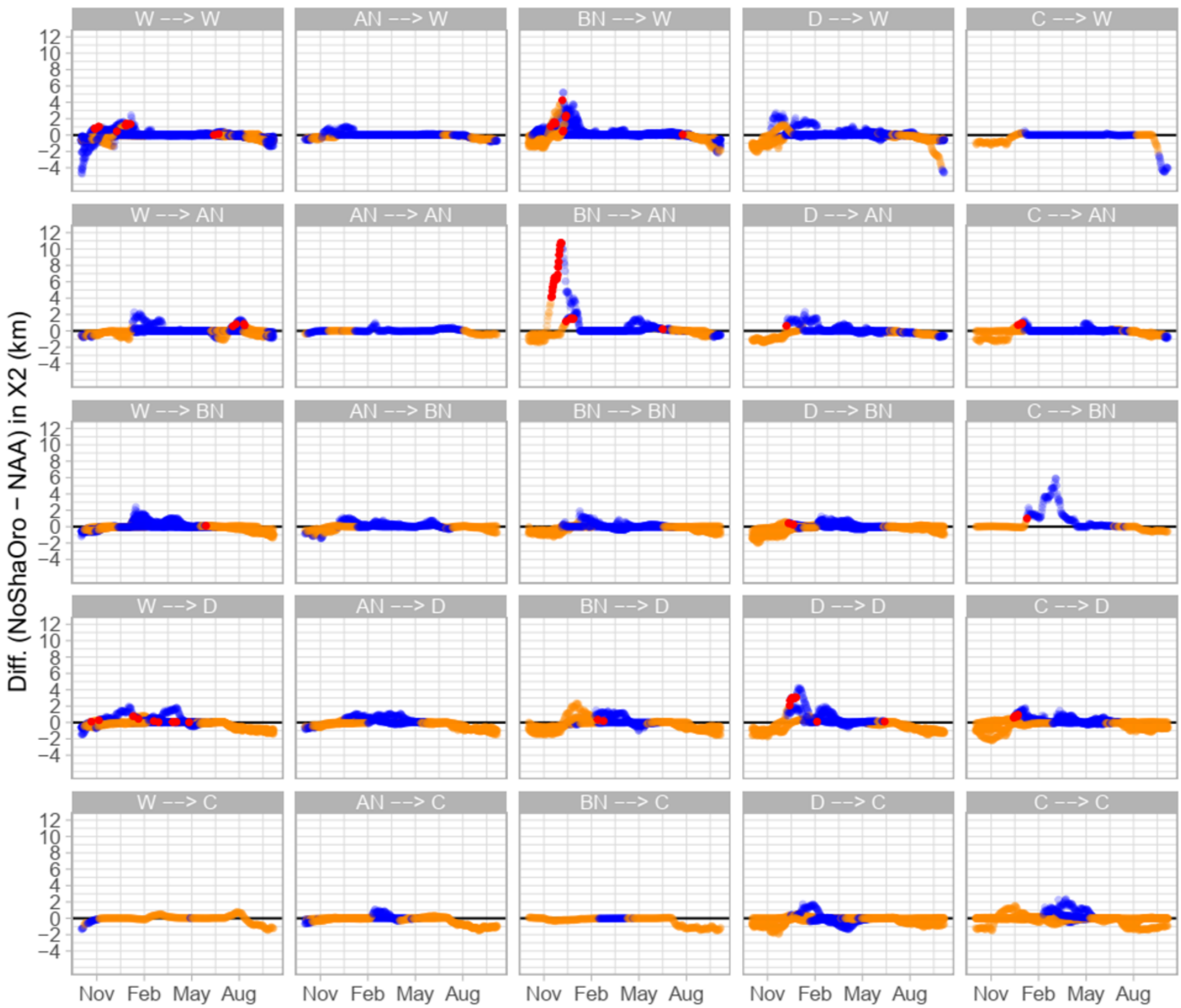

Figure 4-17. Difference in DSM2-simulated X2 (km) between the No Shasta or Oroville (NoShaOro) operational scenario and the No Action Alternative (NAA). Letters in headers preceding the arrow indicate the previous water year type, while letters following the arrow indicate the current water year type. Water year types were classified using the Sacramento Valley Index and noted as Wet (W), Above Normal (AN), Below Normal (BN), Dry (D), and Critical (C). Blue points are less than 80 km, and orange points are greater than 80 km. Red points indicate days on which Project operations would cause X2 to move from <81 km to >81 km. DSM2 data provided by Sites Authority (2023).

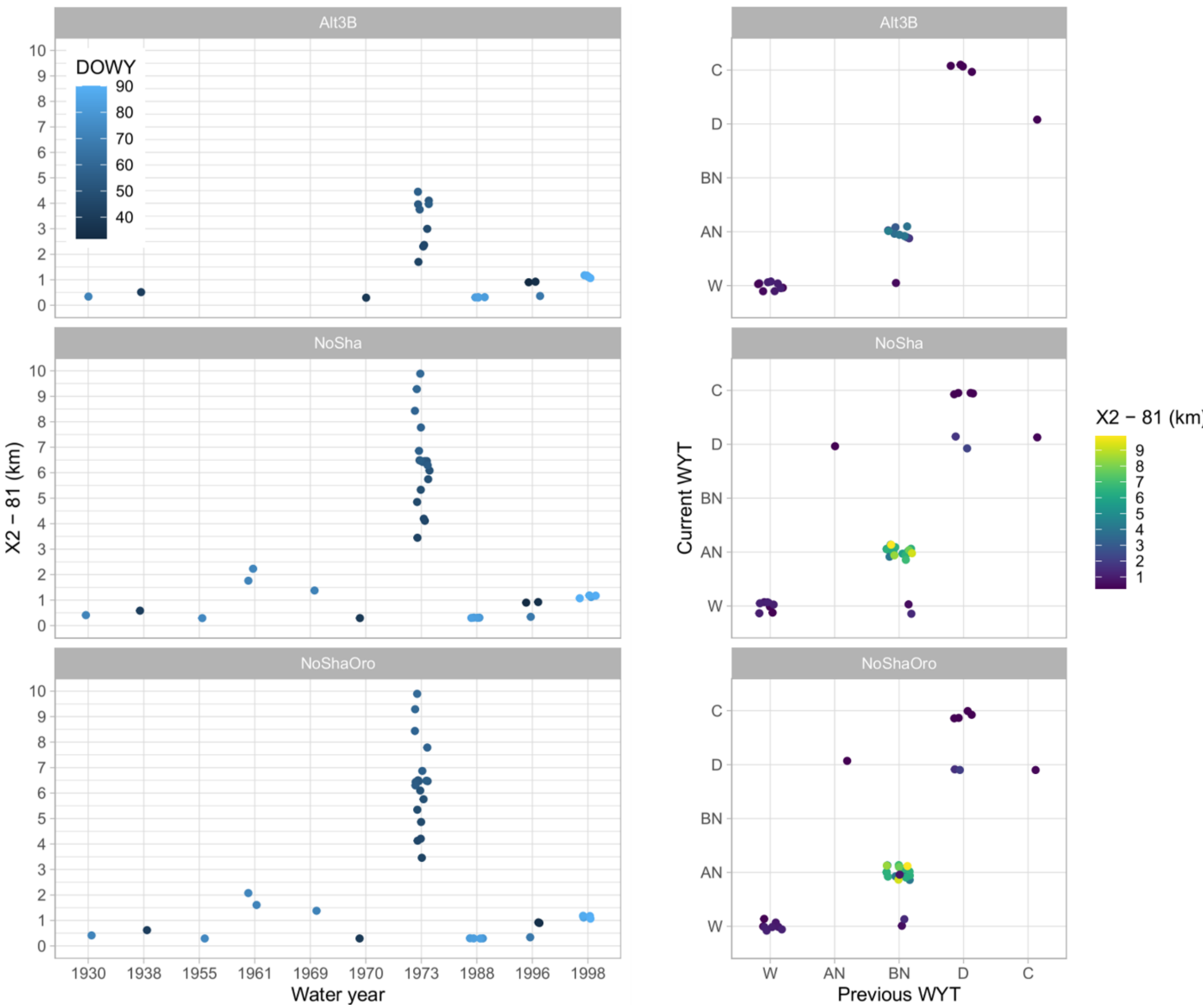

Figure 4-18. (left) Distance by which Project operations caused X2 to exceed 81 km in water years when it occurred in November or December under the Alt3B (top), NoSha (middle) and NoShaOro (bottom) operational scenarios. Shades of blue indicate the day-of-water-year (DOWY). Points on left are horizontally jittered. (right) 81 km X2 exceedance events plotted by current water year type and previous water year type under Alt3B, NoSha and NoShaOro. Colors indicate the distance by which X2 exceeded 81 km. Points on right are horizontally and vertically jittered. Water year types were classified using the Sacramento Valley Index and noted as Wet (W), Above Normal (AN), Below Normal (BN), Dry (D), and Critical (C). DSM2 simulated output provided by Sites Authority (2023).

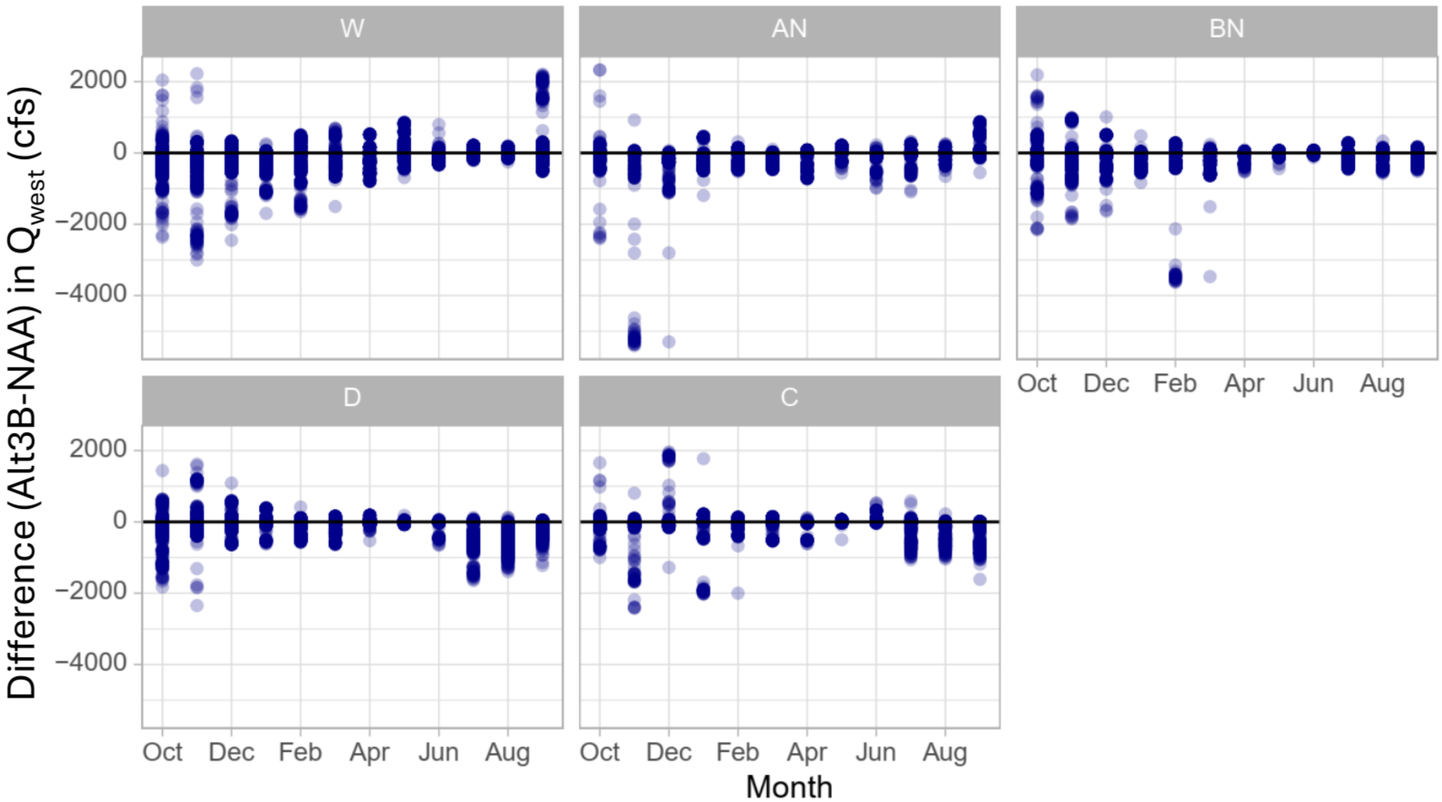

Figure 4-19. The difference in San Joaquin River flow past Jersey Point (Qwest) between the Alt3B operational scenario and the NAA for each month by water year type. Water year types were classified using the Sacramento Valley Index and noted as Wet (W), Above Normal (AN), Below Normal (BN), Dry (D), and Critical (C). DSM2 simulated output provided by Sites Authority (2023).

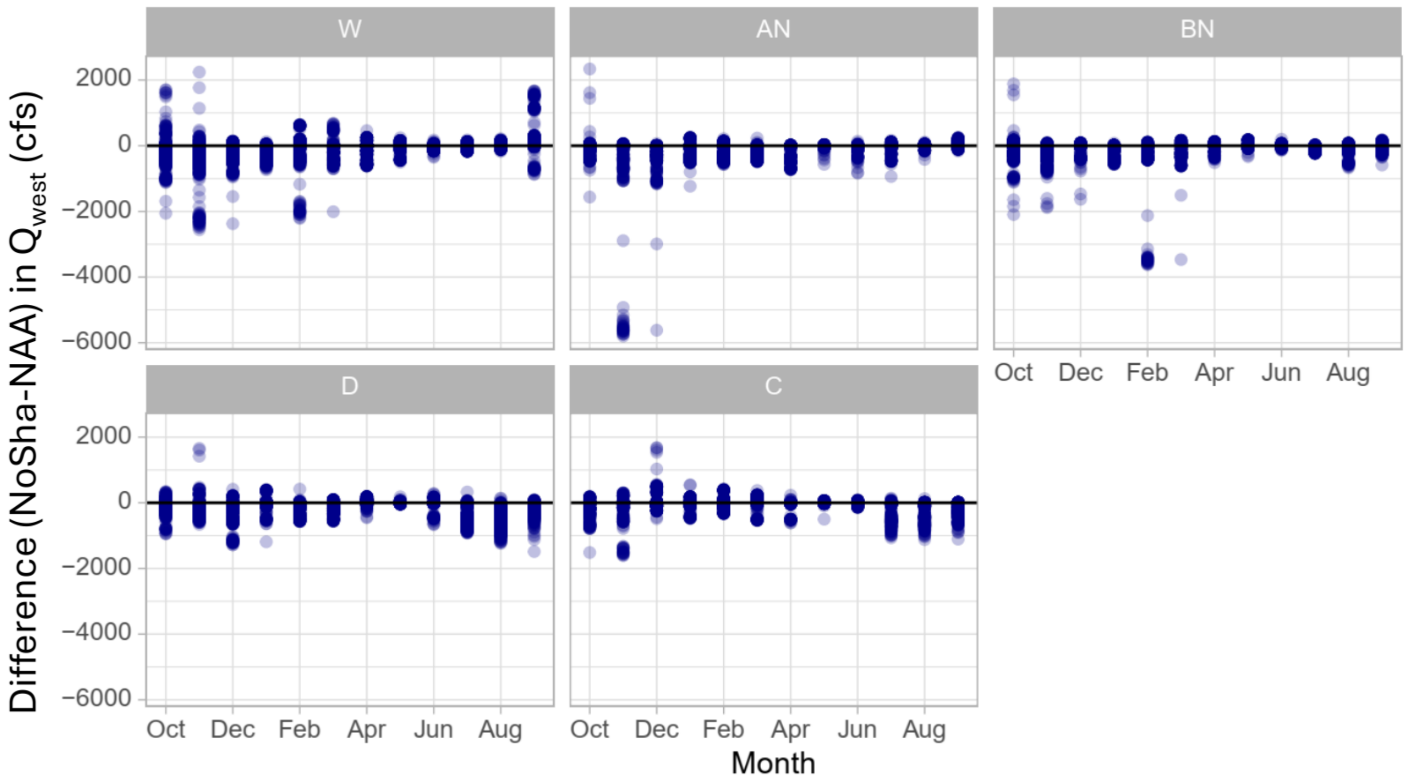

Figure 4-20. The difference in San Joaquin River flow past Jersey Point (Qwest) between the NoSha operational scenario and the NAA for each month by water year type. Water year types were classified using the Sacramento Valley Index and noted as Wet (W), Above Normal (AN), Below Normal (BN), Dry (D), and Critical (C). DSM2 simulated output provided by Sites Authority (2023).

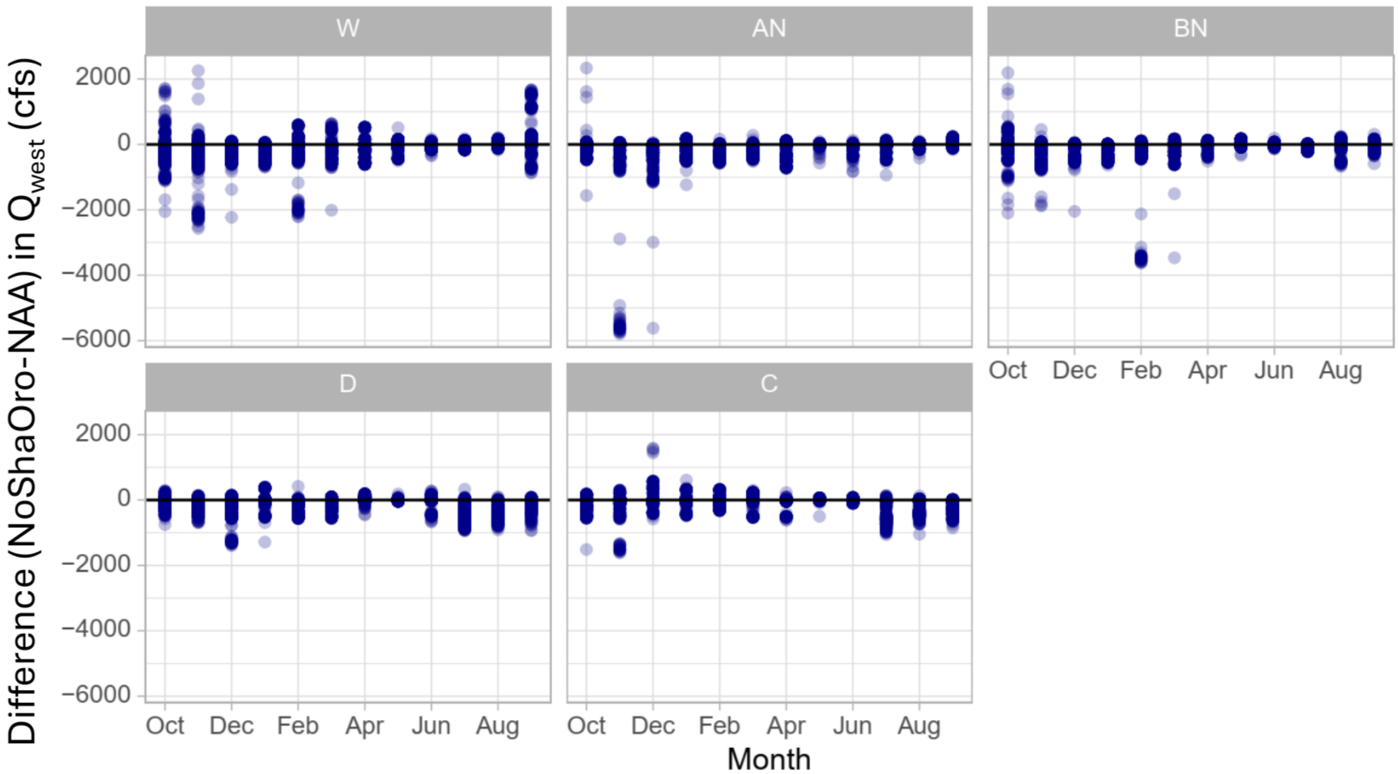

Figure 4-21. The difference in San Joaquin River flow past Jersey Point (Qwest) between the NoShaOro operational scenario and the NAA for each month by water year type. Water year types were classified using the Sacramento Valley Index and noted as Wet (W), Above Normal (AN), Below Normal (BN), Dry (D), and Critical (C). DSM2 simulated output provided by Sites Authority (2023).

4.1. Take and Impacts of Taking on CHNWR and CHNSR

CHNWR and CHNSR may be present in the Sacramento River upstream of and near Project diversion facilities, in the Sacramento River and its floodplains downstream of diversions, in the Feather River, as and the Delta. This section describes analyses of take and impacts of the taking due to Project operations at the diversion facilities (i.e., near-field effects) as well as Project-related take and impacts of the taking that occurs elsewhere in the Project area.

4.1.1. Near-Field Effects

Diversion of water from the Sacramento River for human use is a known hazard to outmigrating juvenile salmonids (Herren and Kawasaki 2001; Moyle and White 2002; Moyle and Israel 2005). Fish entrained by unscreened diversions are typically lost to the system (Moyle and White 2002); however, even screened diversions may be a source of injury or mortality. Very small fish may be entrained through fish screens (Turnpenny 1981; Young et al. 1997; Gowan and Garman 2002), while small or weak-swimming fish too large to be entrained may be unable to escape high diversion flows and may be impinged upon the screen surface (NMFS 1998; CDFG 2000; Swanson et al. 2004). The risk of impingement and injury due to screen contact are highest when the approach velocity (i.e., water velocity toward the screen face) is high, relative to the sweeping velocity (i.e., water velocity parallel to the screen face), and/or passage time along the screen is very long, causing fish to tire (NMFS 1997; NMFS 1998; CDFG 2000; Swanson et al. 2004). Fish may be stranded behind a screen if it is overtopped during a high flow event (e.g., the Hamilton City Fish Screen (HCFS) was overtopped in February 2017). Finally, fish screens may locally increase predation of small fish by changing fish movement patterns, locally increasing the densities of small fish or otherwise reducing their ability to escape predator fish, and by presenting novel, underwater structures that may give cover to predator fish (Hall 1979; Cramer et al. 1992; Vogel 2007; Vogel 2008). Each of these hazards may increase in proportion to the size of the screened diversion and the diversion rate.

4.1.1.1. Screen Exposure

Increased diversions due to Project operations could increase the number of juvenile winter-run Chinook Salmon and spring-run Chinook Salmon that are exposed to the fish screens at the Red Bluff Pumping Plant and the Hamilton City Pump Station. Project operations will increase diversion rates at these locations during periods of high juvenile winter-run Chinook Salmon and spring-run Chinook Salmon passage, which may increase the risk of injury or death due to impingement on or physical contact with the fish screens. Fish screens are also known to locally increase the risk of predation of juvenile salmon.

Project operations will increase diversions of water from the Sacramento River at the Red Bluff Pumping Plant and the Hamilton City Pump Station, which may increase take of outmigrating juvenile CHNWR and CHNSR at these locations. The ITP Application (Sites Authority 2023) discusses the effects of the local spatial distribution of fish on screen exposure and showed how the percentage of instream flow entering the Hamilton City Oxbow (Oxbow) depends on both instream flow itself and the percentage of instream flow diverted. However, the field data used to estimate the percentage of instream flow entering the Oxbow were collected in 2018, when the Oxbow channel was 15% obstructed (Sites Authority 2023); furthermore, the ITP Application (Sites Authority 2023) did not analyze how the timing of diversions and CHNWR outmigration might interact with instream flow and diversion rate to affect potential screen exposure.

To understand the degree to which Project diversions may increase take of CHNWR and CHNSR at and around the Red Bluff and Hamilton City intakes, CDFW evaluated (1) the timing and frequency of CHNWR and CHNSR exposure, (2) the risk of take posed by the three operational scenarios evaluated (i.e., Alt3B, NoSha, NoShaOro), and (3) the relative increase in exposure and risk of take under these operational scenarios, relative to the NAA. CDFW further estimated the percentage of instream flow entering the Oxbow under a variety of flow and diversion rate conditions by fitting a statistical model to 10.5 years (March 2013 – August 2023) of instream flow, Oxbow flow and HCPS diversion rate data provided with the ITP Application (Sites Authority 2023).

The USRDOM provided in the ITP Application (Sites Authority 2023) shows that, under the three operational scenarios, episodic diversions for the Project at Hamilton City and Red Bluff would occur annually between September 1 and June 14, with large diversions occurring primarily during high-flow events. The Project would not divert when Sacramento River flow at Wilkins Slough is less than 10,700 cfs, the flow above which Michel et al. (2021) found the highest survival of outmigrating Chinook Salmon.

Positive-barrier fish screens on the Red Bluff and Hamilton City diversion intakes are designed to prevent entrainment of fish larger than 22 mm and 30 mm, respectively (Young et al. 1997). The

Red Bluff Fish Screen (RBFS) is located on the mainstem Sacramento River at approximately RM 243, and is parallel to the direction of river flow (Figure 4-22). The HCFS is located on an Oxbow channel on the western bank of the river at approximately RM 205.5. When Sacramento River flow is less than approximately 15,000 cfs, diversions at Hamilton City Pump Station can account for most of the flow entering the Oxbow, and greatly reduce the outflow of the Oxbow, relative to its inflow (Figure 4-23).

Figure 4-22. Red Bluff Fish Screen, 40°90’19.74” N, 122°12’38.87” W. Image from Google Earth. Blue text added by CDFW.

Figure 4-23. Hamilton City Oxbow and Hamilton City Fish Screen, 39°47’25.59” N, 122°03’2.12” W. Images from Google Earth. Blue text and inset added by CDFW.

Winter-run Chinook Salmon Screen Exposure

Juvenile CHNWR begin leaving spawning areas north of Redding and migrating down the Sacramento River in late summer. Most pass RBFS between September and December, typically passing the HCFS a few days to three weeks later. Migration speed and survival rates of outmigrating juvenile CHNWR increase with increasing Sacramento River flow during outmigration (Notch et al. 2020a; Michel et al. 2021; Hassrick et al. 2022). Mortality during outmigration may be caused by predation, disease, starvation, thermal stress, stranding, contact injuries, or other causes.

The level of CHNWR take at and around RBFS and HCFS due to current operations is unknown; however, TCCA and GCID conduct most of their diversions during spring and summer, when few CHNWR are present in the system, and may thus pose a low risk to CHNWR passing the facilities. Relative to the NAA, Alt3B, NoSha and NoShaOro operational scenarios would increase diversions through both fish screens during the time of peak CHNWR outmigration (September–December) and would therefore increase exposure of CHNWR to the screens (Figures 4-24 and 4-25). Although the CHNWR that may be exposed to RBFS and HCFS are typically >30 mm FL and are thus protected from entrainment (Turnpenny 1981; Young et al. 1997; Gowan and Garman 2002), the risks of impingement, injury due to screen contact, stranding and predation remain of primary concern to CDFW.

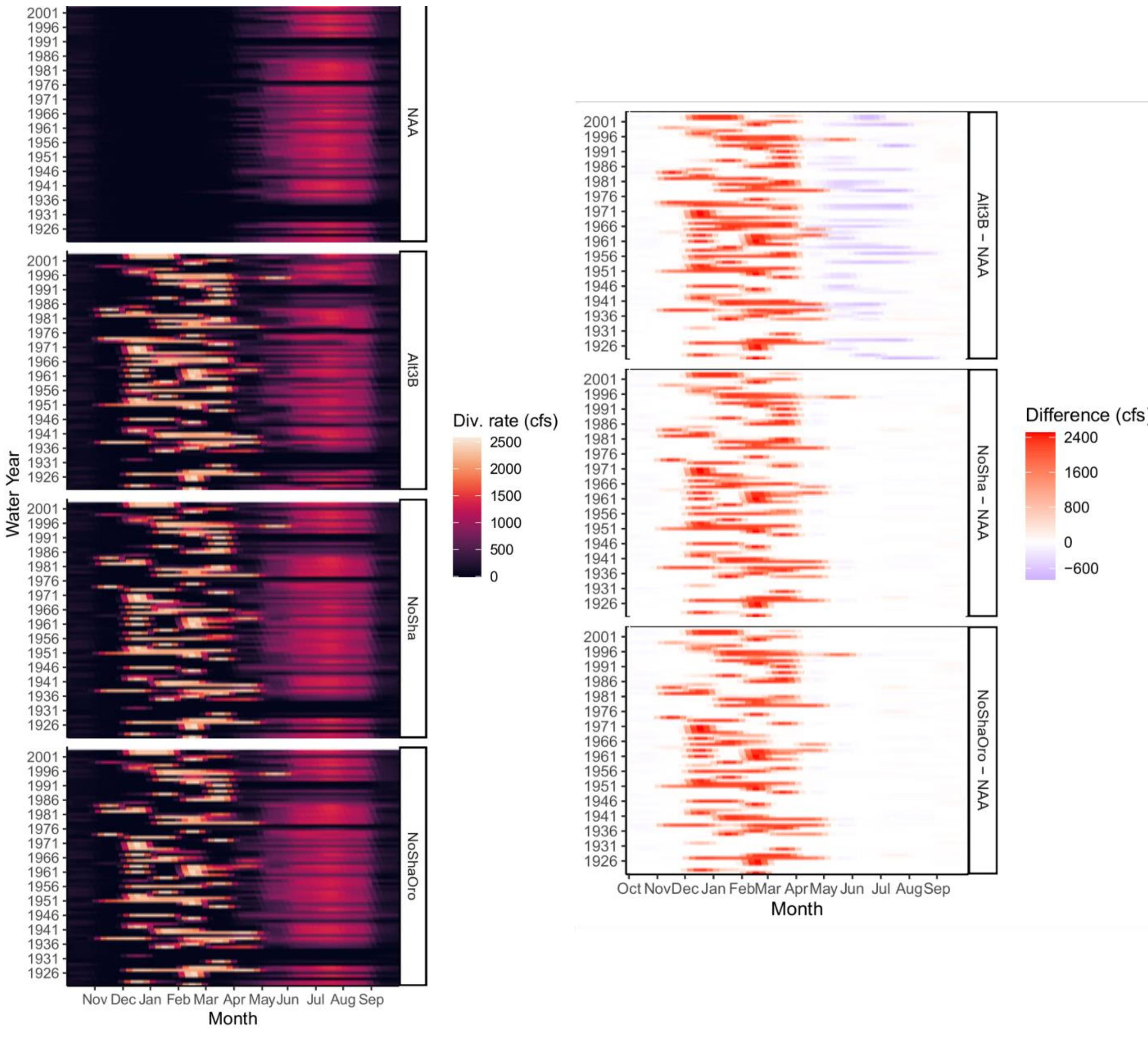

Figure 4-24. (left) Upper Sacramento River Daily Operations Model (USRDOM) simulated daily diversion rate at the Red Bluff Pumping Plant under the No Action Alternative (NAA; top), Alt3B (second), NoSha (third), and NoShaOro (bottom) during water years 1922 – 2003. Color brightness indicates the diversion rate. (right) The differences in diversion rate between Alt3B and NAA, NoSha and NAA, and NoShaOro and NAA are shown on the right from top to bottom, respectively. Red shades indicate a higher diversion rate under the Project than under the NAA, while blue shades indicate a lower diversion rate under the Project than under the NAA. USRDOM data provided by Sites Authority (2023).

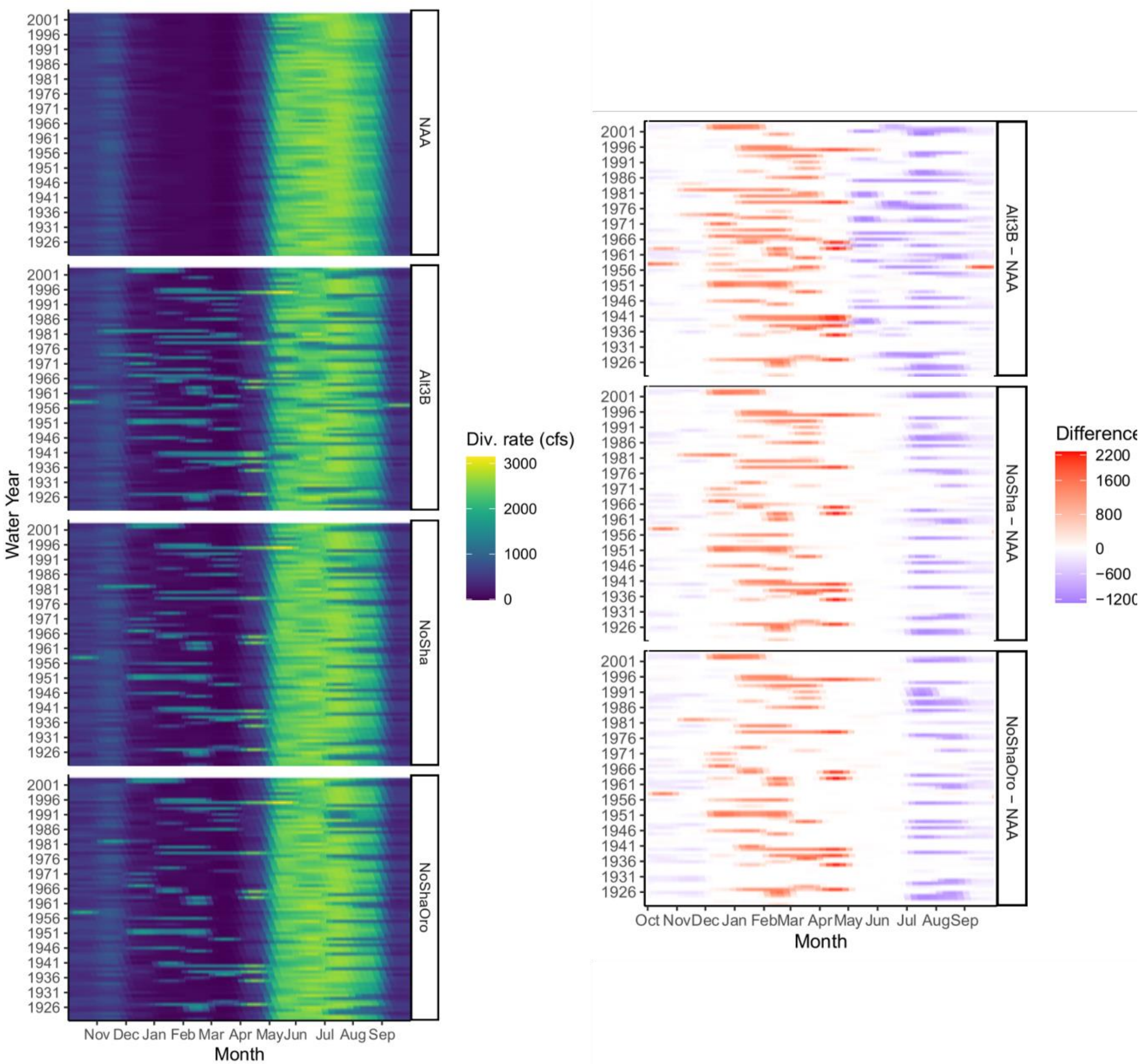

Figure 4-25. (left) Upper Sacramento River Daily Operations Model (USRDOM) -simulated daily diversion rate at the Hamilton City Pump Station under the No Action Alternative (NAA; top), Alt3B (second), NoSha (third), and NoShaOro (bottom) during water years 1922 – 2003. Color brightness indicates the diversion rate. The differences in diversion rate between Alt3B and NAA, NoSha and NAA, and NoShaOro and NAA are shown on the right from top to bottom, respectively. Red shades indicate a higher diversion rate under the Project than under the NAA, while blue shades indicate a lower diversion rate under the Project than under the NAA. USRDOM data provided by Sites Authority (2023).

CHNWR Migration Timing: Red Bluff and Hamilton City

Outmigrating juvenile CHNWR are typically observed in USFWS's Red Bluff RSTs beginning in July and may be caught as late as June of the following year; however, approximately 90% of catch of CHNWR in the Red Bluff RST occurs between September and January, peaking between September 1 and November 1 (Figure 4-26). Seasonal exposure to RBFS can be expected to occur during these times. Catch data from the Hamilton City RST from 2013–2023 show most outmigrating CHNWR passing the HCFS during September–January (Figure 4-26), peaking between September 15 and December 15, suggesting a travel time between Red Bluff and Hamilton City (approximately 37 RMs) of perhaps a few weeks. In comparison, the median travel time from Red Bluff to Hamilton City in National Oceanic and Atmospheric Administration (NOAA) Fisheries CHNWR acoustic telemetry studies during 2013–2023 was 2.3 days, though some fish took as long as 30–40 days to make the transit (Figure 4-27). Notably, the fish released in these studies were much larger (>80 mm) than the majority of outmigrating CHNWR (most are 30 mm–39 mm; Sites Authority 2023) and may have traveled faster than is typical among wild fish.

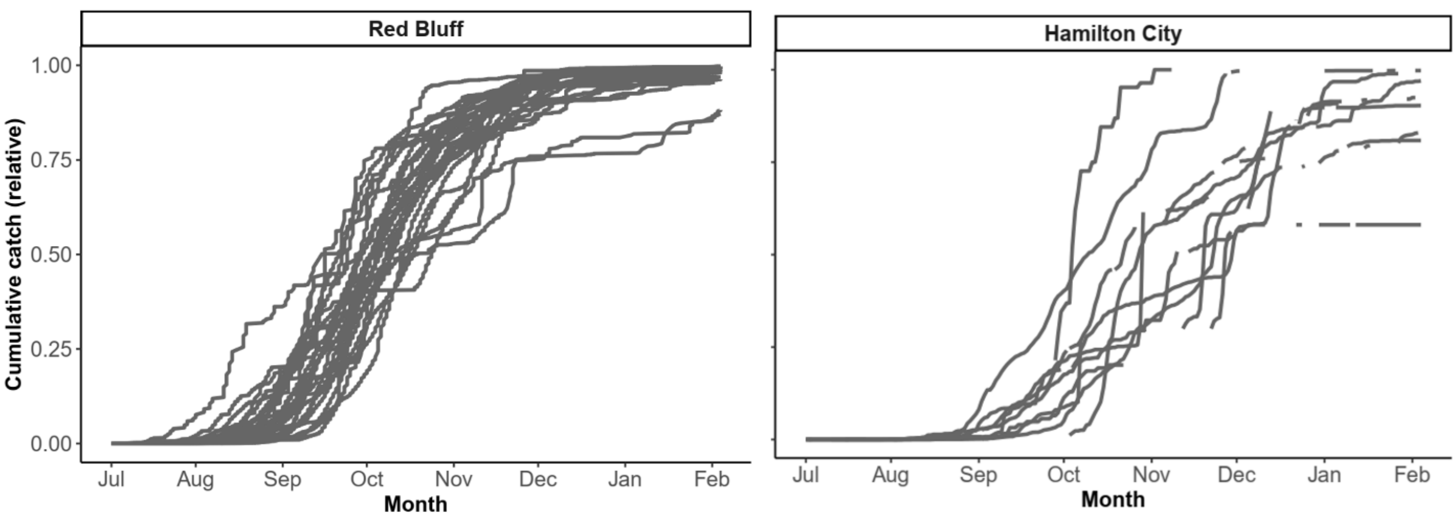

Figure 4-26. Cumulative catch of juvenile winter-run Chinook Salmon in the National Oceanic and Atmospheric Administration Fisheries rotary screw traps (RST) at Red Bluff, 1994 – 2023 (left) and the in the GCID RST in the Hamilton City Oxbow, 2013 – 2023 (right). Curves show individual brood years. Red Bluff data downloaded from the Environmental Data Initiative portal (Poytress 2024). Hamilton City RST data provided by Sites Authority (2023).

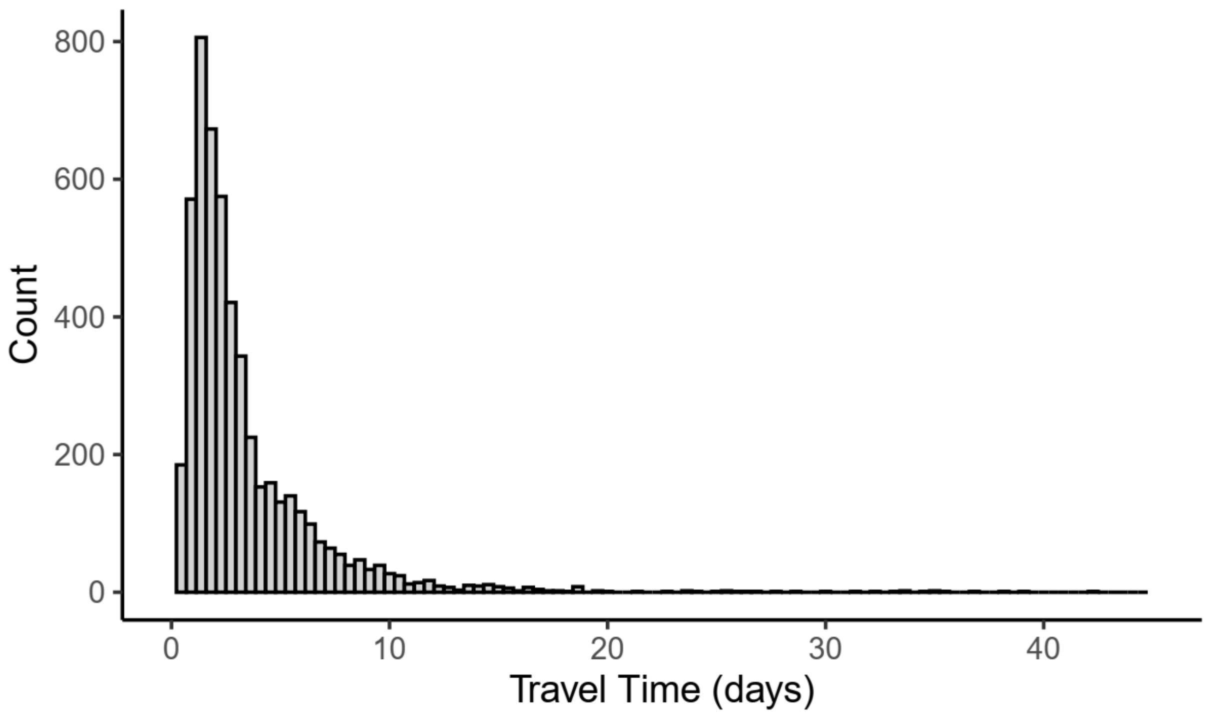

Figure 4-27. Histogram of travel times of acoustic-tagged, juvenile winter-run Chinook Salmon from Red Bluff to Hamilton City. Median travel time was 2.3 days. Experimental releases at Redding and in Battle Creek were conducted by National Oceanic and Atmospheric Administration (NOAA) Fisheries in April and May of 2013 – 2023. CDFW calculated travel times from NOAA Fisheries acoustic receiver records (https://oceanview.pfeg.noaa.gov/shiny/FED/telemetry/).

CHNWR Encounter Rates with Red Bluff Fish Screen

The number of CHNWR that encounter RBFS will depend on the fraction of Sacramento River flow diverted at each intake during the period when CHNWR are migrating past Red Bluff. Under the NAA (simulated using USRDOM), the Red Bluff Pumping Plant may divert between 0% and 16% of the Sacramento River’s flow at any given time, with the highest percentages occurring during May–September. Under Alt3B, NoSha and NoShaOro operational scenarios, the highest percentages would occur during November–May, reaching up to 55% of Sacramento River flow (Figure 4-28).

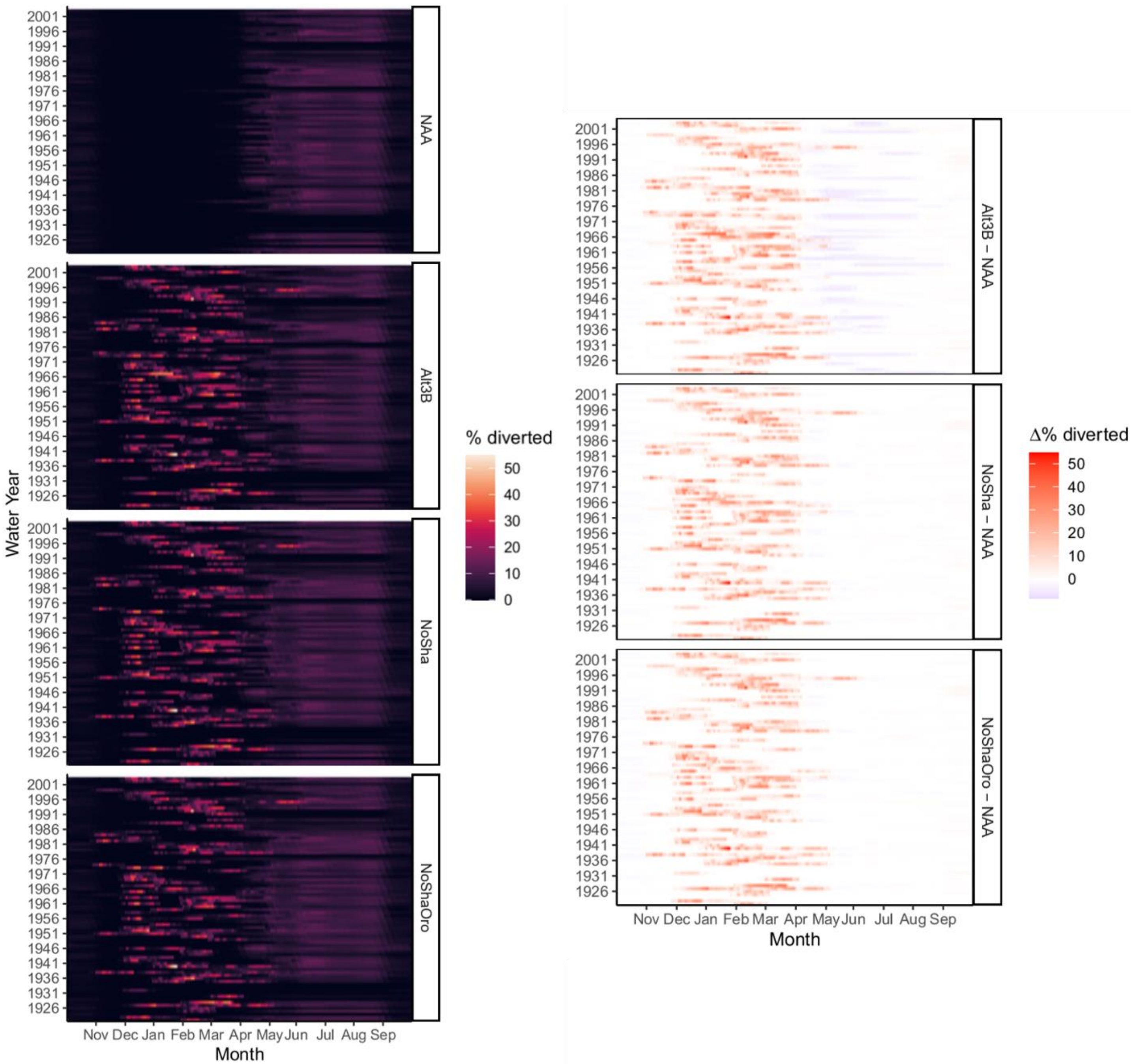

Figure 4-28. (left) Upper Sacramento River Daily Operations Model (USRDOM) simulated daily percentage of Sacramento River flow diverted by the Red Bluff Pumping Plant under (top to bottom) the No Action Alternative (NAA), Alt3B, NoSha, and NoShaOro during water years 1922 – 2003. Color brightness indicates percent diverted. The differences in percent diverted between Alt3B and NAA, NoSha and NAA, and NoShaOro and NAA are shown on the right from top to bottom, respectively. Red shades indicate positive differences (Project > NAA), while blue shades indicate negative differences (Project < NAA). USRDOM data provided by Sites Authority (2023).

The degree to which outmigrating juvenile CHNWR are drawn toward RBFS by diversions at Red Bluff, and the probability that an individual fish will encounter the screen, increase with decreasing distance from the screen. Assuming that fish are evenly distributed within the volume from which the diversion occurs, the instantaneous fraction that is diverted will contain a corresponding instantaneous fraction of the fish present. Thus, a baseline assumption of this Effects Analysis is that the exposure rate of outmigrating juvenile CHNWR to RBFS is proportional to the percentage of Sacramento River flow being diverted at Red Bluff:

Equation 1.

$$E_{RBFS} = P_{RB} \cdot \frac{Q_{RBPP}}{Q_{SacRB}}$$

where E_{RBFS} is the exposure rate of juvenile CHNWR to RBFS, P_{RB} is the USFWS daily juvenile CHNWR passage estimate at Red Bluff, Q_{RBPP} is the diversion rate at Red Bluff Pumping Plant and Q_{SacRB} is the Sacramento River Flow above Red Bluff. Note that E_{RBFS} does not represent certain physical contact with RBFS, but rather the proportion of outmigrating CHNWR that are at a high risk of screen contact. Red Bluff Pumping Plant is not diverting, $Q_{RBPP} = 0$ and thus $E_{RBFS} = 0$. In reality, some CHNWR may be exposed RBFS even when $Q_{RBPP} = 0$, however the probability of impingement or injury due to contact during these exposures is low, as CHNWR may swim freely away from the screen. When $Q_{RBPP} > 0$, this probability increases, but may remain low, provided the approach velocity does not exceed 0.33 fps, the sweeping velocity is at least twice the approach velocity, and the passage time along the screen is short (NMFS 1997; CDFG 2000).

USFWS has estimated daily CHNWR passage at Red Bluff (P_{RB}) using catch data from the Red Bluff RST since 2004; however, the USRDOM modeled dataset ends in 2003. To estimate E_{RBFS} for water years 2005–2019, CDFW used a routed and temporally expanded version of the DDFT called DRAT, which simulates daily diversions and Sacramento River flows with and without Project diversions. DRAT assumes that the Project would divert the maximum allowable amount each day, under historical Sacramento River flows, and does not distinguish among Alt3B, NoSha, and NoShaOro operational scenarios. Thus, the analysis only compares E_{RBFS} under the NAA versus the Project's maximum diversions. Substituting DRAT-simulated Red Bluff Pumping Plant diversion rates for Q_{RBPP} and DRAT-simulated Sacramento River flow for Q_{SacRB}, CDFW used Equation 1 to show the difference in E_{RBFS} between the Project and the NAA from 2005 to 2019 (Figure 4-29). Exposure of juvenile CHNWR to RBFS may frequently be higher under the Project than under the NAA, especially during October–April. The predicted maximum daily CHNWR exposed to RBFS under the NAA was 11,091 fish, versus 89,926 fish under the Project (not on the same date). The maximum daily difference in predicted screen exposure occurred on September 25, 2005, when 78,835 additional exposures were predicted under the Project that were not predicted under the NAA (Figure 4-29). In total, between 2004 and 2019, the predicted total number of CHNWR screen exposures at RBFS under the NAA was 761,491, versus 1,901,520 under the Project. This represents a 149.7% increase in screen exposure under the Project as compared to the NAA.

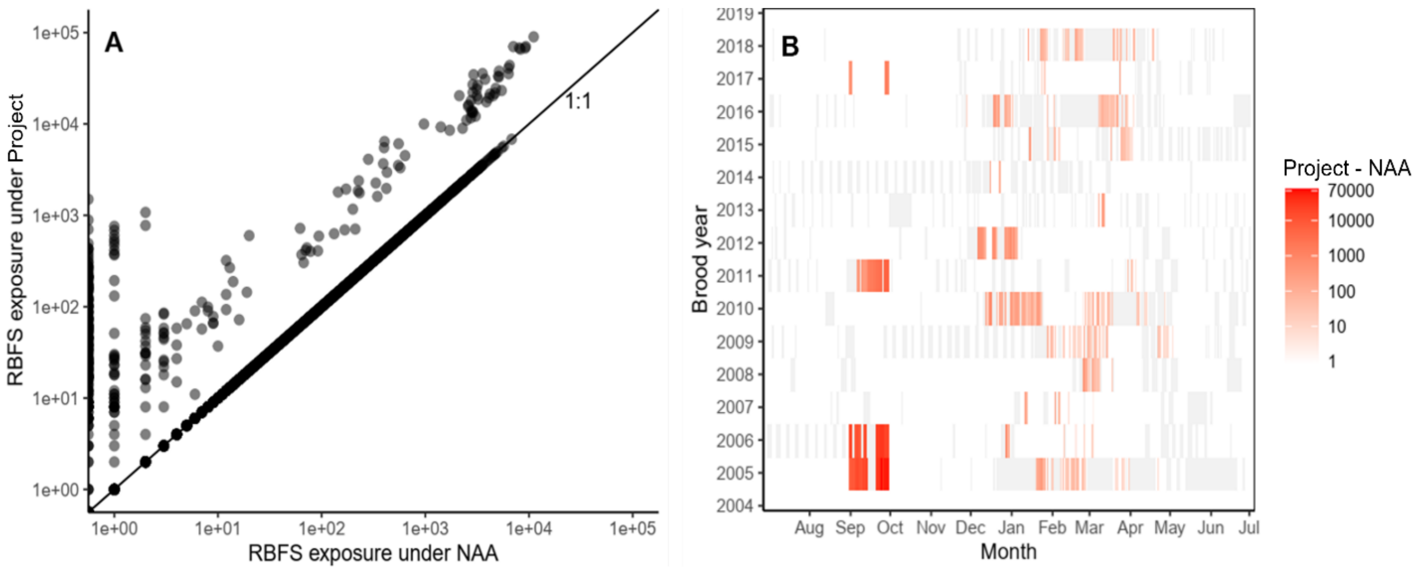

Figure 4-29. (A) Estimated number of juvenile winter-run Chinook Salmon exposed to the Red Bluff Fish Screen (E_{RBFS}) during 2005 – 2019 under the Project versus under the No Action Alternative (NAA). The diagonal line indicates 1:1 correspondence. (B) Difference in E_{RBFS} under the Project versus under the NAA by day of brood year (x-axis) and brood year (y-axis). Note that in both panels, values are on a $\log_{10}$ scale for visibility. Gray areas in (B) indicate missing data.

CHNWR Encounter Rates with Hamilton City Fish Screen

The number of CHNWR that encounter HCFS will depend on the fraction of Sacramento River flow diverted at Hamilton City during the period when CHNWR are migrating past or through the Oxbow. Under the NAA (simulated using USRDOM), Hamilton City Pump Station may divert between 0% and 42% of the Sacramento River's flow at any given time (although <15% throughout most of the USRDOM time series), with the highest percentages occurring during May–September. Under the Project (Alt3B, NoSha, and NoShaOro operational scenarios), the highest percentages would occur during November–May, reaching up to 45% of Sacramento River flow (Figure 4-30).

USRDOM does not explicitly simulate flows through the Oxbow, either upstream or downstream of the diversion. However, Sites Authority provided Oxbow inflow, Oxbow outflow, and Hamilton City Pump Station daily mean diversion rate data in the Hamiton City RST dataset (Figure 4-26). CDFW combined these flows with daily Sacramento River flow at Hamilton City from CDEC (Station HMC) and fit a linear mixed-effects model (R^2 = 0.98) to predict Oxbow flows (Appendix A1). As predicted by the model, natural flow through the Oxbow is typically 10–20% of total Sacramento River flow; as Sacramento River flow increases, Oxbow flow also increases but becomes a smaller fraction of the total (Figure 4-31). However, Hamilton City Pump Station can increase this fraction to greater than 50% of Sacramento River flow when actively diverting at low Sacramento River flow; the maximum diversion rate at Hamilton City Pump Station is 3,000 cfs, which can be up to 80% of Oxbow inflow (Figure 4-31).

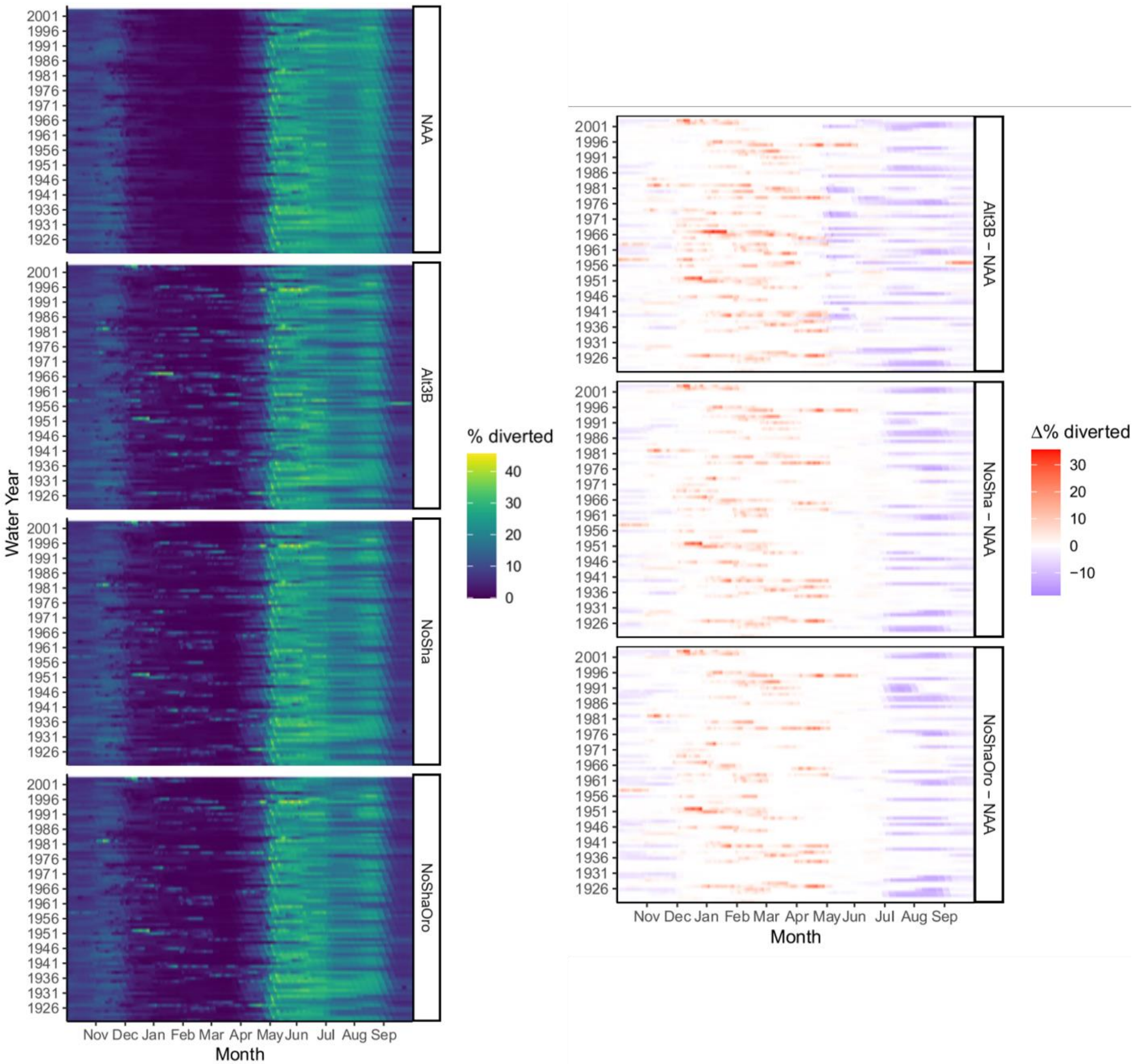

Figure 4-30. (left) Upper Sacramento River Daily Operations Model (USRDOM) simulated daily percentage of Sacramento River flow diverted by the Hamilton City Pump Station under (top to bottom) the No Action Alternative (NAA), Alt3B, NoSha, and NoShaOro during water years 1922 – 2003. Color brightness indicates percent diverted. The differences in percent diverted between Alt3B and NAA, NoSha and NAA, and NoShaOro operational scenarios and NAA are shown on the right from top to bottom, respectively. Red shades indicate positive differences (Project > NAA), while blue shades indicate negative differences (Project < NAA). USRDOM data provided by Sites Authority (2023).

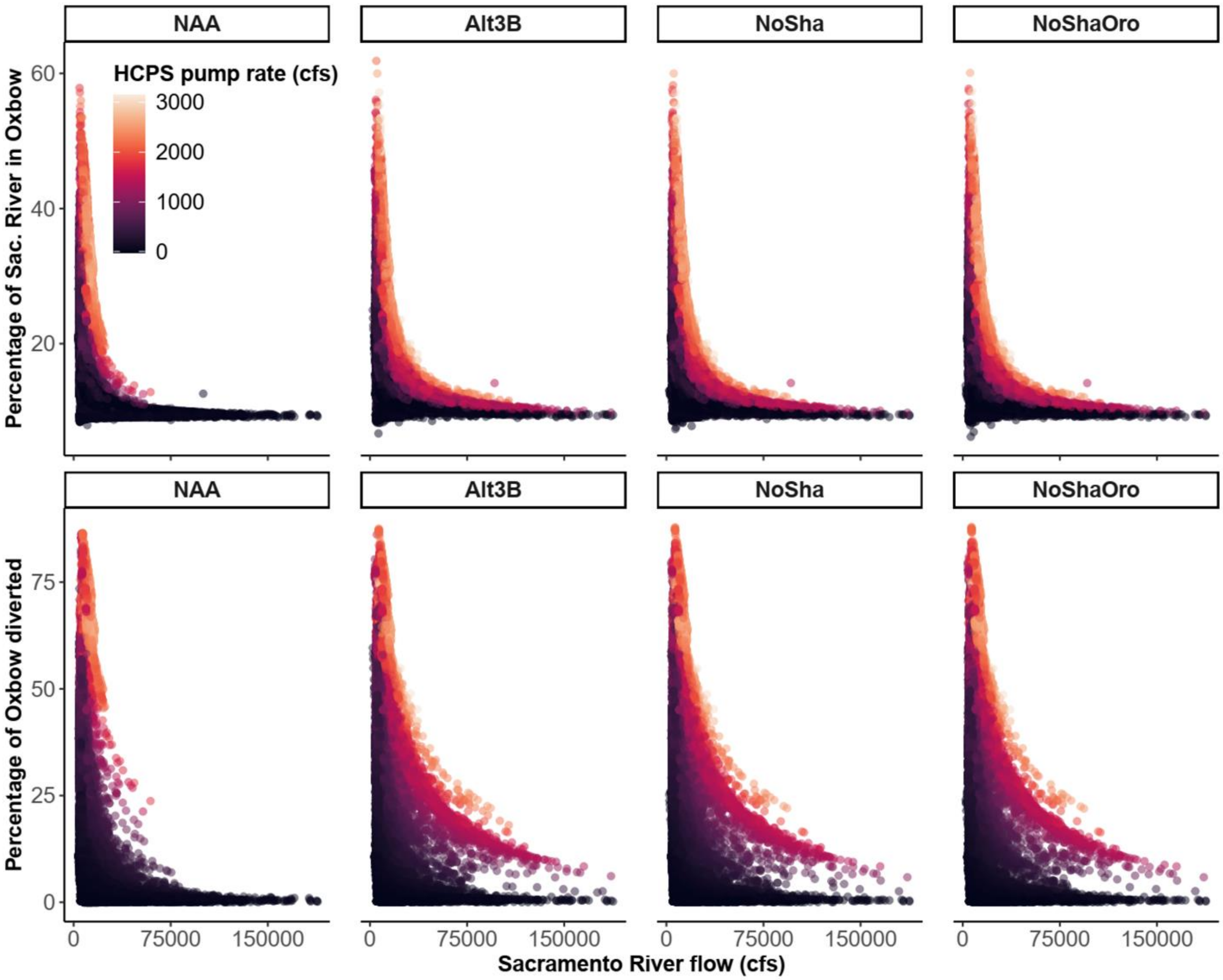

Figure 4-31. Percentage of Sacramento River flow entering the Hamilton City Oxbow versus total Sacramento River flow upstream of the Oxbow under (left to right) the No Action Alternative (NAA), Alt3B, NoSha, and NoShaOro operational scenarios. (bottom) Percentage of Hamilton City Oxbow flow diverted versus Sacramento River flow (cfs) under (left to right) the NAA, Alt3B, NoSha and NoShaOro. Color brightness indicates the pumping rate (cfs) at Hamilton City Pump Station. See Appendix A1 for Hamilton City Oxbow inflow and outflow estimation procedure.

A baseline assumption of this analysis is that fish are evenly distributed in the main channel of the Sacramento River. Thus, the proportion of outmigrating juvenile CHNWR entering the Oxbow is assumed to be equal to the proportion of Sacramento River flow entering the Oxbow. The rate of exposure of CHNWR in the Oxbow to HCFS increases proportionally to the fraction of Oxbow flow diverted through the screen (see Figure 4-31). Thus, the exposure rate of CHNWR with HCFS may be expressed as:

Equation 2.

$$E_{HCFS} = P_{HC} \cdot \frac{Q_{HCOX}}{Q_{SacHC}} \cdot \frac{Q_{HCPS}}{Q_{HCOX}}$$

where E_{HCFS} is the exposure rate, P_{HC} is the total annual CHNWR passage immediately upstream of the Hamilton City Oxbow, Q_{HCOX} is the total Oxbow flow upstream of the Hamilton City Pump Station, Q_{SacHC} is Sacramento River flow immediately upstream of the Hamilton City Oxbow, and Q_{HCPS} is the Hamilton City Pump Station diversion rate. Q_{HCOX} in the numerator and denominator cancel, leaving:

Equation 3.

$$E_{HCFS} = P_{HC} \cdot \frac{Q_{HCPS}}{Q_{SacHC}}$$

As with E_{RBFS}, E_{HCFS} does not represent certain physical contact with HCFS, but rather the proportion of outmigrating CHNWR that are at a high risk of screen contact. The probability of impingement or injury due to contact when $Q_{HCPS} = 0$ is low but increases as Q_{HCPS} increases above 0. Provided the approach velocity does not exceed 0.33 fps, the sweeping velocity is at least twice the approach velocity, and fish passage time along the screen is low, the risk of impingement or contact injury may be low (NMFS 1997; CDFG 2000).

CDFW estimated P_{HC} by multiplying the USFWS Red Bluff RST-based daily CHNWR passage estimate by the rate of CHNWR survival from RBDD to the Oxbow. CDFW used survival rate estimates from the 2013–2023 NOAA Fisheries Livingston Stone and 2019–2023 Battle Creek Jumpstart CHNWR acoustic telemetry studies[2] to estimate the number of juvenile CHNWR that have been routed into the Oxbow and exposed to HCFS since Red Bluff RST monitoring began in 2004 (see Table 4-1 for details of included acoustic telemetry releases). As there were no acoustic receivers at Red Bluff or immediately upstream of the Oxbow in many years; CDFW imputed survival and its uncertainty from reach-specific cumulative survival estimated by NOAA Fisheries (Appendix A2).

[2] https://oceanview.pfeg.noaa.gov/shiny/FED/telemetry/

Table 4-1. Study and release details of acoustically tagged, juvenile winter-run Chinook Salmon included in the present winter-run survival analysis. * river kilometer (rkm), i.e., distance from the Golden Gate Bridge, traveling up the Sacramento River.

Study ID	Release Dates	Release Coordinates	Release rkm*	Run	Number released
Winter_H_2013	2/7/2013	40.59383N, 122.3984W	551.28	Winter	148
Winter_H_2014	2/10/2014	40.59383N, 122.3984W	551.28	Winter	358
Winter_H_2015	2/5/2015	40.59383N, 122.3984W	551.28	Winter	567
Winter_H_2016	2/17/2016	40.53758N, 122.3572W	540.26	Winter	570
Winter_H_2017	2/2/2017	40.59383N, 122.3984W	551.28	Winter	569
Winter_H_2018	3/1/2018, 3/13/2018	40.53758N, 122.3572W	540.26	Winter	361, 237
Winter_H_2019	2/14/2019	40.59383N, 122.3984W	551.28	Winter	650
Winter_H_2020	3/10/2020, 3/23/2020	40.59383N, 122.3984W	551.28	Winter	367, 135
Winter_H_2021	1/30/2021	40.59383N, 122.3984W	551.28	Winter	555
Winter_H_2022	2/10/2022, 3/2/2022	40.59383N, 122.3984W	551.28	Winter	139, 430
Winter_H_2023	1/27/2023, 3/1/2023	40.53758N, 122.3572W	540.26	Winter	507, 362
BC_Jumpstart_2019	3/26/2019	40.42459N, 121.9873W	536.18	Winter	500
BC_Jumpstart_2020	3/23/2020, 5/18/2020	40.42459N, 121.9873W 40.39816N, 122.1456W	536.18, 517.34	Winter	125, 64
BC_Jumpstart_2021	3/9/2021, 3/18/2021	40.53758N, 122.3572W	540.26	Winter	600, 300
BC_Jumpstart_2022	3/16/2022	40.41685N, 121.9442W	540.51	Winter	1196
BC_Jumpstart_2023	4/24/2023	40.44721N, 121.8680W	549.00	Winter	595

CDFW estimated juvenile CHNWR passage at the Oxbow under the NAA versus Alt3B, NoSha and NoShaOro operational scenarios by modeling estimated survival from Red Bluff to the Oxbow as a function of Sacramento River flow. CDFW examined relationships between the obtained survival estimates (Appendix A2) and historical mean daily flows at Bend Bridge (CDEC Station BND), Vina (CDEC Station VIN), Hamilton City (CDEC Station HMC) and Wilkins Slough (CDEC Station WLK) and found that WLK flow was the strongest predictor of survival from Red Bluff to the Oxbow. CDFW tested several averaging periods and found the strongest predictor of CHNWR survival to be the 22-day average flow, beginning on the mean release date of each CHNWR acoustic telemetry cohort (Appendix A3). CDFW placed an *a priori* flow threshold at a 22-day WLK flow of 10,700 cfs based on the findings of Michel et al. (2021), as CHNWR survival from Red Bluff to the Oxbow increased with flow below this threshold and did not systematically change with flow above this threshold. Below 10,700 cfs, CDFW fit a linear meta-regression model of survival as a function of $\log_{10}$ WLK flow, while above 10,700 cfs CDFW fit an intercept-only meta-regression model to estimate mean survival, independent of flow (Figure 4-32). Meta-regression is a weighted least-squares, mixed-effects technique used in meta-analysis to account for known uncertainties in response observations (e.g., when each response observation is a modeled estimate with an associated standard error; Harrer et al. 2021) (see Appendix A3).

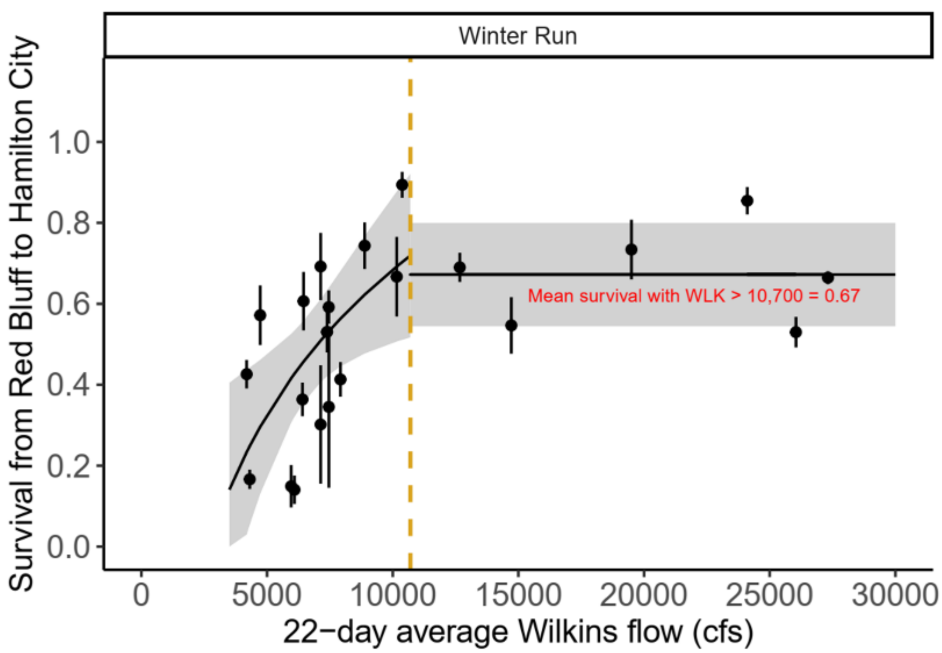

Figure 4-32. Winter-run Chinook Salmon survival estimates from Red Bluff to the Hamilton City Oxbow ±1 SE (points) and fitted meta-regression models (curves) with 95% confidence bands (shaded areas), plotted against the 22-day average Sacramento River flow at Wilkins Slough (WLK). The 22-day averaging period begins on the mean release date of each tagged cohort, and the dashed, vertical line indicates the 10,700 cfs flow threshold. Survival data calculated from Central Valley Enhanced Acoustic Tagging Project survival estimates (Appendix A2).

CDFW used the fitted flow-survival relationships to estimate juvenile CHNWR passage at the Hamilton City Oxbow between 2008 and 2018 (the period simulated in the DDFT). The daily USFWS daily CHNWR passage estimate at the Red Bluff RST was multiplied by the modeled, flow-based Red Bluff to Oxbow survival rate to obtain the Oxbow passage estimate at t+22 days (Figure 4-33). CDFW estimated $\mathrm{E}_{\mathrm{HCFS}}$ for juvenile CHNWR between 2008 and 2018 by substituting this passage estimate and DDFT-simulated Sacramento River flow and Hamilton City diversion rate into Equation 4 (Figure 4-34).

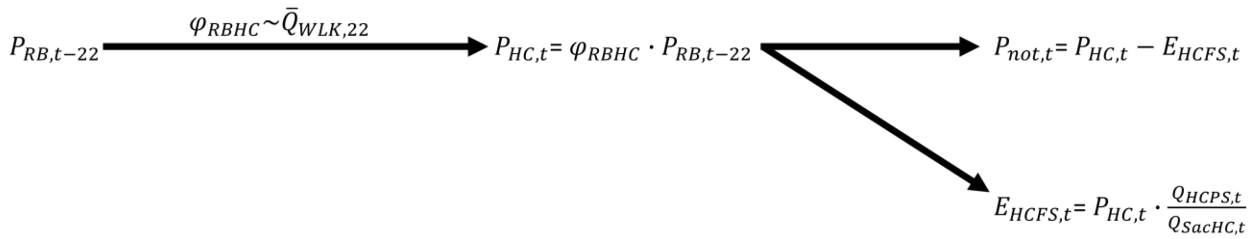

Figure 4-33. Juvenile winter-run Chinook Salmon (CHNWR) Hamilton City Fish Screen (HCFS) exposure calculation schematic. $P_{RB,t-22}$ is the USFWS daily CHNWR passage estimate at t-22 days; $\phi_{RBHC} \sim \bar{Q}_{WLK,22}$ indicates that survival from Red Bluff to Hamilton City Oxbow, ϕ_{RBHC}, is a function of 22-day mean flow at Wilkins Slough, $\bar{Q}_{WLK,22}$; $P_{HC,t}$ is daily juvenile CHNWR passage at Hamilton City at time t, $E_{HCFS,t}$ is the daily number of juvenile CHNWR exposed to HCFS, $Q_{HCPS,t}$ is the daily mean diversion rate at the Hamilton City Pump Station in cfs, $Q_{SacHC,t}$ is daily mean Sacramento River flow above the Hamilton City Oxbow at time t, and $P_{not,t}$ is the number of juvenile CHNWR not exposed to the screen, which includes those remaining in the mainstem Sacramento River and the fraction of $P_{HC,t}$ that passed through the Hamilton City Oxbow without being exposed, equal to $P_{HC,t} \cdot (Q_{HCOX,t}-Q_{HCPS,t})/Q_{SacHC,t}$.

As was the case at Red Bluff, exposure of juvenile CHNWR to HCFS may frequently be higher under the Project than under the NAA (Figure 4-34A), especially during December – April (Figure 4-34B). The predicted maximum number of CHNWR exposed to HCFS under the NAA was 20,863 versus 22,158 under Alt3B (not on the same date) (Figure 4-34). On September 22, 2006, 13,968 additional exposures were predicted under Alt3B that were not predicted under the NAA (Figure 4-34). In total, between 2004 and 2019, the predicted total number of CHNWR screen exposures at HCFS under the NAA was 1,066,445, versus 1,232,075 under Alt3B, or a 15.5% increase in screen exposure under the Project as compared to the NAA.

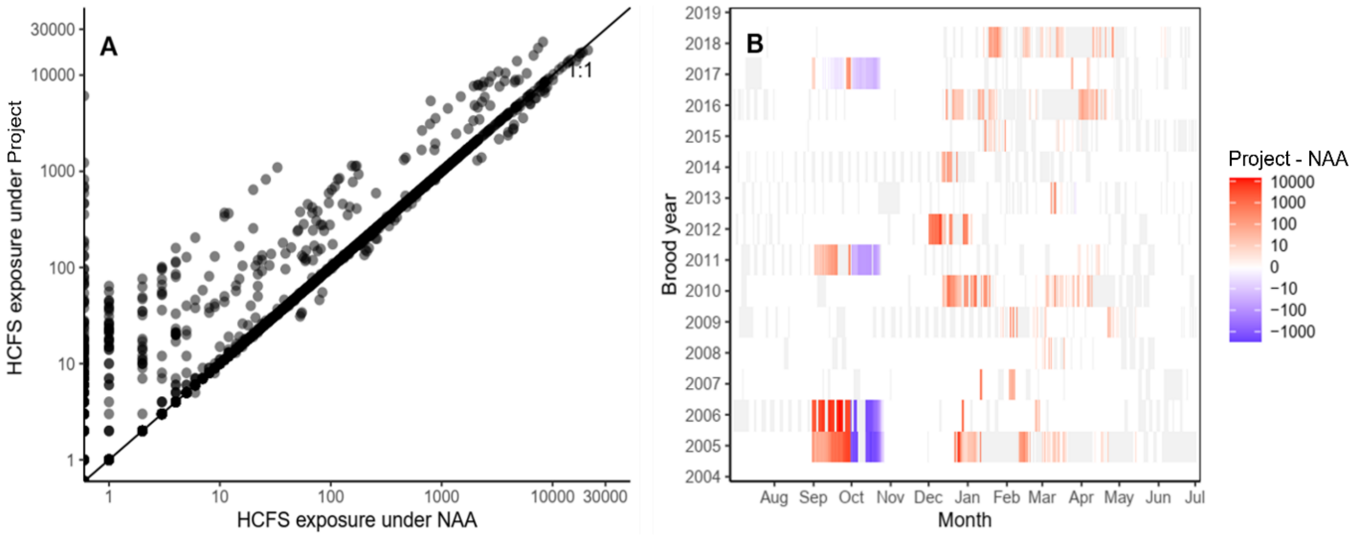

Figure 4-34. (A) Estimated number of juvenile winer-run Chinook Salmon exposed to the Hamilton City Fish Screen (E_{HCFS}) during 2005 – 2019 under the Project versus under the NAA. Diagonal line indicates 1:1 correspondence. (B) Difference in E_{HCFS} under the Project versus under the NAA by day of brood year (x-axis) and brood year (y-axis). Note that in both panels, values are on a log10 scale for visibility. Gray areas in (B) indicate missing data.

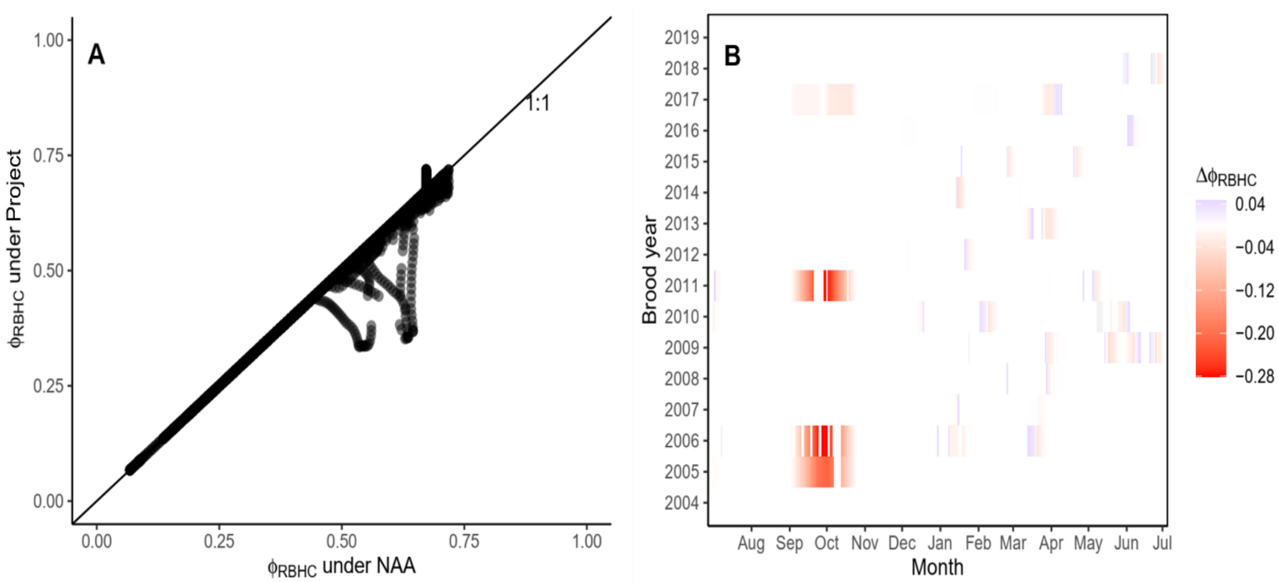

Figure 4-35. (A) Estimated survival of juvenile winter-run Chinook Salmon from Red Bluff to Hamilton City (ϕ_{RBCH}) during 2005 – 2019 under Project versus under the NAA. The diagonal line indicates 1:1 correspondence. (B) Difference in ϕ_{RBCH} under Project versus under the NAA by day of brood year (x-axis) and brood year (y-axis).

Whereas there were some large increases in exposure to RBFS indicated in September 2005, 2006, 2011, and 2017 (Figure 4-29B), some reductions in exposure to HCFS of up to 2,655 CHNWR under Alt3B were indicated in October of those years (Figure 4-34B). These reductions are due to lower estimated survival of CHNWR from Red Bluff to Hamilton City caused by diversion at Red Bluff (Figure 4-35), which reduced Hamilton City passage (P_{HC}); therefore, these reductions do not represent a reduction in take compared to the NAA.

CHNWR Entrainment into the Hamilton City Oxbow

Juvenile CHNWR entrained into the Oxbow may be at a heightened risk of predation whether or not they are directly exposed to HCFS, due to the great reduction in volume caused by Hamilton City Pump Station diversions. Thus, the number of fish entrained into the Hamilton City Oxbow, P_{HCOX}, may be a more accurate metric of the risk of take posed by Hamilton City Pump Station diversions than E_{HCFS}. CDFW substituted DDFT-simulated Sacramento River flow and Hamilton City Pump Station diversion rates into Model A1 to predict Hamilton City Oxbow flow, based on the DDFT. CDFW then calculated the number of juvenile CHNWR entering the Oxbow as:

Equation 4.

$$P_{HCOX} = P_{HC} \cdot \frac{Q_{HCOX}}{Q_{SacHC}}$$

where Q_{HCOX} is Hamilton City Oxbow flow upstream of Hamilton City Pump Station, as predicted by Model A1. Other symbols are as above. Figure 4-36 shows P_{HCOX} under the Project versus the NAA. The modeled Oxbow flows result in maximum predicted daily Oxbow entrainment of 50,182 and 50,075 CHNWR under the NAA and Project, respectively (Fiugre 4-36A). The difference in P_{HCOX} between the Project and the NAA ranged from -18,645 on 19 October, 2005 to 8,100 on 22 September, 2006. i.e., as many as 8,100 more CHNWR Oxbow entrainments were predicted under the Project than were predicted under the NAA on that day (Figure 4-36B). As with HCFS screen exposure, reductions in Oxbow entrainment are attributable to reductions in survival from Red Bluff to Hamilton City, and those losses would also be attributed to operations of the Project (Figure 4-35). In total, between 2004 and 2019, the predicted total number of CHNWR entrainments into the Oxbow under the NAA was 2,987,472, versus 3,076,001 under the Project, or a 2.96% increase in entrainment into the Oxbow under the Project as compared to the NAA.

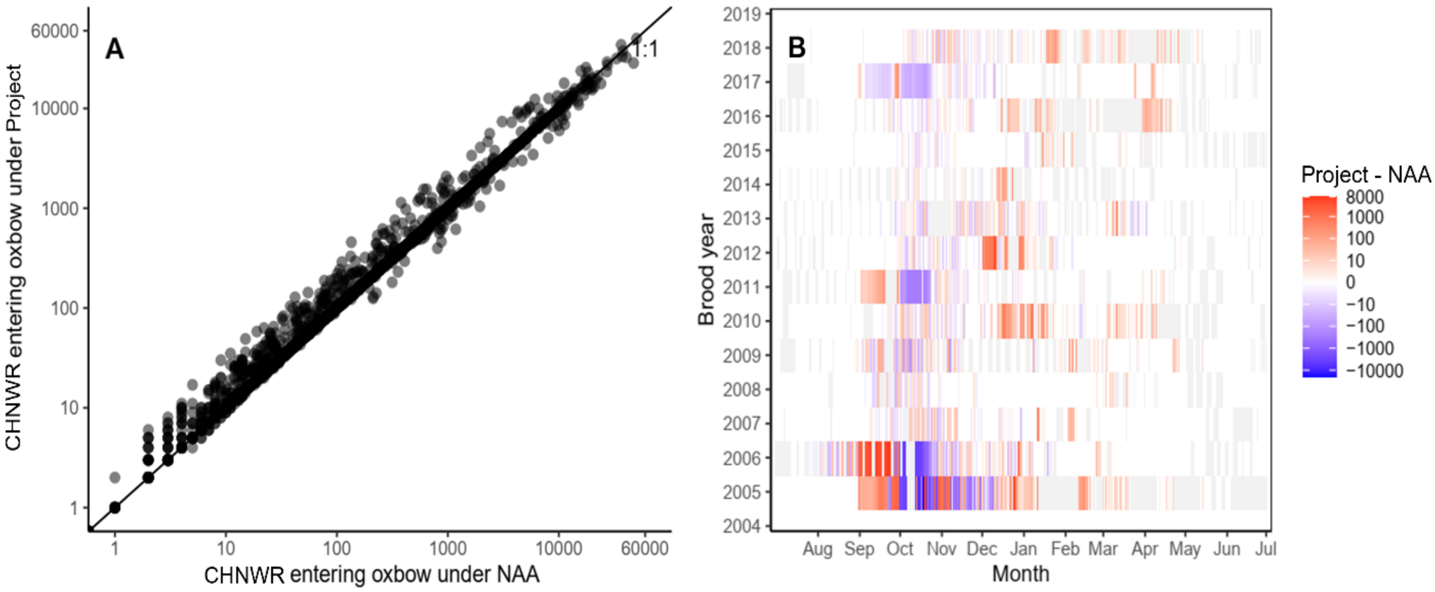

Figure 4-36. (A) Estimated number of juvenile winter-run Chinook Salmon entrained into the Hamilton City Oxbow, P_{HCOX}, during 2008 – 2018 under the Project versus under the NAA. The diagonal line indicates 1:1 correspondence. (B) Difference in P_{HCOX} under the Project versus under the NAA by day of brood year (x-axis) and brood year (y-axis). Note that in both panels, values are on a $\log_{10}$ scale for visibility. Gray areas in (B) indicate missing data.

Spring Run Chinook Salmon Screen Exposure

The four remaining independent Sacramento River populations of CHNSR spawn in Battle, Mill, Deer and Butte creeks (Cordoleani et al. 2020); of these, the Battle Creek population and meta-populations in Clear Creek or the Sacramento River pass both RBFS and HCFS during their juvenile outmigration, while the Mill and Deer Creek populations pass only HCFS. Juvenile outmigration typically begins in early fall and may continue into the following summer.

Relative to the NAA, Alt3B, NoSha and NoShaOro would increase diversions through both fish screens during the time of peak CHNSR outmigration (October–June) and may thus increase exposure of CHNSR to the screens (Figures 4-24 and 4-25). Although the CHNSR that may be exposed to RBFS and HCFS are typically >30 mm FL and are thus protected from entrainment (Turnpenny 1981; Young et al. 1997; Gowan and Garmin 2002), the risks of impingement, injury due to screen contact, stranding and predation remain of primary concern to CDFW.

CHNSR Migration Timing: Red Bluff and Hamilton City

Outmigrating juvenile CHNSR typically begin to appear in the USFWS Red Bluff RSTs in October and may be caught as late as July of the following year. Beginning around 2014, the temporal distribution of CHNSR catch in the Red Bluff RST shifted from the majority being caught in October–December to the majority being caught in March–June (Figure 4-37). Seasonal exposure to RBFS can be expected to reflect trends in Red Bluff RST catch. Hamilton City RST data from 2013–2023 also show most outmigrating CHNSR passing the HCFS during the March–June period (Figure 4-37), consistent with the 2013–2023 Red Bluff RST catch and suggesting a short travel time between Red Bluff and Hamilton City. Acoustic telemetry data for CHNSR are not available, but the median travel time from Red Bluff to Hamilton City in NOAA Fisheries CHNSR surrogate acoustic telemetry studies (Table 4-2) in 2022 and 2023 was 0.8 days, while some fish took as long as 20–30 days to make the transit (Figure 4-38). Notably, CHNFR and late fall-run Chinook salmon (CHNLFR) released in these studies were much larger (>80 mm FL) than the majority of outmigrating CHNSR (most are 30–39 mm FL; Sites Authority 2023) and may have traveled faster than is typical among wild fish.

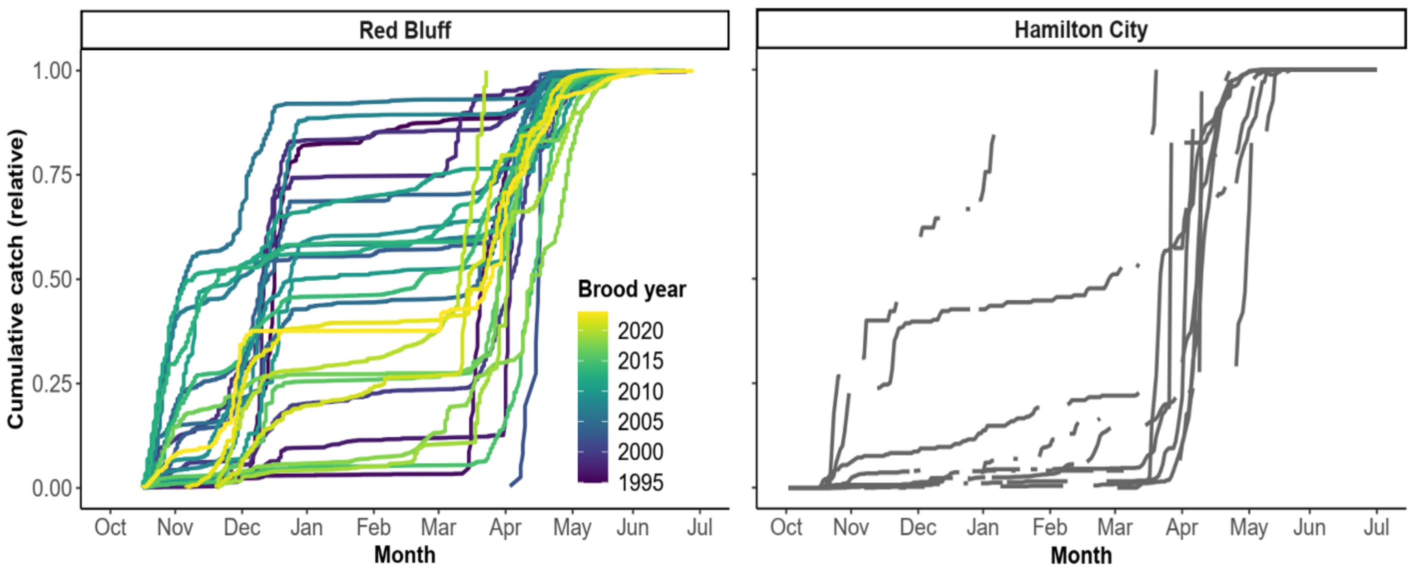

Figure 4-37. Cumulative catch of juvenile spring-run Chinook Salmon in the rotary screw traps (RSTs) at Red Bluff, 1994–2023 (left) and in the GCID RST in the Hamilton City Oxbow, 2013–2023 (right). Curves show individual brood years. Colors in the left panel indicate brood year. Red Bluff data downloaded from the Environmental Data Initiative portal (Poytress, 2024). Hamilton City RST data provided by Sites Authority (2023).

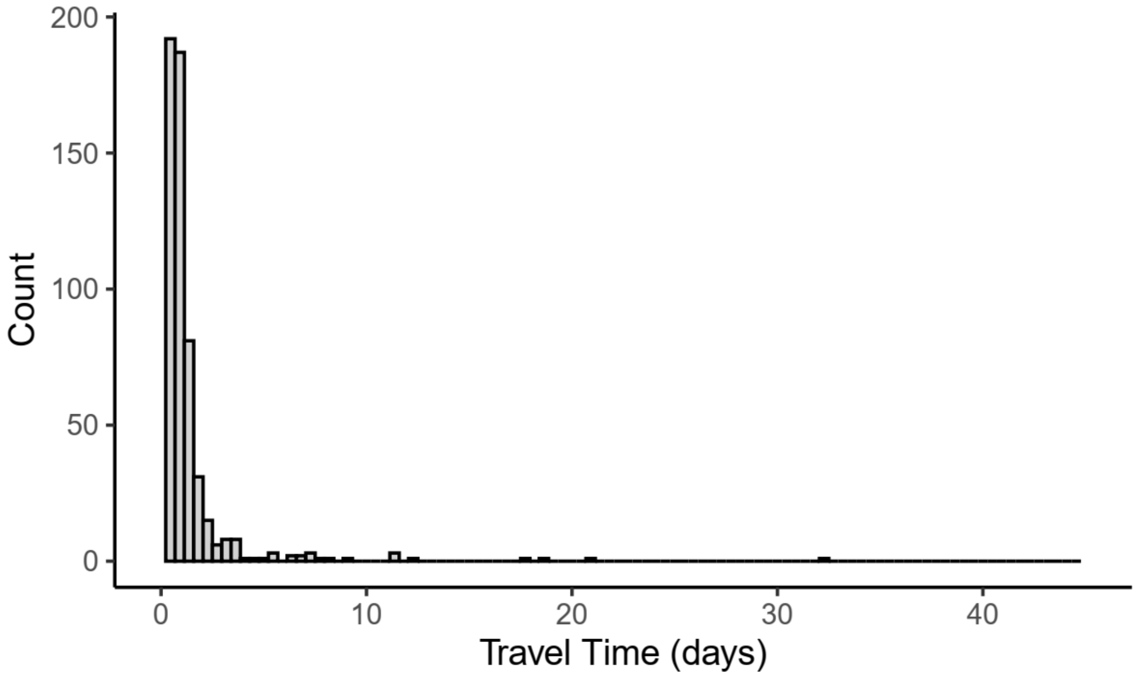

Figure 4-38. Histogram of travel times of acoustic-tagged, juvenile spring-run Chinook Salmon from Red Bluff to Hamilton City. Median travel time was 0.8 days. Experimental releases at Redding and in Battle Creek were conducted by NOAA fisheries in April and May of 2013–2023. Travel times were imputed from NOAA Fisheries acoustic receiver records. (https://oceanview.pfeg.noaa.gov/shiny/FED/telemetry/)

CHNSR Encounter Rates with Red Bluff Fish Screen

The number of CHNSR that encounter RBFS will depend on the fraction of Sacramento River flow diverted and P_{RB}, estimated using USFWS daily estimates of CHNSR passage at Red Bluff RSTs. CDFW calculated E_{RBFS} using these daily estimates of P_{RB} and simulated daily diversions and Sacramento River flows from DRAT for water years 2005–2019, substituted into Equation 1. As was done for the CHNWR analysis, CDFW compared predicted exposure with and without Project diversions (Figure 4-39). Exposure of juvenile CHNSR to RBFS is predicted to frequently be higher under the Project than under the NAA (Figure 4-39A), especially during October–April (Figure 4-39B). The predicted maximum daily CHNSR exposed to RBFS under the NAA was 6,566, versus 30,515 under the Project (not on the same date) (Figure 4-39). The maximum daily difference in predicted screen exposure occurred on March 23, 2016, when 30,515 additional exposures were predicted under the Project that were not predicted under the NAA (Figure 4-39B). In total, between 2004 and 2019, the predicted total number of CHNSR screen exposures at RBFS under the NAA was 74,523, versus 291,712 under the Project, or a 291.4% increase in screen exposure under Alt3B as compared to the NAA.

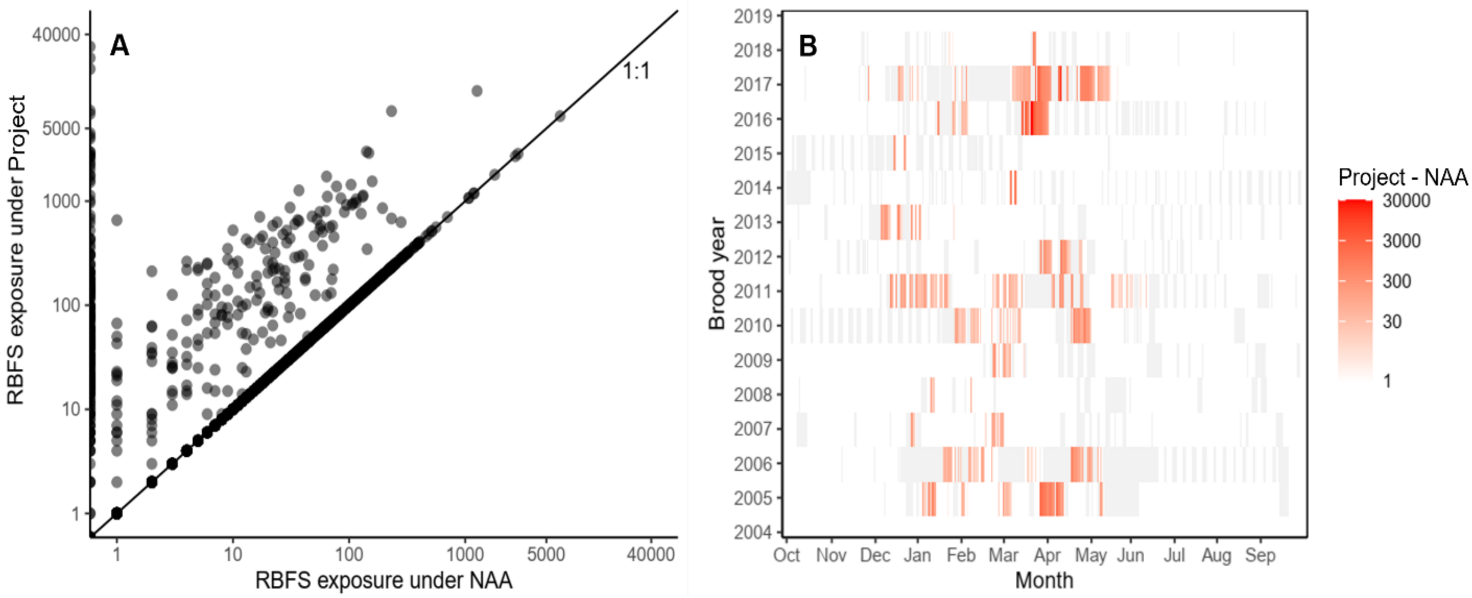

Figure 4-39. (A) Estimated number of juvenile spring-run Chinook Salmon exposed to the Red Bluff Fish Screen (E_{RBFS}) during 2005 – 2019 under the Project versus under the NAA. The diagonal line indicates 1:1 correspondence. (B) Difference in E_{RBFS} under the Project versus under the NAA by day of brood year (x-axis) and brood year (y-axis). Note that in both panels, values are on a $\log_{10}$ scale for visibility. Gray areas in (B) indicate missing data.

CHNSR Encounter Rates with Hamilton City Fish Screen

The number of CHNSR that encounter HCFS will depend on the fraction of Sacramento River flow diverted by Hamilton City Pump Station during the period when CHNSR are migrating past or through the Hamilton City Oxbow. Similar to the analysis for CHWR, we assume that the proportion of outmigrating juvenile CHNSR entering the Hamilton City Oxbow is equal to the proportion of Sacramento River flow entering the Oxbow, and the rate of exposure of CHNSR in the Oxbow to HCFS will increase proportionally to the fraction of Oxbow flow diverted through the screen.

CDFW estimated P_{HC} by multiplying the USFWS Red Bluff RST-based daily CHNSR passage estimate by the rate of CHNSR survival from RBDD to the Oxbow. As no survival studies have been conducted using CHNSR on this upper reach of the Sacramento River, CDFW used surrogates for CHNSR from acoustic telemetry studies designed to estimate survival for the 2022 and 2023 CHNSR JPE. NOAA Fisheries CHNFR and CHNLFR acoustic telemetry studies from 2012–2023 were found to have similar Red Bluff-to-Hamilton City survival rates to the surrogates in the JPE studies; therefore, these[3] were also used as surrogates for CHNSR survival rates in this analysis (see Table 4-2 for details of included acoustic telemetry releases). CDFW used these rates to estimate the number of juvenile CHNSR that have been routed into the Hamilton City Oxbow and exposed to HCFS since Red Bluff RST monitoring began in 2004. During the NOAA Fisheries studies, there were no acoustic receivers at Red Bluff or immediately upstream of the Oxbow in many years; imputation of RBDD–Hamilton City Oxbow survival and its uncertainty from reach-specific, cumulative survival estimated by NOAA Fisheries can be found in Appendix A2.

Table 4-2. Study and release details of acoustically tagged, juvenile Chinook Salmon included in the spring-run Chinook Salmon surrogate survival analysis. * River kilometer, i.e., distance from the Golden Gate Bridge, traveling up the Sacramento River.

Study ID	Release Dates	Release Coordinates	Release rkm*	Run	Number released
ColemanFall_2012	4/19/2012, 5/1/2012	40.39816N, 122.1456W	517.34	Fall	97, 72
ColemanFall_2013	4/10/2013, 4/24/2013	40.39816N, 122.1456W	517.34	Fall	151, 149
ColemanFall_2016	4/9/2016, 4/29/2016	40.39816N, 122.1456W	517.34	Fall	400, 197

[3] https://oceanview.pfeg.noaa.gov/shiny/FED/telemetry/

Study ID	Release Dates	Release Coordinates	Release rkm*	Run	Number released
ColemanFall_2017	4/5/2017, 4/21/2017	40.39816N, 122.1456W	517.34	Fall	290, 290
CNFH_FMR_2019	5/16/2019, 5/23/2019	40.15444N, 122.2025W	461.57	Fall	250, 250
CNFH_FMR_2020	5/14/2020 5/21/2020	40.15444N, 122.2025W	461.57	Fall	400, 323
CNFH_FMR_2021	4/29/2021 5/13/2021	40.15444N, 122.2025W	461.57	Fall	480, 481
ColemanAltRel_2021	3/24/2021	40.39816N, 122.1456W	517.34	Fall	300
ColemanAltRel_2022	4/5/2022	40.39816N, 122.1456W	517.34	Fall	300
SacRiverSpringJPE_2022	4/17/2022 4/28/2022	40.15444N, 122.2025W	461.57	Fall	299, 297
SacRiverSpringJPE_2023	4/21/2023 4/27/2023 5/4/2023 5/11/2023 5/18/2023 5/24/2023 6/1/2023	40.15444N, 122.2025W	461.57	Fall	45, 99, 98, 101, 93, 99, 99
ColemanLateFall_2018	12/21/2017, 1/5/2018	40.39816N, 122.1456W	517.34	Late Fall	228, 356
ColemanLateFall_2019	11/29/2018	40.39816N, 122.1456W	517.34	Late Fall	440
ColemanLateFall_2020	12/05/2019	40.39816N, 122.1456W	517.34	Late Fall	603
ColemanLateFall_2021	1/4/2021	40.39816N, 122.1456W	517.34	Late Fall	601

Similar to the CHNWR analysis, CDFW estimated juvenile CHNSR passage at the Oxbow under the NAA versus Alt3B, NoSha and NoShaOro by modeling estimated survival from Red Bluff to the Oxbow as a function of Sacramento River flow. CDFW examined relationships between the obtained survival estimates (Appendix A2) and historical mean daily flows at Bend Bridge (CDEC Station BBR), Vina (CDEC Station VIN), Hamilton City (CDEC Station HMC) and Wilkins Slough (CDEC Station WLK) and found that WLK flow was the strongest predictor of survival from RBDD to the Oxbow. CDFW tested several averaging periods and found the strongest predictor of CHNSR survival to be the 9-day average flow, beginning on the mean release date of each CHNSR acoustic telemetry cohort. CDFW placed a threshold at a 9-day WLK flow of 10,700 cfs (Michel et al. 2021) and visually determined that CHNSR survival from RBDD to the Oxbow increased with flow below this threshold and did not systematically change with flow above this threshold, the latter being consistent with the findings of Michel et al. (2021). CDFW therefore fit separate flow-survival models to pooled surrogate survival estimates for flows below and above 10,700 cfs. Below 10,700 cfs, CDFW fit a linear meta-regression model (Appendix A3) of survival as a function of $\log_{10}$ WLK flow, while above 10,700 cfs CDFW fit an intercept-only meta-regression model to estimate mean survival, independent of flow (Figure 4-40).

The fitted flow-survival relationships can be used to estimate juvenile CHNSR passage at the Ha Oxbow between 2008 and 2018 (the period simulated in the DDFT). The daily USFWS daily CHNSR passage estimate at the Red Bluff RST is multiplied by the modeled, flow-based Red Bluff to Oxbow survival rate to obtain the Oxbow passage estimate at t+9 days (Figure 4-41). Substituting this passage estimate and DDFT-simulated Sacramento River flow and Hamilton City Pump Station diversion rate into Equation 3, we estimated $\mathrm{E_{HCFS}}$ for juvenile CHNSR between 2008 and 2018 (Figure 4-42).

As was the case at Red Bluff, exposure of juvenile CHNSR to HCFS may frequently be higher under the Project than under the NAA (Figure 4-42A), especially during December–April (Figure 4-42). The predicted maximum number of CHNSR exposed to HCFS under the NAA was 23,445, versus 27,617 under the Project (not on the same date) (Figure 4-42). On March 30, 2006, 13,712 additional exposures were predicted under the Project that were not predicted under the NAA (Figure 4-42B). In total, between 2004 and 2019, the predicted total number of CHNSR screen exposures at HCFS under the NAA was 231,462, versus 339,102 under the Project, or a 46.5% increase in screen exposure under the Project as compared to the NAA.

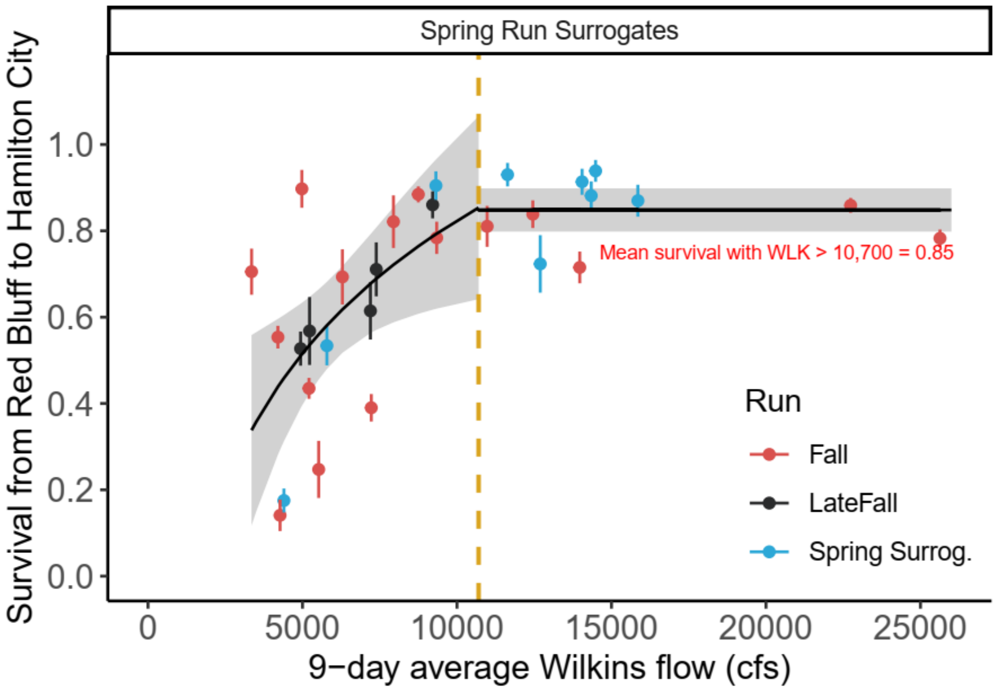

Figure 4-40. Spring-run Chinook Salmon (CHNSR) surrogate survival estimates from Red Bluff to the Hamilton City Oxbow ±1 SE (points) and fitted meta-regression models (curves) with 95% confidence bands (shaded areas). Dashed, vertical line indicates the 10,700 cfs flow threshold. 9-day averaging periods begin on the mean release date of each tagged cohort. Point colors on the indicate run. CHNSR surrogates include juvenile fall-run Chinook Salmon (released in March–May) and late-fall-run Chinook Salmon (released in November–January); "Spring Surrog." are fall-run Chinook Salmon released in April and May, 2022 and 2023 for the purpose serving as CHNSR surrogates in CHNSR juvenile production estimate studies conducted by DWR and CDFW. Survival data calculated from Central Valley Enhanced Acoustic Tagging Project survival estimates (Appendix A2).

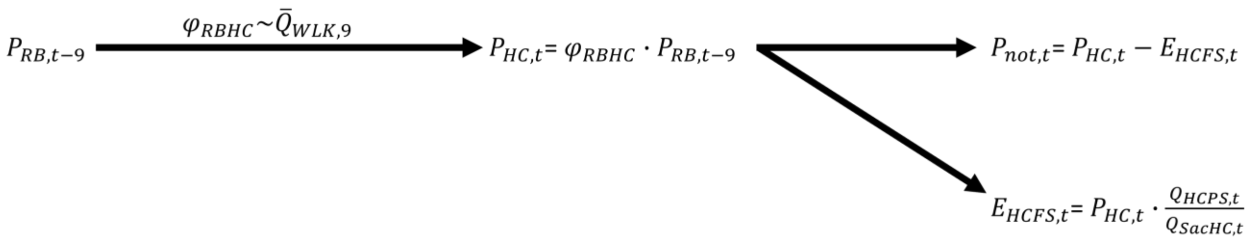

Figure 4-41. Juvenile spring-run Chinook Salmon (CHNSR) Hamilton City Fish Screen (HCFS) exposure calculation schematic. $P_{RB,t\text{-}9}$ is the USFWS daily CHNSR passage estimate at t-9 days; $\phi_{RBHC} \sim \bar{Q}_{WLK,9}$ indicates that survival from Red Bluff to Hamilton City, ϕ_{RBHC}, is a function of 9-day mean flow at Wilkins Slough, $\bar{Q}_{WLK,9}$; $P_{HC,t}$ is daily juvenile CHNSR passage at Hamilton City at time t, $E_{HCFS,t}$ is the daily number of juvenile CHNSR exposed to HCFS, $Q_{HCPS,t}$ is the daily mean diversion rate at the Hamilton City Pump Station in cfs, $Q_{SacHC,t}$ is daily mean Sacramento River flow above the Hamilton City Oxbow at time t, and $P_{not,t}$ is the number of juvenile CHNSR not exposed to the screen, which includes those remaining in the mainstem Sacramento River and the fraction of $P_{HC,t}$ that passed through the Oxbow without being exposed, equal to $P_{HC,t} \cdot \frac{Q_{HCOX,t} - Q_{HCPS,t}}{Q_{SacHC,t}}$.

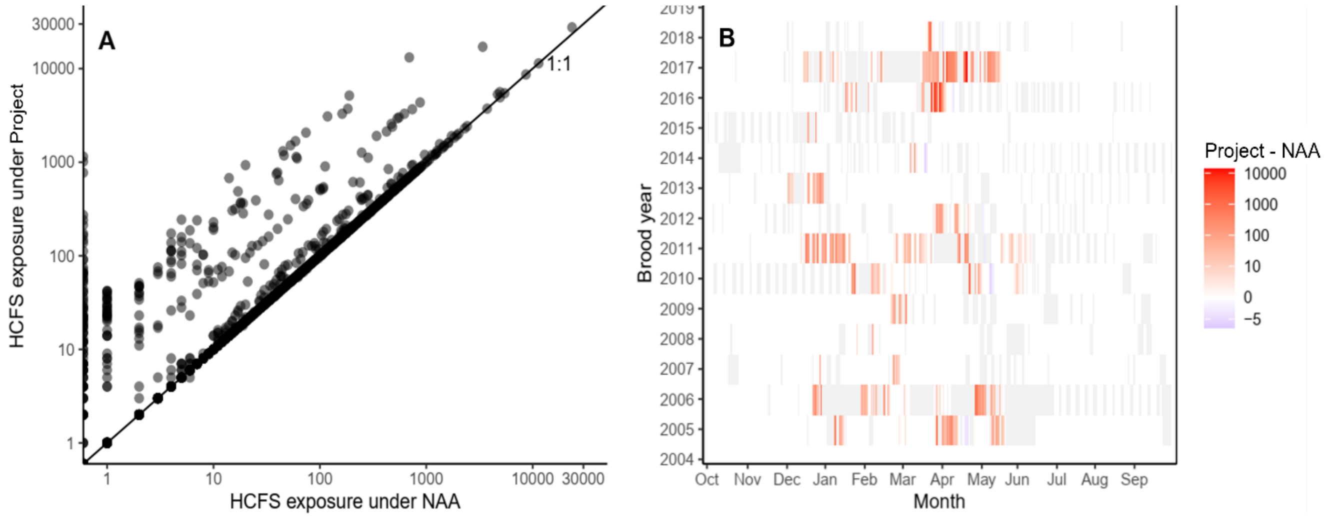

Figure 4-42. (A) Estimated number of juvenile spring-run Chinook Salmon exposed to the Hamilton City Fish Screen (E_{HCFS}) during 2005 – 2019 under the Project versus under the NAA. The diagonal line indicates 1:1 correspondence. (B) Difference in E_{HCFS} under the Project versus under the NAA by day of brood year (x-axis) and brood year (y-axis). Note that in both panels, values are on a log_{10} scale for visibility. Gray areas in (B) indicate missing data.

Whereas there were some large increases were in exposure to RBFS were indicated in September of 2005, 2006, 2011, and 2017 (Figure 4-39B), some small reductions in exposure to HCFS of up to nine CHNSR under the Project were indicated in March - May of those years (Figure 4-42B). These reductions are attributable to reduced survival from Red Bluff to Hamilton City due to diversion at Red Bluff (Figure 4-43), and thus reduced Hamilton City passage (P_{HC}).

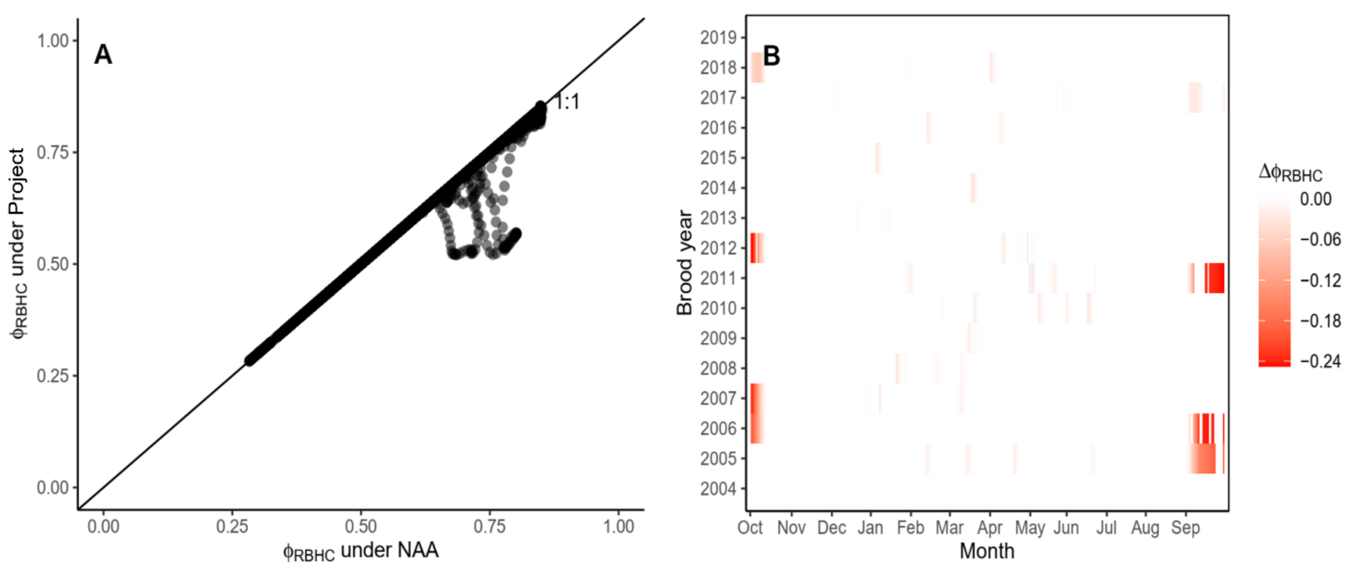

Figure 4-43. (A) Estimated survival of juvenile spring-run Chinook Salmon from Red Bluff to Hamilton City (ϕ_{RBCH}) during 2005 – 2019 under the Project versus under the NAA. The diagonal line indicates 1:1 correspondence. (B) Difference in ϕ_{RBCH} under the Project versus under the NAA by day of brood year (x-axis) and brood year (y-axis).

CHNSR Entrainment into the Hamilton City Oxbow

To calculate the risk of take posed by Hamilton City Pump Station diversions, CDFW estimated the number of juvenile CHNWR entrained into the Hamilton City Oxbow using the same equation as for CHNWR (Equation 4). Figure 4-43 shows P_{HCOX} under the Project versus the NAA. The modeled Oxbow flows result in maximum predicted daily Oxbow entrainment of 61,696 and 67,127 CHNSR under the NAA and the Project, respectively (Figure 4-44A). The difference in P_{HCOX} between the Project and the NAA ranged from -3,555 on December 3, 2005 to 12,496 on March 30, 2019. i.e., as many as 12,496 more CHNSR Oxbow entrainments were predicted under the Project than were predicted under the NAA on that day (Figure 4-44B). As with HCFS screen exposure, reductions in Oxbow entrainment are attributable to reductions in survival from Red Bluff to Hamilton City (Figure 4-43). In total, between 2004 and 2019, the predicted total number of CHNSR entrainments into the Oxbow under the NAA was 759,892, versus 857,495 under the Project, or a 12.8% increase in entrainment into the Oxbow under the Project.

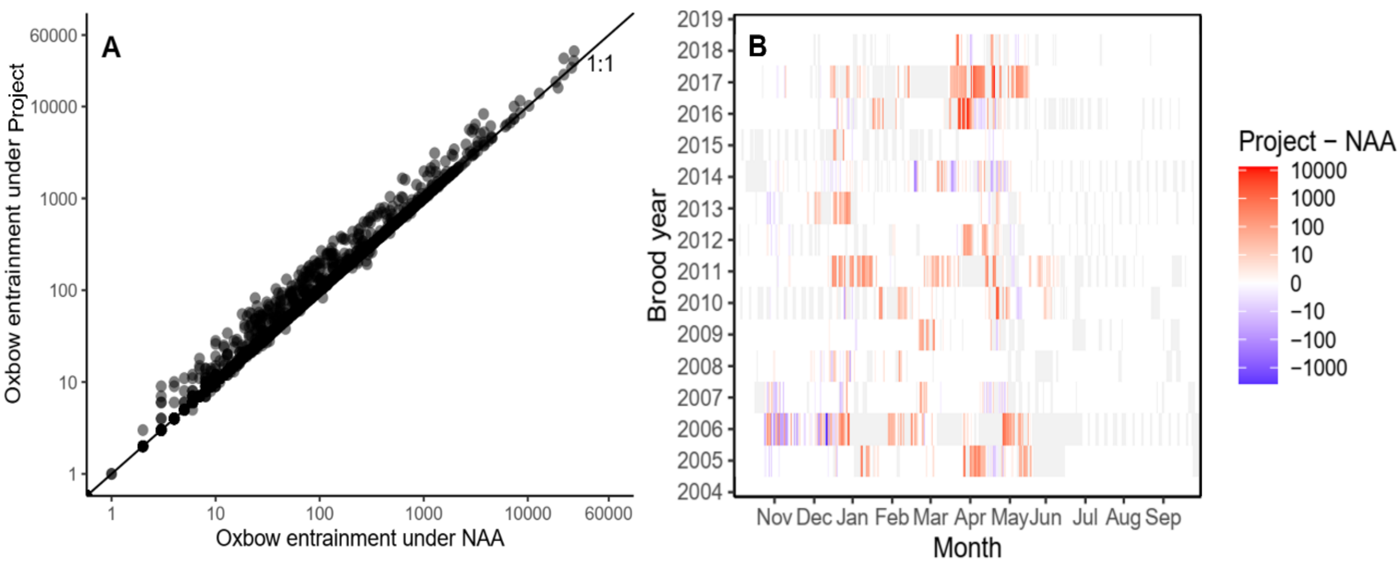

Figure 4-44. (A) Estimated number of juvenile spring-run Chinook Salmon entrained into the Hamilton City Oxbow, P_{HCOX}, during 2008 – 2018 under the Project versus under the NAA. The diagonal line indicates 1:1 correspondence. (B) Difference in P_{HCOX} under the Project versus under the NAA by day of brood year (y-axis). Note that in both panels, values are on a $\log_{10}$ scale for visibility. Gray areas in (B) indicate missing data.

Conclusions

Project diversions at Red Bluff Pumping Plant and Hamilton City Pump Station under the Project will result in more juvenile CHNWR and CHNSR being exposed to the RBFS and HCFS than under the NAA. This is not unexpected, as exposure risk is proportional to the instantaneous fraction of Sacramento River flow diverted at each location and to the number of outmigrating CHNWR and

CHNSR present near the screens during diversion. CHNWR and CHNSR migrate downriver during fall, winter, and early spring, when diversions for the Project will be most frequent. The Project may, on occasion, divert up to 55% of the Sacramento River's flow at Red Bluff Pumping Plant and 45% at Hamilton City Pump Station; the maximum CHNWR passage estimate recorded by USFWS at Red Bluff on a single day was 372,576, recorded on 16 October, 2009 (Voss, 2024), and the maximum single day estimate for CHNSR was 391,941, recorded on March 23, 2016 (Poytress, 2024). A "worst-case scenario" would be an instance in which the Project is diverting a high percentage of total instream flow during a period when a high number of CHNSR are present in the area—which is possible, given the seasonal overlap of Project diversions and the CHNWR and CHNSR outmigration.

There is evidence that fish screens pose specific mortality risks to small fish, including juvenile salmonids. Prior studies have shown that juvenile salmonids may suffer high predation losses near fish screens as they are drawn toward the screens by diversion flows and their density is increased by the removal of much of the water they are swimming in (Hall 1979; NMFS 1998). High diversion flows increase the risk of mortality due to impingement or other physical contact with fish screens (NMFS 1998; CDFG 2000; Swanson et al. 2004). The risk of predation, in particular, may be greatly increased at Hamilton City by the funneling of fish into a confined volume downstream of the screen in the Hamilton City Oxbow channel (Vogel 2006; Vogel 2007; Vogel 2008). The current understanding of the risk of predation at HCFS is incomplete, however some predation studies have been conducted there (Vogel 2006; Vogel 2007; Vogel 2008; Notch et al. 2020b). The predation risk at Red Bluff has not been studied. The risk of impingement and injury of juvenile salmonids due to contact with RBFS and HCFS is similarly poorly understood; impingement on these screens has not been directly studied, and hydraulic testing of both screens has been limited to a narrow set of diversion rates, flow conditions and screen panels (CH2M Hill 2008; USBR 2018). Additional research is needed to confirm our understanding of the level of take of CHNWR and CHNSR caused by Project diversions at Red Bluff and Hamilton City, in part because Project diversions would occur during time of year and under flows that are different than historical diversions at these locations.

4.1.1.2. Entrainment

Increased diversions due to operation of the Project could increase risk of entrainment of juvenile winter-run Chinook Salmon and spring-run Chinook Salmon into pumping stations and conveyance facilities.

The ITP Application (Sites Authority 2023) assessed the risk of juvenile CHNWR and CHNSR entrainment through the RBPP and HCPS fish screens and concluded that the risk of entrainment is low. CDFW concurs, based on the additional analysis below.

Red Bluff and Hamilton City Fish Screens

Positive barrier fish screens are installed at both the Red Bluff and Hamilton City diversions. Completed in 2012, the RBFS is constructed of stainless-steel profile wire with a gap size of 1.75 mm (USBR 2018). This design is state-of-the-art and prevents entrainment of fish larger than 22 mm TL (Turnpenny 1981; Young et al. 1997; Gowan and Garman 2002).

The HCFS consists of two sections, a 470-foot section completed in 1993 and a newer, 630-foot section completed in 2002. The former is made of flat-plate stainless steel with a slot size of 2.38 mm, while the latter, also flat-plate stainless steel, has the more modern slot size of 1.75 mm. The older section of HCFS is protective of fish larger than 30 mm TL, while the latter is protective of fish larger than 22 mm TL (Turnpenny, 1981; Young et al., 1997; Gowan and Garman 2002).

Risk of Entrainment of Juvenile Winter-run and Spring-run Chinook Salmon

Fewer than 0.05% of juvenile CHNWR and approximately 0.1% of CHNSR caught in USFWS RSTs at Red Bluff are <30 mm FL (Figure 4-45). Young et al. (1997) and Gowan and Garman (2002) reported fish measurements in TL while USFWS reports measurements in FL; a 30 mm FL fish will be slightly longer in TL. Thus, the risk of taking CHNWR and CHNSR due to entrainment through RBFS is minimal.

Hamilton City RSTs FL data are limited to the minimum and maximum FL of all salmonids caught on a given day; therefore, species-specific size distributions cannot be determined. CDFW reconstructed FL ranges by day of brood year for CHNWR by filtering catch days to those on which only length-at-date CHNWR were caught. Summarized in this way, the Hamilton City RST FL data show that CHNWR passing HCFS are likely similar in size to those caught in the Red Bluff RST (Figure 4-45), consistent with a short travel time from Red Bluff to Hamilton City. An approximate estimate of the CHNWR FL distributions in the Hamilton City RST was obtained by taking the midpoint between the minimum FL and the maximum FL on each day and tallying the catch of CHNWR within midpoint size categories aligned with the FL categories delineated in the ITP Application (Sites Authority 2023) CHNWR caught in the Red Bluff RST. Thus, a pie chart analogous to that of Red Bluff can be created for the Hamilton City RST CHNWR. The proportional catch in these midpoint categories should be compared to that of Red Bluff with caution; however, the midpoint distribution obtained is consistent with CHNWR caught in the Hamilton City RST being approximately equal in size to those caught in the Red Bluff RST (Figure 4-45).

Too few known CHNSR measurements exist for a meaningful analysis of CHNSR size distributions at Hamilton City, however CHNSR passing HCFS are likely similar in size to those caught in the Red Bluff RST. CHNSR have a more protracted outmigration period than do CHNWR; during the first seven months of their respective brood years, CHNSR and CHNWR are similar in size;

however, CHNSR caught in April–July are typically somewhat larger than the largest CHNWR caught in the Red Bluff RST (Figure 4-46).

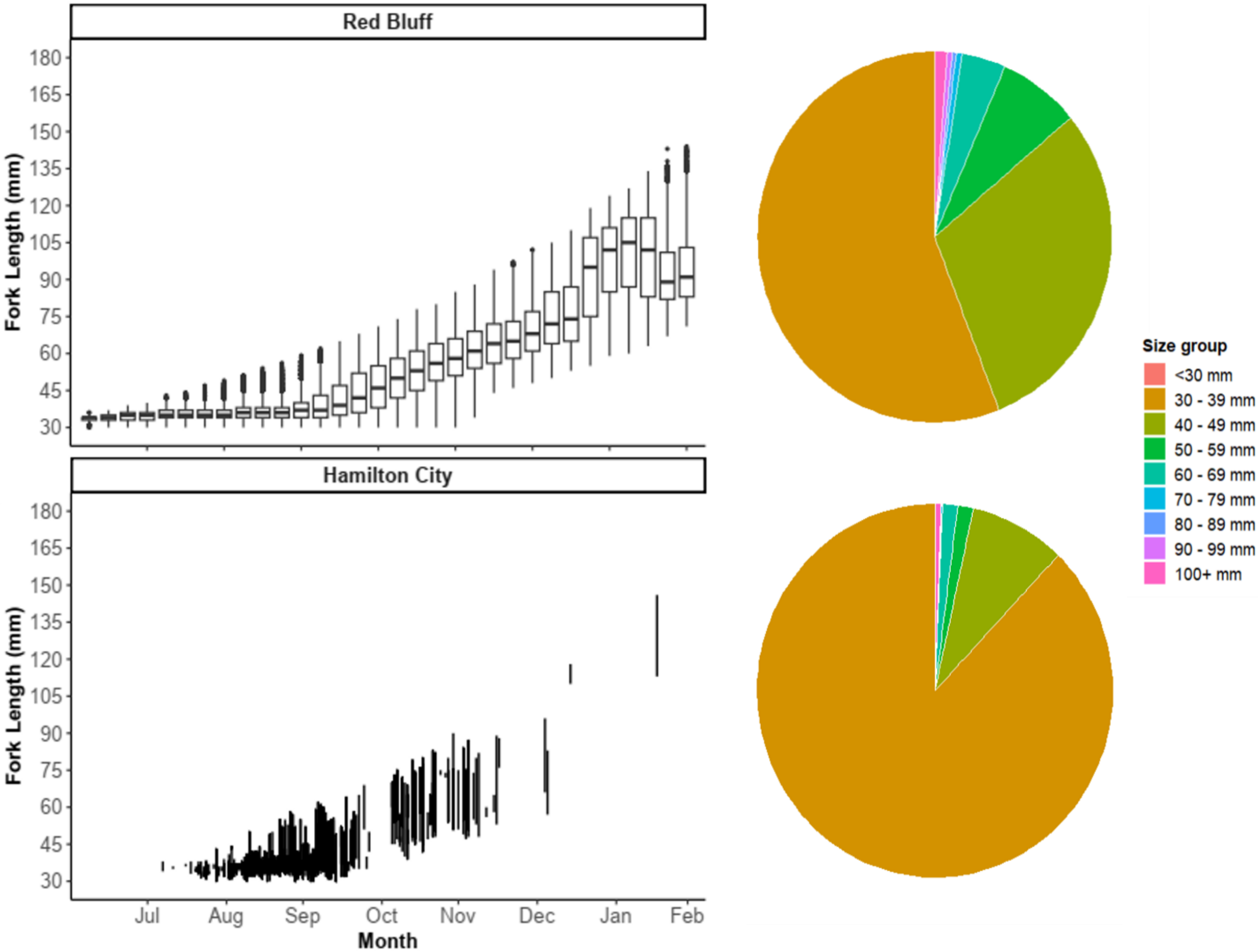

Figure 4-45. Fork lengths (FL) of combined marked and unmarked juvenile winter-run Chinook Salmon (CHNWR) caught in the rotary screw traps (RSTs) during 1994–2023 at Red Bluff (top) and during 2013 – 2023 at Hamilton City (bottom). Boxplots (top-left) summarize weekly data at Red Bluff. Vertical bars (bottom-left) indicate the daily range (minimum to maximum) of CHNWR fork lengths at Hamilton City. The size distribution of CHNWR caught in the Hamilton City RST (bottom-right) is based on daily fork length midpoints and is an approximation. Red Bluff data from EDI (Poytress 2024); Hamilton City RST data provided by Sites Authority (2023).

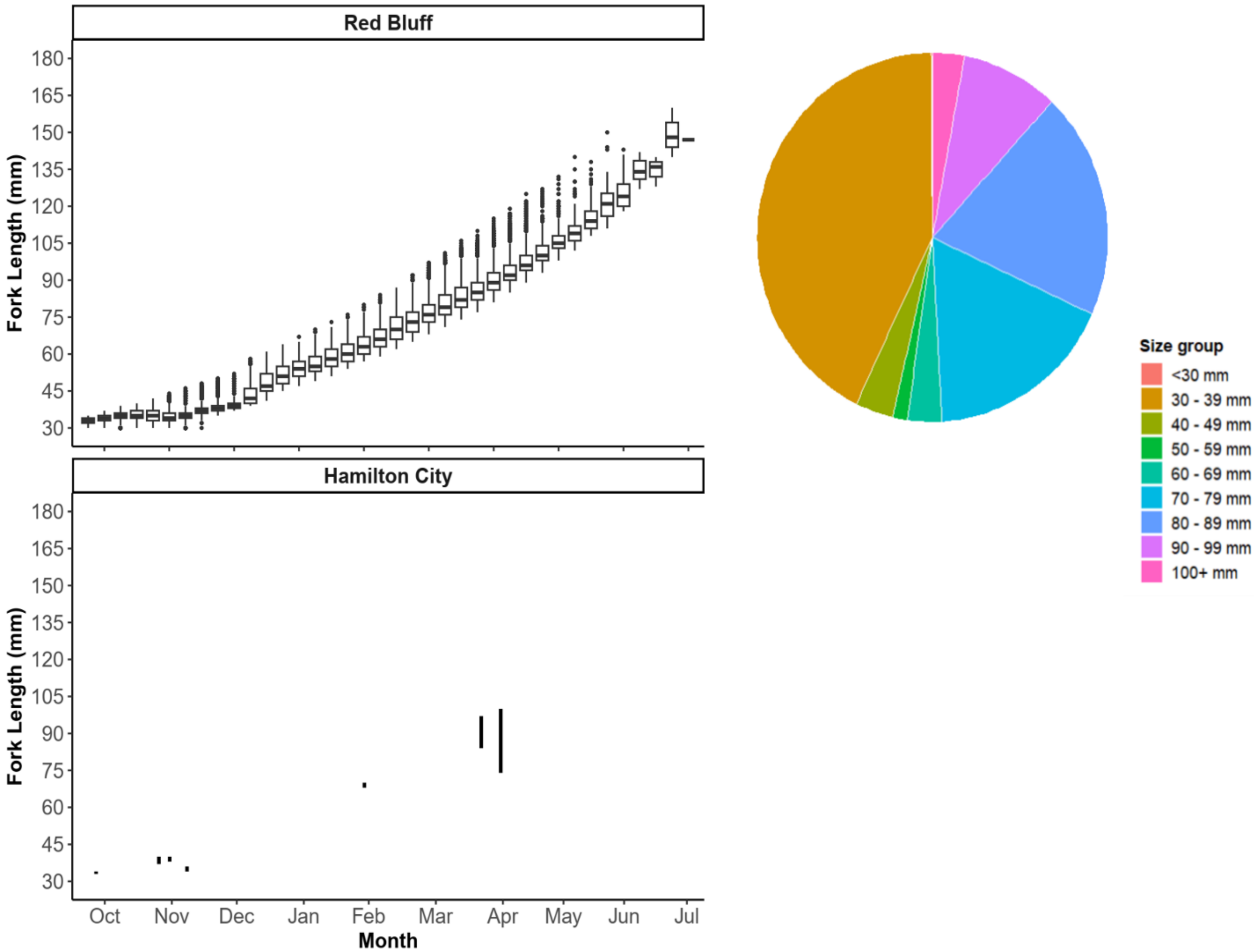

Figure 4-46. Fork lengths of combined marked and unmarked juvenile spring-run Chinook Salmon (CHNSR) caught in the rotary screw traps (RSTs) during 1994 – 2023 at Red Bluff (top) and during 2013 – 2023 at Hamilton City (bottom). Boxplots (top-left) summarize weekly data at Red Bluff. Vertical bars (bottom-left) indicate the daily range (minimum to maximum) of CHNSR fork lengths at Hamilton City. Too few known CHNSR length data were available to create a pie chart for the Hamilton City RST. Red Bluff data from EDI (Poytress 2024); Hamilton City RST data provided by Sites Authority (2023).

Conclusions

Entrainment is unlikely to be a significant source of take of juvenile CHNWR or CHNSR at the RBFS and HCFS. A negligible fraction of CHNWR and CHNSR are small enough to pass through the screens when passing Red Bluff and Hamilton City.

4.1.1.3. Impingement

Operations of the Project will increase diversion rates at the Red Bluff Pumping Plant and the Hamilton City Pump Station, which could increase the risk of impingement of juvenile *winter-run Chinook Salmon* and *spring-run Chinook Salmon* if diversions occur when they are present. Impingement on and physical contact with fish screens could cause take of juvenile *winter-run Chinook Salmon* and *spring-run Chinook Salmon* in the form of injury or death.

The ITP Application (Sites Authority 2023) analyzed impingement risk using a statistical model by Swanson et al. (2004). However, the experiments by Swanson et al. (2004) were conducted in an annular, laboratory "treadmill" facility, which poorly represents the 1,100-foot-long, linear fish screens at RBPP and HCPS. Given the small sample size of the Swanson et al. (2004) experiments, predictions made by their model come with high uncertainty. Furthermore, the screen exposure times of juvenile Chinook under the laboratory conditions may have been much shorter than those experienced by CHNWR and CHNSR passing the RBPP and HCPS fish screens. CDFW analyzed current RBPP and HCPS fish screen hydraulic testing data and evaluated necessary measures to ensure operational compliance below.

Although the number of juvenile CHNWR and CHNSR small enough to be entrained while passing the RBFS and HCFS during outmigration is negligible (Section 4.1.1.2; Sites Authority 2023), there is a risk of take due to impingement upon and injury due to contact with RBFS and HCFS. Fish <40 mm TL are particularly vulnerable to impingement (NMFS 1998), and the majority of outmigrating CHNWR and nearly half of CHNSR are <40 mm FL when they pass RBFS and HCFS (see section 4.1.1.2).

The risk of impingement and injury due to screen contact are highest when the approach velocity (V_a; water velocity toward the screen face) is high, relative to the sweeping velocity (V_s water velocity parallel to the screen face), and/or passage time along the screen is very long, causing fish to tire. Juvenile salmonids are protected from impingement on positive-barrier fish screens when V_s is at least $2V_a$, and when V_a is less than 0.33 fps (CDFG 2000; NMFS 1997; NMFS 2022b). While hydraulic models of sweeping velocity depend on multiple factors (river flow, channel morphology, etc.), theoretical approach velocity can be calculated as:

Equation 5.

$$V_a = Q_d / A_s$$

where Q_d is the diversion rate in cfs and A_s is the effective wetted area of the fish screen face in square feet. This relationship is theoretical because screen fouling and stochastic hydraulic processes may cause the realized relationship to vary over time and by location on the screen face (e.g., NMFS 2006 and USBR 2018). Screen fouling (i.e., the accumulation materials such as debris or algae on the fish screen) can cause V_a "hotspots", where the risk of impingement is high (NMFS 1998). For this reason, both RBFS and HCFS have automated screen sweeping systems that are triggered when screen fouling causes the head loss (i.e., the difference between water elevation on either side of the fish screen) across the screen to exceed 6 inches (USBR 2010). Hydraulic testing of fish screens is necessary to validate theoretical performance calculations.

RBFS and HCFS are designed to prevent V_a from exceeding 0.33 fps under ideal circumstances (Table 4-3). The maximum allowable Q_d at each screen is directly proportional to A_s, which varies with the water surface elevation (WSE) at the screen face. RBFS is located on the western bank of the mainstem Sacramento River just upstream of RBDD, which partly controls the WSE at the screen; HCFS is located on an Oxbow channel and the WSE at the screen is partly controlled by an adjustable flow control weir in the channel downstream of the screen, which is also designed to maintain V_s ≥2 fps (USBR 2010).

Table 4-3. Red Bluff and Hamilton City maximum effective fish screen dimensions (approximate). [a]Old; [b]New; [c]Total. [1]USBR (2018); [2]USBR (2010).

Location	Max. Q_d (cfs)	Screen invert elev. (ft)	Screen top elev. (ft)	Effective Screen length (ft)	Effective Screen Height (ft)	Total Screen Length (ft)	Max. A_s (ft^2)	Slot Size (mm)
Red Bluff[1]	2,500	235.82	245.65	895.2	9.83	1,100[c]	8,800[c]	1.75
Hamilton City[2]	3,000	127.3[a]; 126.5[b]	139.2[a]; 138.4[b]	400[a]; 563[b]	12.7[a]; 11.2[b]	1,100[c]	11,395[c]	2.83[a]; 1.75[b]

The maximum Q_d of the Red Bluff pumping plant is 2,500 cfs, which is allowable given a WSE of ≥244.23 ft and a corresponding A_s of ≥7,573.4 square ft, assuming the screen operates optimally (USBR 2018). The maximum Q_d of the Hamilton City Pump Station is 3,000 cfs, which is allowable given a WSE of ≥136.5 ft and a corresponding A_s of ≥9,185 square ft, assuming optimal screen operation (USBR 2010). The flow control weir downstream of HCFS is designed to maintain the WSE at the screen at or above this level. When WSE at Red Bluff and Hamilton City drop below these respective minima, the pumping facilities must set lower respective Q_d limits to maintain protective V_a (Figure 4-47).

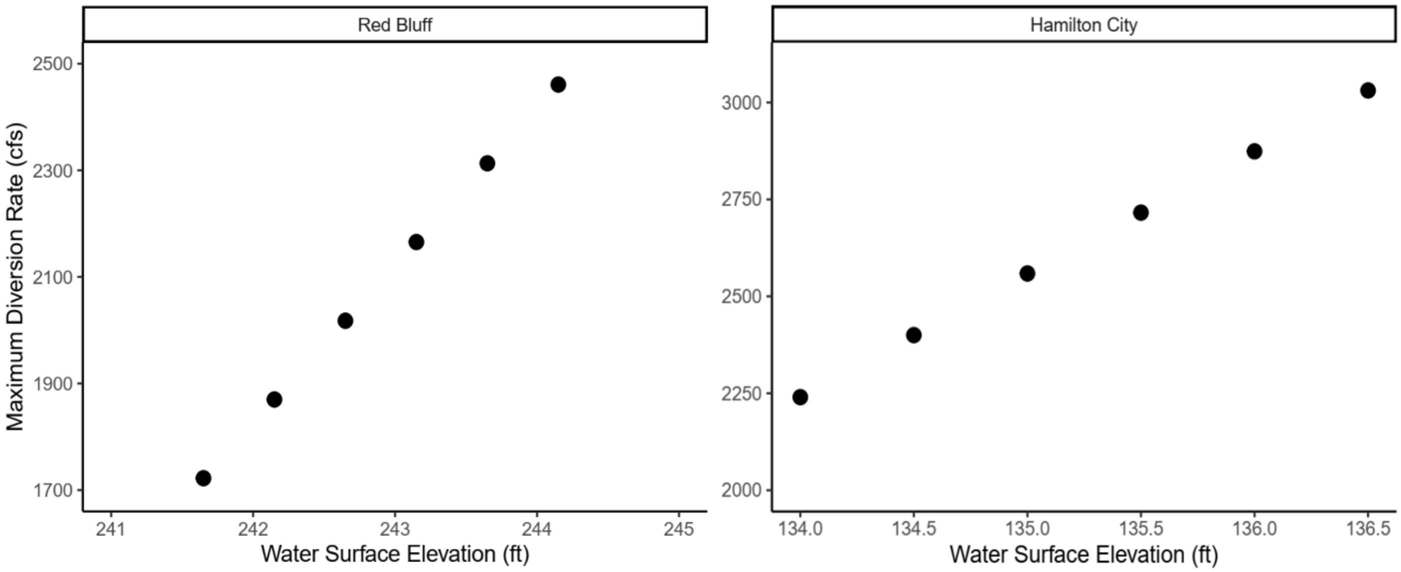

Figure 4-47. Designed maximum allowable diversion rate at Red Bluff (left) and Hamilton City (right) to maintain an approach velocity of 0.33 fps across a range of water surface elevations. Maximum diversion rates are calculated from net screen area, which varies with WSE at the screen face. Note that x and y axis scales differ between panels.

Approach Velocity and Sweeping Velocity: Hydraulic Testing

Hydraulic testing of RBFS was conducted by the U.S. Bureau of Reclamation (USBR 2018), and testing of HCFS was conducted by NMFS in 2006 (NMFS 2006) and CH2M Hill in 2007 (CH2M Hill 2008) to determine whether the screens met state and federal fish screening criteria (i.e., approach velocity of ≤0.33 fps and $V_s \geq 2V_a$).

Red Bluff

Post-construction, preliminary hydraulic testing of RBFS in 2013 showed significant heterogeneity of V_a among the screen sections tested (Sections 2, 3 and 4): V_a of sections 3 and 4 exceeded the NMFS and CDFW criterion of 0.33 fps (USBR, 2018). One goal of the 2017 hydraulic testing of RBFS was to determine whether adjusting the tuning baffles located behind the screen effectively reduced V_a and increased uniformity of V_a across the screen face. Each screen panel is equipped with ten tuning baffles, which can be rotated from fully open to fully closed to adjust V_a at that panel. Per recommendations following the 2013 preliminary testing, TCCA adjusted the baffles on all screen sections for testing conducted in June and August 2017 (USBR, 2018).

USBR (2018) measured V_s and V_a on June 20–21, 2017 on a grid of 254 locations across sections 2, 3 and 4 of RBFS, from approximately 1 ft above the invert to an elevation of 244 ft, just below the surface; this procedure was repeated on August 9–10, 2017 at 225 grid locations. Section 1 of

RBFS was still under construction, reducing the screen's effective area by 25%. River conditions and diversion parameters for each hydraulic testing session are given in Table 4-4 (USBR 2018). Operating at 75% efficiency and given these conditions, RBFS is designed to allow a maximum diversion rate of approximately 1,875 cfs.

Table 4-4. Sacramento River conditions and Red Bluff pumping plant diversion parameters during 2017 hydraulic testing at the Red Bluff fish screen. Data from Tables 3 and 5 of USBR (2018).

Parameter	June 20	June 21	August 9	August 10
Sacramento River flow, cfs	12,400	12,300	11,000	11,280
Red Bluff pumping plant flow, cfs	1,795	1,895	1,779	1,754
Sacramento River stage, ft	244.36	244.35	243.96	244.15
Red Bluff pumping plant forebay el., ft	244.17	244.13	243.78	243.90
Head loss across fish screen, ft	0.19	0.22	0.18	0.25

For the June 20–21, 2017 hydraulic tests, TCCA adjusted the baffles in screen sections 2, 3, and 4 to 5.0, 7.5, and 7.5% porosity, respectively. Velocity measurements showed a downstream gradient in V_a across sections 2–4. V_a in section 2 was mostly below 0.33 fps ($\overline{V}_a = 0.26$ fps), while V_a in sections 3 and 4 exceeded 0.33 fps in several locations (Figures 4-48 and 4-49). The highest V_a in section 2, six measurements (out of 90) of 0.35–0.38 fps, were observed at the surface; V_a was relatively uniform (0.32–0.38 fps; $\overline{V}_a = 0.36$ fps) in section 3 and was relatively heterogeneous in section 4, ranging from 0.23 fps to 0.5 fps ($\overline{V}_a = 0.40$ fps). V_s ranged from 1.0 fps at extreme lower, downstream corner of section 4 to 3.0 fps at several locations across the screen; V_s was $>2V_a$ in all locations (Figure 4-49). Data from the June 20–21, 2017 hydraulic tests were not provided by USBR (2018) in tabular form and were approximated from graph contour levels in the PDF images of USBR (2018), Figures 12 and 13.

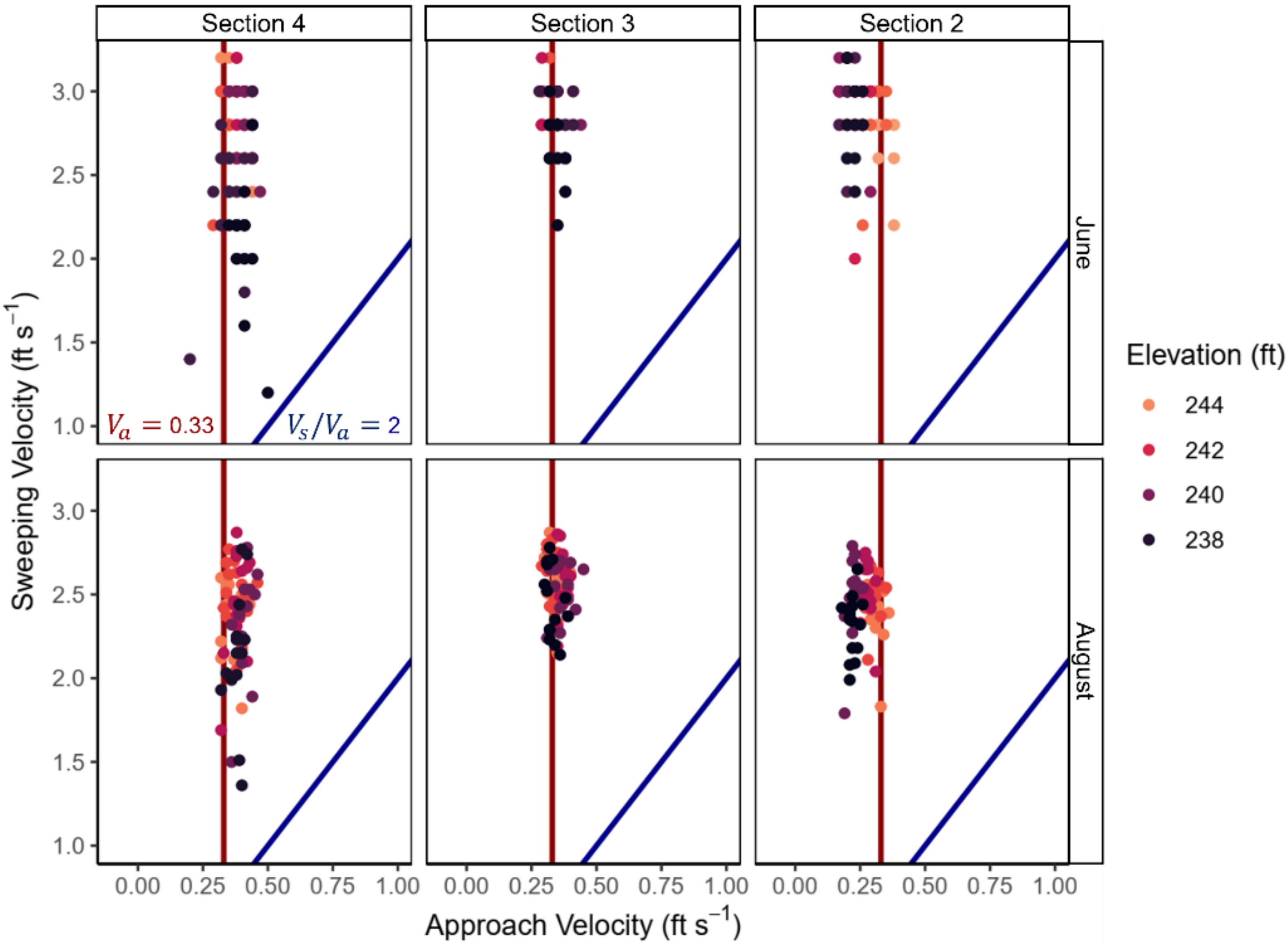

Figure 4-48. Sweeping velocity (V_s) versus approach velocity (V_a) measured using acoustic doppler velocimetry across sections 4, 3 and 2 (left – right, respectively) of the Red Bluff fish screen during June 20 – 21 (top) and August 9 – 10 (bottom), 2017. Point colors indicate measurement elevations (ft). Dark red, vertical lines show the maximum approach velocity criterion of 0.33 fps; dark blue, diagonal line shows where V_s / V_a $= 2$. Sections are in reverse order to indicate the direction of flow (right to left). Data from USBR (2018). June data are approximate, as they were scraped from PDF images.

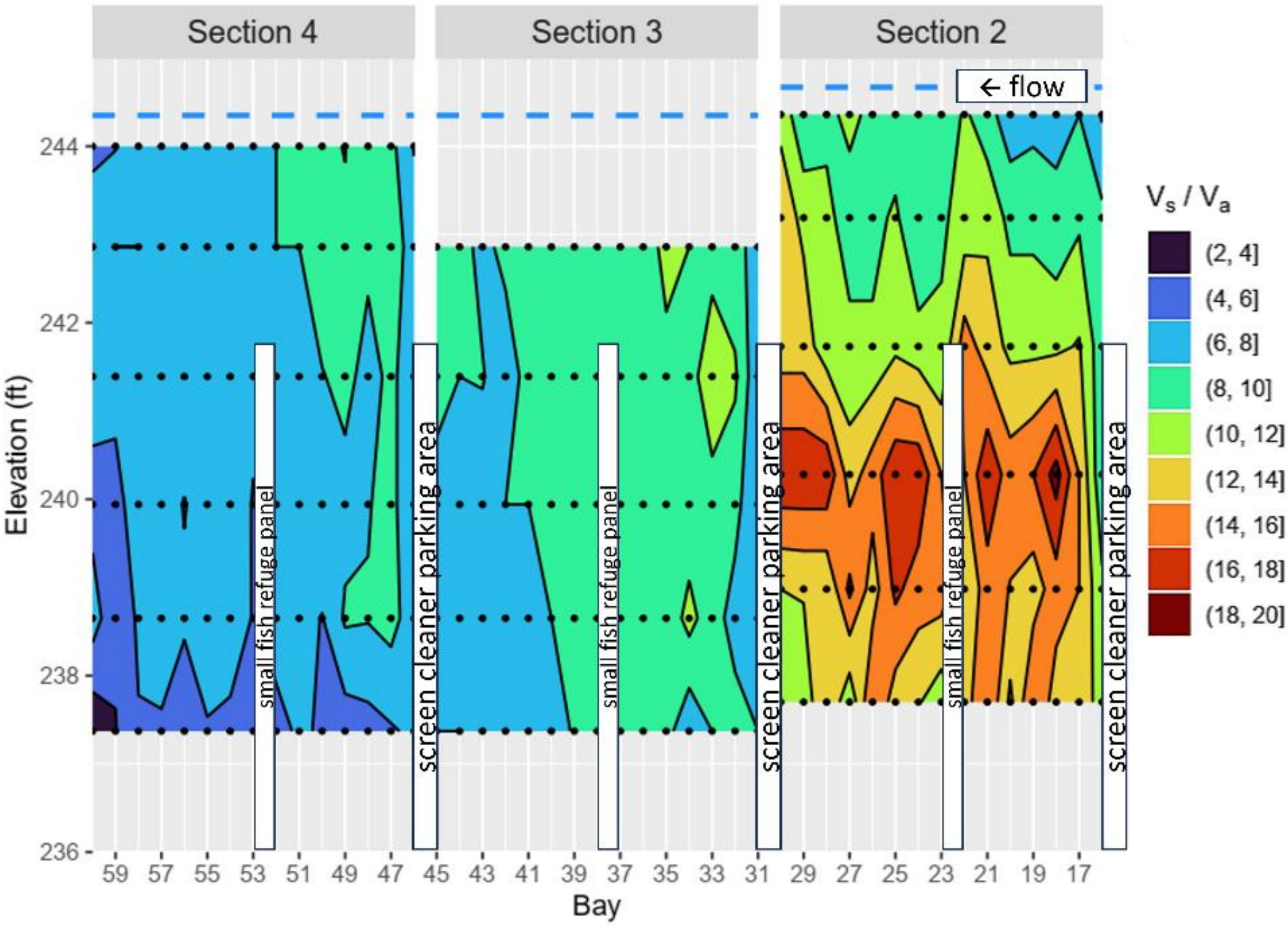

Figure 4-49. V_s/V_a across Red Bluff fish screen sections 2, 3, and 4 on June 20 – 21, 2017. Black dots indicate locations where acoustic doppler velocimeter measurements were taken. Blue, dashed line indicates the water surface elevation. Data from USBR (2018), Figures 12 and 13. Velocity data are approximate, as data were scraped from PDF images.

For the August 9–10, 2017 hydraulic tests, TCCA adjusted the baffles on screen sections 2, 3 and 4 to 5.0, 6.5 and 6.0 percent porosity, respectively. Similar to the June results, a downstream gradient in V_a was observed (Figures 4-49 and 4-50). August V_a in sections 2 and 3 was similar to that observed in June ($\overline{V}_a$ = 0.27 and $\overline{V}_a$ = 0.35 fps, respectively), while V_a in section 4 was less variable (0.32 – 0.46 fps) and somewhat lower in August than in June ($\overline{V}_a$ = 0.38). Due to somewhat lower Sacramento River flows in August than in June (Table 4-4), V_s was also somewhat lower across all three screen sections, however V_s remained uniformly >$2V_a$ (Figure 4-50).

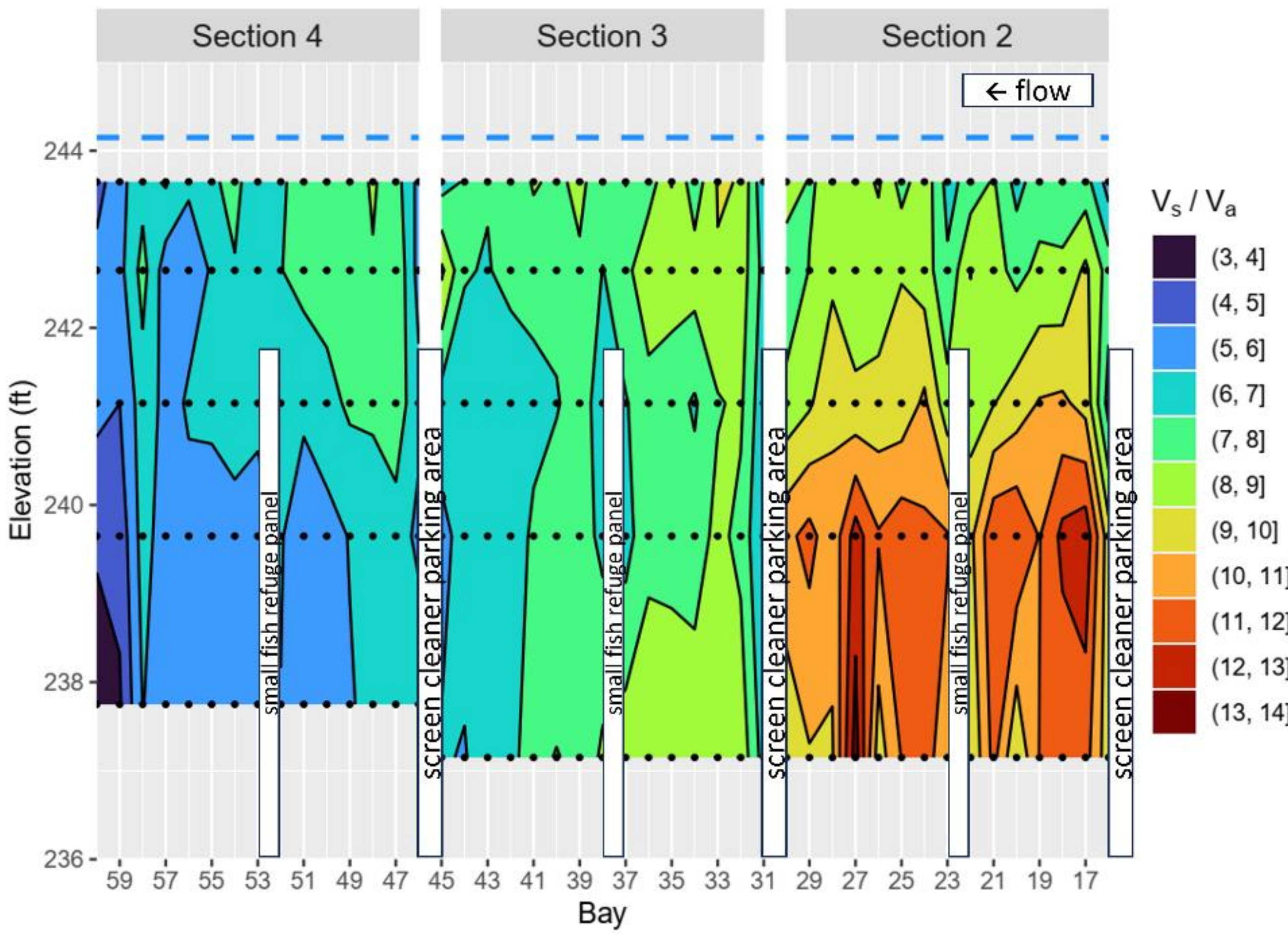

Figure 4-50. V_s/V_a across Red Bluff fish screen sections 2, 3, and 4 on August 9 – 10, 2017. Black dots indicate locations where acoustic doppler velocimeter measurements were taken. Blue, dashed line indicates the water surface elevation. Data from USBR (2018), Appendix A2.

USBR (2018) showed that adjusting the screen baffles can reduce V_a and increase its uniformity across the screen, however V_a at several locations in sections 3 and 4 remained at or above 0.33 fps (Figure 4-48). It should be noted that, with the exception of the June 21 test, the diversion rate was approximately 100 cfs lower than the designed maximum of 1,875 cfs (Table 4-4). Further refinements of baffle adjustments in those sections may decrease V_a magnitude and increase its uniformity. NMFS (2018) suggested that further hydraulic testing would be required once the RBFS reached its built-out capacity of 2,500 cfs, which it now has (see also USBR 2018). To ensure that juvenile salmonids are protected from impingement on RBFS, hydraulic tests of all four screen sections should be conducted under a wider range of Sacramento River flow conditions and diversion conditions than were tested in 2017.

Hamilton City, 2006

NMFS (2006) conducted hydraulic testing of 82 panels of HCFS in July 11 (panels 1 – 23) and 12 (panels 24 – 85), 2006 (note that "panels", of which HCFS has 85, should not be confused with "sections", of which RBFS has 4, each containing 15 panels). Panels 31, 32, 41, 52 and 53 could not be measured, as the measurement equipment could not be mounted. Sacramento River flow ranged from 11,000 cfs to 11,500 cfs and the diversion rate was 2,600 cfs during all testing. Given the diversion rate, NMFS (2006) estimated that the theoretical V_a should have been roughly 0.22 fps. A single, 1.5-minute measurement of V_a and V_s was made at the center of each panel. Panels 41 – 64 were not cleaned prior to testing due to technical difficulties. Additional testing was performed on panel 66 to characterize vertical variation in V_a and V_s. Measurements were made at three depths, two feet from the invert, at the vertical center, and two feet from the top of the panel, and at three horizontal locations, the upstream edge, the horizontal center, and the downstream edge, for a total of nine measurements.

Ten of the panel-center measurements indicated $V_a > 0.33$ fps (Figure 4-51). V_a was most variable across panels 1–20, but was uniformly less than 0.33 fps across panels 20–85, except for panels 51 and 85. V_s increased from approximately 2 fps at the upstream end (panel 85) to approximately 4 fps on the downstream end (panel 1). V_s was greater than $6V_a$ across all panels except panel 51, where V_s was marginally lower than $2V_a$ (Figure 4-51).

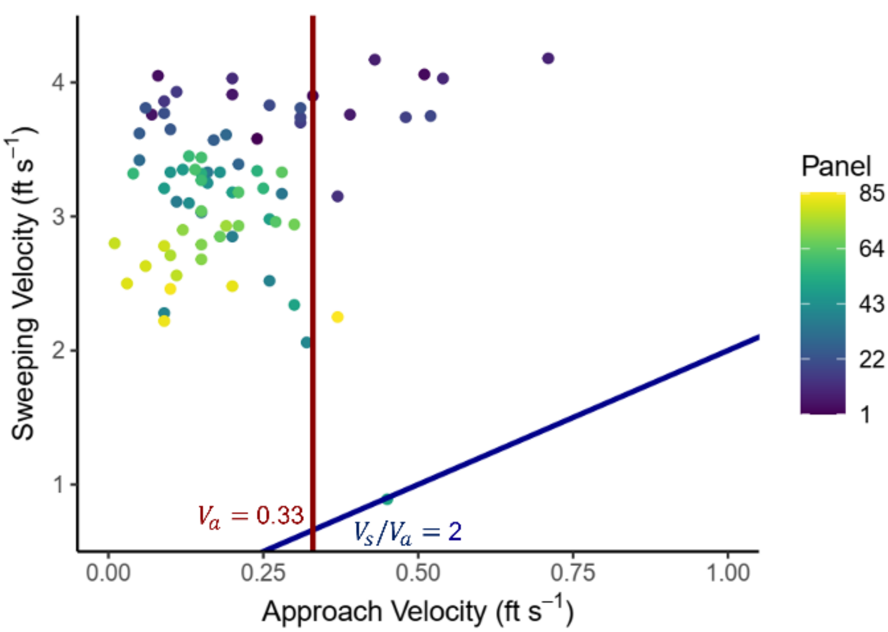

Figure 4-51. Sweeping velocity (V_s) versus approach velocity (V_a) measured using acoustic doppler velocimetry at the middles of panels 1 – 85 (minus panels 31, 32, 41, 52 and 53) of the Hamilton City fish screen on 11 and 12 July, 2006. Point colors indicate fish screen panels. Dark red, vertical lines show the maximum approach velocity criterion of 0.33 fps; dark blue, diagonal line shows where $V_s / V_a = 2$. The lowest two points right of the red line are from panels 51 (blue) and 85 (yellow). Data from NMFS (2006).

V_a and V_s measurements at three depths on panel 66 revealed considerable variation in both parameters across depth, though less variation in the horizontal dimension. V_a increased from top to bottom and exceeded 0.33 fps in all bottom measurements. V_s was slightly lower in bottom measurements than in center or top measurements. V_a/V_s did not exceed 0.5 at any point on panel 66. See Table 4-5 for all measurements and ratios.

Table 4-5. Approach velocity, V_a (top), sweeping velocity V_s (middle) and V_a/V_s (bottom) measurements on Hamilton City Fish Screen panel 66. Top and middle table sections reproduced from NMFS (2006).

Velocity	Downstream	Middle	Upstream	Average
V_a - average	**0.25**	**0.27**	**0.29**	**0.27**
V_a - top	0.16	0.12	0.15	0.14
V_a - middle	0.19	0.35	0.27	0.27
V_a - bottom	0.39	0.35	0.45	0.40
V_s - average	**2.94**	**2.99**	**2.81**	**2.91**
V_s - top	3.12	3.10	2.90	3.04
V_s - middle	3.09	3.15	3.02	3.09
V_s - bottom	2.62	2.71	2.50	2.61
V_a/ V_s - average	**0.09**	**0.09**	**0.11**	**0.10**
V_a/ V_s - top	0.05	0.04	0.05	0.05
V_a/ V_s - middle	0.06	0.11	0.09	0.09
V_a/ V_s - bottom	0.15	0.13	0.18	0.15

NMFS (2006) showed that while the vertical and horizontal center of most panels of HCFS may generally perform within CDFW (2000) fish screen approach and sweeping velocity parameters at a high diversion rate, there is significant spatial variation in V_a across the screen in both the vertical and horizontal dimensions. In particular, V_a may exceed 0.33 fps on the downstream end of the screen (panels 1 – 20) and near the invert of the screen. NMFS (2006) observed large amounts of sediment behind the downstream panels, which may have contributed to the large variations in V_a at those panels. NMFS (2006) recommends regular dredging of sediment behind all screen panels.

NMFS (2006) also identified considerable temporal variation in point measurements as a major concern. Three measurements made on July 10, 11 and 12, at the center of panel 66, under nearly identical flow and diversion conditions, yielded V_a of 0.30, 0.18 and 0.35 fps, respectively. NMFS (2006) recommends taking longer measurements and analyzing variation over 15-minute recording periods and repeating each point measurement three times over a single day. While this approach would present logistical challenges if applied to the entire screen, some sub-sampling of the screen may be possible for the purpose of characterizing temporal variation. Finally, NMFS (2006) recommends that future hydraulic testing of Hamilton City Pump Station be conducted at three depths (as on panel 66), at a diversion rate in excess of 2,200 cfs, and with moderate or low river flow.

Hamilton City, 2007

CH2M Hill (2008) conducted hydraulic testing of three panels of HCFS in 2007. Hydraulic testing of HCFS was conducted in November and December, 2007. The diversion rate during testing was 750 cfs (low) and Sacramento River flow upstream of the Oxbow inlet was approximately 4,500 cfs (also low). The WSE along the screen was 138.45 ft and the wetted surface area of the screen was 10,886 ft^2. Based on the design specifications of the screen, the expected $\overline{V}_a$ was 0.07 fps. V_a and V_s were measured at three depths on screen panels 17, 54, and 78 using an acoustic doppler velocimeter. The measurement depths were two feet from the top of the screen, at the vertical center of the screen and two feet from the bottom of the screen. Measurements were taken every 10 seconds, for 15-minute intervals. Panel 17 is part of the old fish screen, while panels 54 and 78 are both part of the upgraded structure.

87% of V_a measurements on panels 17, 54, and 78 of HCFS were below the CDFG (2000) maximum V_a criterion of 0.33 fps (Figure 4-52). However, V_a met or exceeded 0.33 fps on all three panels and in all three locations (top, center and bottom) in 13% of measurements. The bottom of panel 17 most frequently exceeded 0.33 fps, with 51.7% of bottom measurements exceeding the criterion. There was little systematic variation in V_a by location on panel 54, and panel 78 performed best, with only 4.1% of measurements exceeding 0.33 fps, all in the center location. 98.9% of V_s measurements were $>2V_a$, with $V_s < 2V_a$ in a small number of bottom (panel 54) and center measurements (panels 54 and 78) (Figure 4-52).

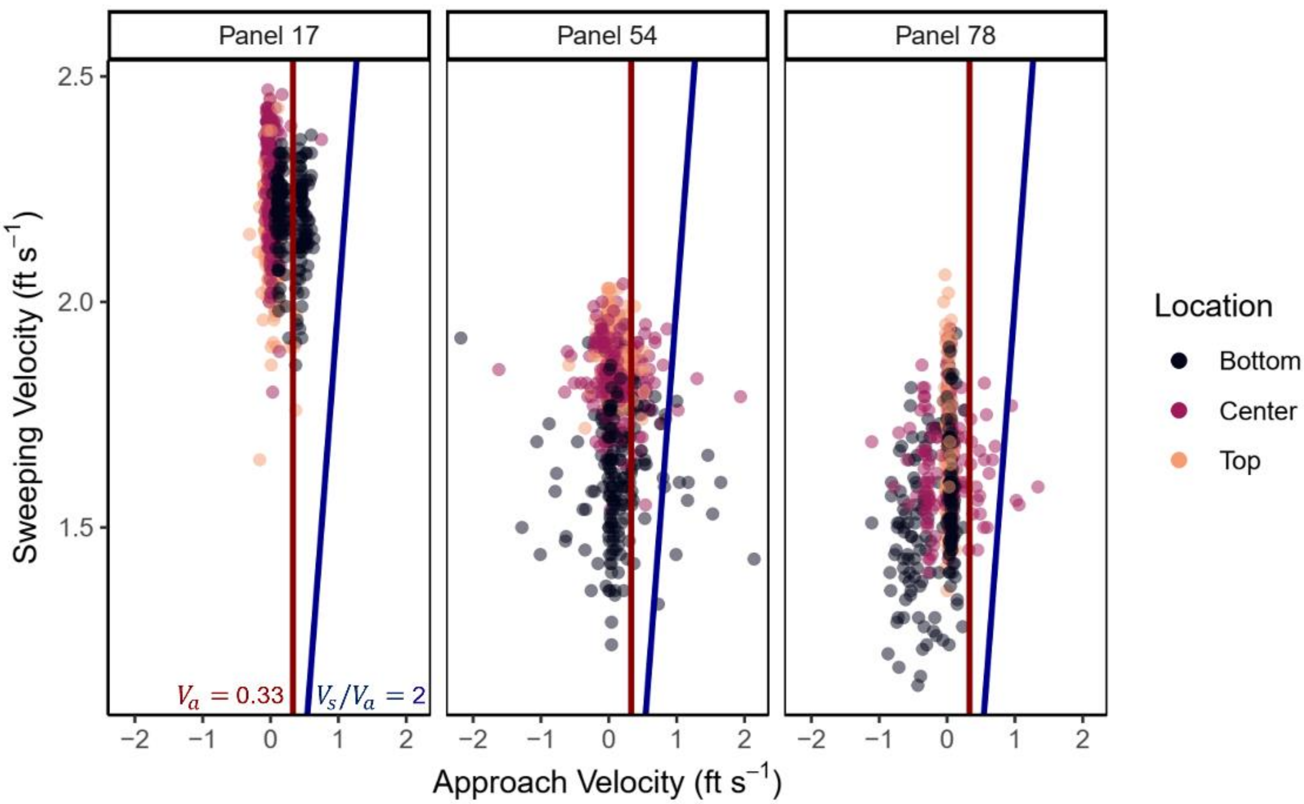

Figure 4-52. Sweeping velocity (V_s) versus approach velocity (V_a) measured using acoustic doppler velocimetry across panels 17, 54 and 78 (left – right, respectively) of the Hamilton City fish screen during November and December, 2007. Point colors indicate measurement locations. Dark red, vertical lines show the maximum approach velocity criterion of 0.33 fps; dark blue, diagonal line shows where $V_s / V_a = 2$. Panel 78 is upstream of Panels 54 and 17, and Panel 17 is furthest downstream. Data from CH2M Hill (2008).

While V_a sometimes exceeded the 0.33 fps criterion during testing, it is possible that much of the variation in V_a observed was due, perhaps counterintuitively, to the low diversion rate. Variation in V_a can be expected to increase as flow across the screen becomes less uniform and less strongly deterministic, i.e., when the diversion rate (and thus the net flow through the screen) is very low. At higher diversion rates, V_a would likely be more uniform and would more closely approximate the theoretical V_a. GCID staff have reported negative flows across lower portions of panels 1 – 10 at very low diversion rates during the irrigation season (CH2M Hill 2008). Variation in flow would also likely cause V_a to exceed 0.33 fps or to cause V_s to be <$2V_a$ less often at higher Sacramento River flows, as the wetted area of the screen would be greater, as would the flow through the Hamilton City Oxbow.

As shown by the hydraulic testing of the RBFS, it may be possible to reduce variation in V_a across the HCFS by adjusting the flow-control baffles behind each panel. The Hamilton City baffles were adjusted for hydraulic testing in 2005, however no additional adjustments were made for the 2007 testing (CH2M Hill 2008).

The 2007 hydraulic testing of the HCFS demonstrated that additional testing across depth is needed. The screen has 85 panels, however only three were tested at multiple depths in 2007. The variation in V_a and V_s within each of the three panels, as well as the variation observed across depth on panel 66 by NMFS (2006) and the variation across 75% of the RBFS observed by USBR (2018), suggest that testing a small subset of panels is insufficient to fully characterize the hydraulic landscape of the whole screen. Testing should be conducted to identify baffle adjustment configurations that increase uniformity and minimize V_a hotspots on the screen. Finally, testing at the low diversion rate of 750 cfs and the low Sacramento River flow of 4,500 cfs cannot adequately characterize screen performance. The HCFS must be hydraulically tested at the highest possible diversion rate (up to 3,000 cfs) across a wide array of Sacramento River flow conditions.

Screen Length and Fish Refuge and Fish Screen Bypass Structures

Resisting diversion flows is energetically costly to fish passing positive-barrier fish screens, and the risk of impingement or injury due to screen contact increases with duration of screen exposure (Swanson et al., 2004). Screen exposure time increases with the length of the screen and decreases with V_s. Notably, the $V_a \leq 0.33$ fps and $V_s \geq 2V_a$ criteria assume a screen exposure time of ≤15 min (CDFG 2000). As of 2016, RBFS and HCFS are the largest flat plate fish screens on Earth (Bettner 2016), each 1,100 ft long, which may present outmigrating juvenile salmonids with exposure times much greater than 15 min and thus an exceptional risk of exhaustion and subsequent impingement or contact injury (Swanson et al., 2004). For this reason, each screen is equipped with enhancements designed to reduce the time fish are exposed to the screens while traveling downstream. On RBFS seven blocking panels, placed at 105-foot intervals, create low-flow fish refuge areas, where small fish may find respite from diversion flows (Figures 4-49 and 4-50; Sutton et al. 2013; USBR 2018). On HCFS, three bypass pipelines, placed at <300 ft intervals, are designed to offer fish an “offramp” by which they may escape screen exposure, routing fish behind the screen and depositing them in the Oxbow channel a short distance downstream (Vogel 2008; USBR 2010); however, these bypasses are not currently in operation due to heightened predation risk to fish exiting the bypass (Vogel 2007; Vogel 2008; see also Section 4.1.1.4 “Predation” below). The effectiveness of the fish refuge panels on RBFS in reducing the exposure time of juvenile salmonids to the screens is uncertain. CDFW is unaware of any tests of the refuge panels on RBFS.

Swanson et al. (2004) conducted factorial experiments at the UC Davis fish treadmill facility to determine passage time along and contact rate between juvenile Chinook Salmon (44 mm – 79 mm standard length (SL)) and a simulated fish screen under a range of flow, temperature and light conditions. Experiments lasted 2 hours. Screen passage time and the number of contacts between experimental fish and the simulated screen varied with fish size (SL), sweeping velocity (0, 1.0 and 2.0 fps), distance from the screen, temperature (12 °C or 19 °C) and light condition (day or night). Notably, there was no effect of approach velocity on either passage time or contact rate, and serious injury and mortality during experiments were negligible. The ITP Application (Sites Authority 2023) applied Swanson et al. (2004)'s fitted models to predict daytime and nighttime screen passage times along an 1,100-ft fish screen for fish of 44 mm and 79 mm SL at sweeping velocities (V_s) ranging from 0.67 to 3.2 fps, assuming a temperature of 12 °C and a distance to screen of 1.0 ft. Estimated daytime passage times of a 44-mm SL fish ranged from 10 min at $V_s =$ 3.2 fps to 67 min at $V_s = 0.67$ fps, while daytime passage times for a 79-mm SL fish ranged from 12.6 min at $V_s = 3.2$ fps to 160 min at $V_s = 0.67$ fps. Nighttime passage times were well within these ranges but were less variable. The uncertainty in these predictions was not reported, however uncertainty should be considered high, given small sample sizes and substantial differences in conformation (annular versus linear) and size (28.9 ft circumference versus 1,100 ft length) between the UC Davis treadmill apparatus and the RBFS and HCFS.

Swanson et al. (2004) and the ITP Application (Sites Authority 2023) demonstrated that passage times along RBFS and HCFS for 44 mm – 79 mm SL fish are likely to be much greater than the CDFW (2000) criterion of 15 minutes. Notably, the ITP Application (Sites Authority 2023) did not account for the fish refuge panels on RBFS, possibly because there is currently little information to indicate whether or not the panels are in regular use or function as intended. Assuming, generously, that the RBFS refuge panels provide a perfect respite for passing juvenile salmonids and that they reduce the effective passage distance to 105 ft (rather than the full 1,100 ft), effective screen passage times along RBFS may rarely exceed 15 min for fish of any size. Because the HCFS internal bypass system is not currently in operation, screen passage times at HCFS are likely to frequently exceed 15 minutes at $V_s < 2.5$ fps (Sites Authority 2023; Figures 4-14 and 4-15), especially at low Sacramento River flows (e.g., 4,500 cfs; Figure 4-52). Finally, most of the juvenile CHNWR and CHNSR passing RBFS and HCFS are <44 mm (see Figures 4-45 and 4-46). While the Swanson et al. (2004) equations suggest that smaller fish have shorter passage times at low V_s, juvenile salmonids <44 mm may be less able to resist high V_a than those used in the Swanson et al. (2004) experiments.

Conclusions

Extensive hydraulic testing of both RBFS and HCFS is necessary to determine whether both screens can be configured and operated to maintain $V_a \leq 0.33$ fps and $V_a \leq 0.5V_s$. Some hydraulic testing has been performed at both RBFS and HCFS and has demonstrated that approach and sweeping velocities at both screens may depart from the standards set forth by CDFG (2000) (e.g., NMFS 2006; CH2M Hill 2008; USBR 2018) under some conditions and in some locations on the screens. The hydraulic testing conducted by USBR (2018) was comprehensive and is a model for future hydraulic testing of both fish screens. USBR (2018) also demonstrated that adjusting the tuning baffles behind the panels of RBFS could reduce V_a "hotspots" and improve overall V_a uniformity across the screen.

4.1.1.4. Predation

High predation rates of juvenile salmonids is a known hazard of positive-barrier fish screens. Increased diversions due to Project operations could increase predation of juvenile winter-run Chinook Salmon and spring-run Chinook Salmon near the diversion facilities by drawing more fish toward the screens, locally increasing their density and reducing their ability to escape predators.

The ITP Application (Sites Authority 2023) discusses the risk of predation at the RBPP and HCPS fish screens as evaluated by Vogel (2008) and Henderson et al. (2019). While noting great uncertainty in the conclusions made by Vogel (2008), the ITP Application (Sites Authority 2023) concluded that the risk of predation around RBPP and HCPS is low. CDFW expands on the discussion of Vogel et al. (2008) and other studies by D. Vogel below, with additional reference to an acoustic telemetry study by Notch et al. (2020b). CDFW emphasizes the need for further study of the predation risk near the fish screens.

Aggregation of predator fish near positive-barrier fish screens in the Sacramento River system has been widely reported to cause increased predation of juvenile salmonids near the screens (Hall 1979; NMFS 1998; Vogel 2007; Vogel, 2008). Predation may be high near fish screens for several reasons. First, fish screens present novel structures that may provide favorable habitat for predator fish. Second, small fish, including juvenile CHNWR and CHNSR can become concentrated near fish screens as they are drawn toward the screens and a portion of the volume of water containing them is removed. Third, juvenile salmonids, which are weak swimmers, may become exhausted by strong diversion flows. Combined, the latter two effects make juvenile salmonids near fish screens attractive prey for predator fish like Striped Bass and Sacramento Pikeminnow (Hall 1979; NMFS 1998). High predation of juvenile salmonids has been reported at the Hamilton City Pump Station (Vogel 2007; Vogel 2008) and at the Hallwood Cordura fish screen on the Yuba River, where Hall (1979) reported predation losses of fingerling Chinook Salmon as high as 50% in mark-recapture experiments. Project diversions at Red Bluff and Hamilton City may increase the density of juvenile CHNWR and CHNSR near the fish screens by increasing flow toward the screens during times of peak outmigration. If predator fish aggregate at or downstream of the fish screens, the increased density of juvenile salmon near the screens may lead to high predation losses (Cramer et al. 1992; NMFS 1998).

The degree to which predator fish aggregate around the RBFS is unknown. Predator surveys and juvenile salmon survival studies are needed to assess the risk of predation near the RBFS. Predation of juvenile salmon by Sacramento Pikeminnow and Striped Bass immediately downstream of the RBDD was estimated to be as high as 50% prior to the permanent opening of the RBDD gates in 2011 (CH2M Hill 2002), indicating that predators frequent this reach of the river and may aggregate around structures that facilitate their feeding.

Some predator surveys and juvenile salmon survival studies have been conducted in the Hamilton City Oxbow channel (Cramer et al. 1992), including several since completion of the extended GCID HCFS in 2002 (Vogel 2006; Vogel 2007; Vogel 2008; Notch et al. 2020b). Vogel (2006) used acoustic telemetry to estimate predation rates near HCFS; Vogel (2007, 2008) combined predator surveys with a juvenile CHNFR mark-recapture study in the Oxbow to evaluate predation risk near HCFS; Notch et al. (2020b) used acoustic telemetry to estimate survival through the Oxbow, relative to the mainstem Sacramento River. Each of these studies is somewhat informative, but none should be taken as a strong predictor of CHNWR and CHNSR predation risk near HCFS during Project operations (see below).

Hamilton City Oxbow Predator Surveys and Juvenile Chinook Salmon Survival Studies

Cramer et al. (1992) reported densities of Sacramento Pikeminnow 3–7 times higher in the segment of the Oxbow downstream of HCFS than adjacent to the screen. The Hamilton City Pump Station removes 75%–90% of the water in the Oxbow, greatly concentrating juvenile salmonids passing through the Oxbow and funneling them into the much narrower outflow channel downstream of HCFS. This concentration of prey may attract predators, and likely greatly facilitates predation (NMFS 1998).

Vogel (2007, 2008) conducted 237 mark-recapture experiments on experimentally released juvenile CHNFR in the Hamilton City Oxbow between 2002 and 2007. Experiments were conducted in a partially-factorial design that included releases upstream of HCFS (treatment group) and in the outflow channel downstream of HCFS (control group). Covariates were Sacramento River flow condition (high, normal, low), GCID pumping condition (high, normal, low), HCFS bypass channel condition (open and closed) and time of day (day and night). Approximately 81% of tests were conducted under "normal" flow and pumping conditions, though 11% were conducted under low-river, high-pump conditions, which produce the highest fish screen approach velocities and lowest sweeping velocities. A third treatment group was added in 2003, released just below the flow control weir on the downstream end of HCFS, which was also the location of the HCFS bypass channel outfall. Fish were recaptured in fyke nets in the lower outlet channel. Vogel (2006) conducted additional survival experiments using acoustic telemetry in 2005. In 2005, Vogel (2006) conducted underwater videography surveys just below the flow control weir. In 2007, Vogel (2007, 2008) conducted predator surveys around HCFS using a boat-mounted dual-frequency identification sonar (DIDSON) camera.

Vogel (2007, 2008) reported that mean survival of juvenile Chinook Salmon in mark-recapture experiments was similar between fish released upstream of HCFS and those released downstream of HCFS when adjusted for distance traveled. However, several caveats must be applied to this finding. First, Vogel (2008) concluded that the primary source of Chinook Salmon mortality was predation; however, releasing hundreds of tagged fish *en masse* likely caused a predator swamping effect, artificially deflating predation rates (Vogel 2008). Indeed, Hall (1979) reported that predation losses of fingerling Chinook Salmon in mark-recapture experiments at the Hallwood Cordura fish screen were highest when fish were “dribble” released into the system than when they were released *en masse*. Outmigrating CHNWR will trickle through the Oxbow over the course of several months and may thus be at a high risk of predation (Vogel, 2008). Second, fish used to estimate survival downstream of HCFS were released prior to those used to estimate survival past the screen. This may have caused predator satiation, artificially decreasing predation rates on fish arriving from upstream of the screen, causing an overestimate of survival of those fish (Vogel 2008). Third, the fish used in Vogel (2008) ranged from 50 mm – 120 mm FL, placing at least some of them above the size range of most of the CHNWR and CHNSR that normally encounter the HCFS (approximately 90% of the CHNWR and 45% of CHNSR caught at the Red Bluff and Hamilton City RSTs are >60 mm FL). Smaller fish may be at a higher risk of predation as they are weaker swimmers and are edible to smaller predator fish, which are typically more abundant than larger ones.

Vogel (2006) conducted four separate acoustic telemetry experiments in 2005, releasing fish in several locations above and below HCFS. A total of 109 acoustic-tagged fish were released into the Oxbow either above or below HCFS, while 16 were released into the HCFS bypass channel. Predation was a major cause of mortality during these experiments. Of 109 fish released into the Oxbow, 43 (39%) were likely eaten. Notably, the 16 released into the HCFS bypass channel were all eaten. Much of the predation observed during the 2005 acoustic telemetry study was believed to have occurred in the turbulent area below the flow control weir. High predation rates observed during Vogel’s (2006) acoustic telemetry study support the hypothesis that release of fish *en masse* during the 2002–2007 mark-recapture experiments caused predator swamping, artificially inflating survival estimates during those experiments.

During all experiments except those conducted in 2007 (when the flow control weir was removed), Vogel (2007; 2008) observed aggregations of predator fish just downstream of HCFS flow control weir, where the concrete wall flares into the channel. Additionally, in 2005, underwater videography below the weir revealed an aggregation of Striped Bass just below the flow control weir. Predators likely aggregated below the flow control weir because high flow velocity over the weir prevents passage upstream, and also because prey fish traveling downstream were delivered to that location by the bypass pipelines or were disoriented by passing over the weir into turbulent water. Due to the rapid removal of most of the flow by the diversion, juvenile Chinook Salmon are funneled into a much smaller volume before passing over the weir; high velocities and turbulent conditions below the weir also likely create ideal conditions for predators (Vogel 2008). The 2007 DIDSON survey also revealed predator fish aggregations at the upstream end of the HCFS. In the upstream location, there is a scour trench along the corrugated sheet piles that retain the concrete footer of the fish screen; Vogel hypothesized that this scour trench, the sheet piles, and the woody debris that collects in the scour trench create favorable habitat for predators (Vogel, 2008).

An acoustic telemetry study by Notch et al. (2020b), estimated survival of juvenile CHNFR released on two dates, May 16, 2019, and May 23, 2019, along all reaches of the Sacramento River from Red Bluff to the Golden Gate Bridge. Notch and colleagues specifically compared survival through the Hamilton City Oxbow to survival through the parallel reach of the mainstem Sacramento River and found that survival was higher through the Oxbow than through the mainstem Sacramento River (100% versus 96% and 100% versus 70% for the 5/16 and 5/23 releases, respectively), despite slower movement speeds through the Oxbow relative to the mainstem. The cause of lower survival in the main channel was unclear, however the GCID gradient facility on the main channel may create ideal predator habitat. Anecdotal evidence indicates that predators congregate in the scour hole below the GCID gradient facility on the main channel and ambush juvenile Chinook Salmon passing over the gradient (J. Notch personal communication July 2024).

Changes to habitat and hydrodynamics associated with water diversion, including the design and operation of the HCFS, may lead to higher predation in the Oxbow than would exist otherwise, for the reasons given above. Additionally, outmigrating juvenile CHNWR and CHNSR, which can be as small as 30 mm SL, may be more likely than the larger acoustic-tagged fish to be impeded or disoriented by diversions through HCFS and turbulence below the flow control weir. In mark-recapture studies, Vogel (2008) used at least some fish that more closely approximated the size of outmigrating CHNWR and early migrating CHNSR than those used in acoustic telemetry studies (acoustic-tagged fish are, by necessity, >80 mm SL) and observed high predation losses in the Oxbow, relative to the mortality observed by Notch et al. (2020b). Although *en masse* releases by Vogel may have elicited a predator response, this remains speculative, and predation risk to outmigrating CHNWR and CHNSR in the Oxbow due to HCFS should still be considered high.

Conclusions

Predation rates of juvenile CHNWR and CHNSR remain uncertain at HCFS and unknown at RBFS. Predator surveys and juvenile salmonid survival studies should be conducted at RBFS to assess whether the screen may increase the risk of juvenile CHNWR and CHNSR predation loss. Limitations of the Vogel (2007, 2008) studies leave much unknown about survival and predation rates of outmigrating juvenile Chinook Salmon in the Oxbow. Notch et al. (2020b) showed high survival rates of >80 mm SL Chinook Salmon through the Hamilton City Oxbow, however the smaller outmigrating CHNWR and CHNSR may be less able to avoid predators near the screens, especially if diversions through the screens impede the passage of smaller fish. The predator survey data collected by Cramer et al. (1992) and Vogel (2006, 2007, 2008) are informative and indicate further study of predator densities and spatial distributions in the Oxbow are needed.

4.1.1.5. Stranding Behind Screens

Juvenile winter-run Chinook Salmon and spring-run Chinook Salmon may become stranded behind the fish screens at the Red Bluff and Hamilton City diversion locations when the screens are overtopped by very high Sacramento River flows. Monitoring or salvage of stranded fish is likely impractical, as stranding will only occur when flows are too high to operate monitoring devices (e.g., rotary screw traps) or for workers to safely enter the water. Fish stranded behind the screens are lost to the system.

The ITP Application (Sites Authority 2023) discusses the risk of stranding of juvenile CHNWR and CHNSR behind the RBPP and HCPS fish screens during high flow overtopping events and concluded that the risk of stranding was low and would not be changed appreciably by Project operations. CDFW concurs, given the analysis below.

The RBFS may be overtopped when Sacramento River flow is 220,000 cfs or greater (Sites Authority 2023); at Hamilton City, a Sacramento River flow of 100,000 cfs or greater may overtop the screen (USBR 2010). The HCFS has been overtopped four times since its expansion in 2002 for a total of 14 days (Figure 4-53). RBFS has not been overtopped since its completion in 2011, nor does USRDOM indicate that any overtopping events would have occurred, had the screen been present between 1922 and 2003. However, USRDOM does indicate that, had the expanded HCFS been present during all of 1922–2003, it would have been overtopped for a total of 162 days (0.54% of days) under the simulated NAA and 170 days (0.57%) under Alt3B, NoSha, and NoShaOro (Figure 5-54). The mean simulated frequency of overtopping days per decade doubled from 15 to 30 from 1930 to 2000 under all operational scenarios (Figure 4-55).

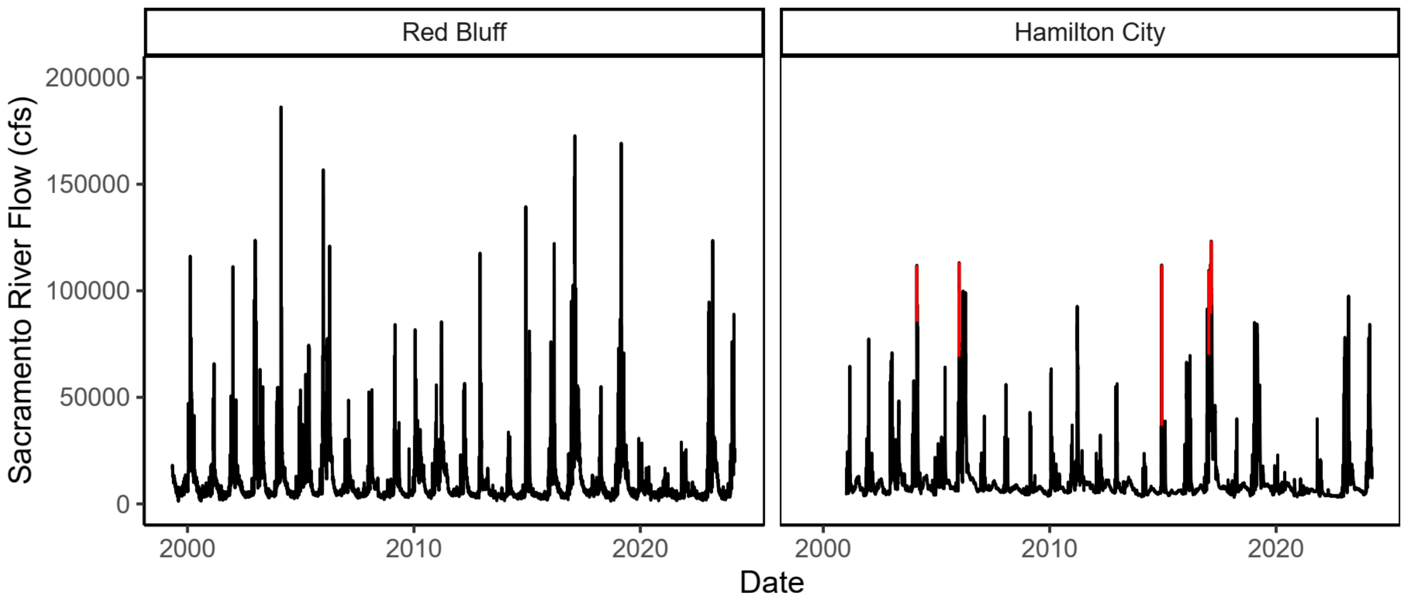

Figure 4-53. Observed Sacramento River flow at Red Bluff (left) and Hamilton City (right) from 1999 to 2024. Red indicates the dates of overtopping events. All available daily records shown. Data from the California Data Exchange Center (CDEC).

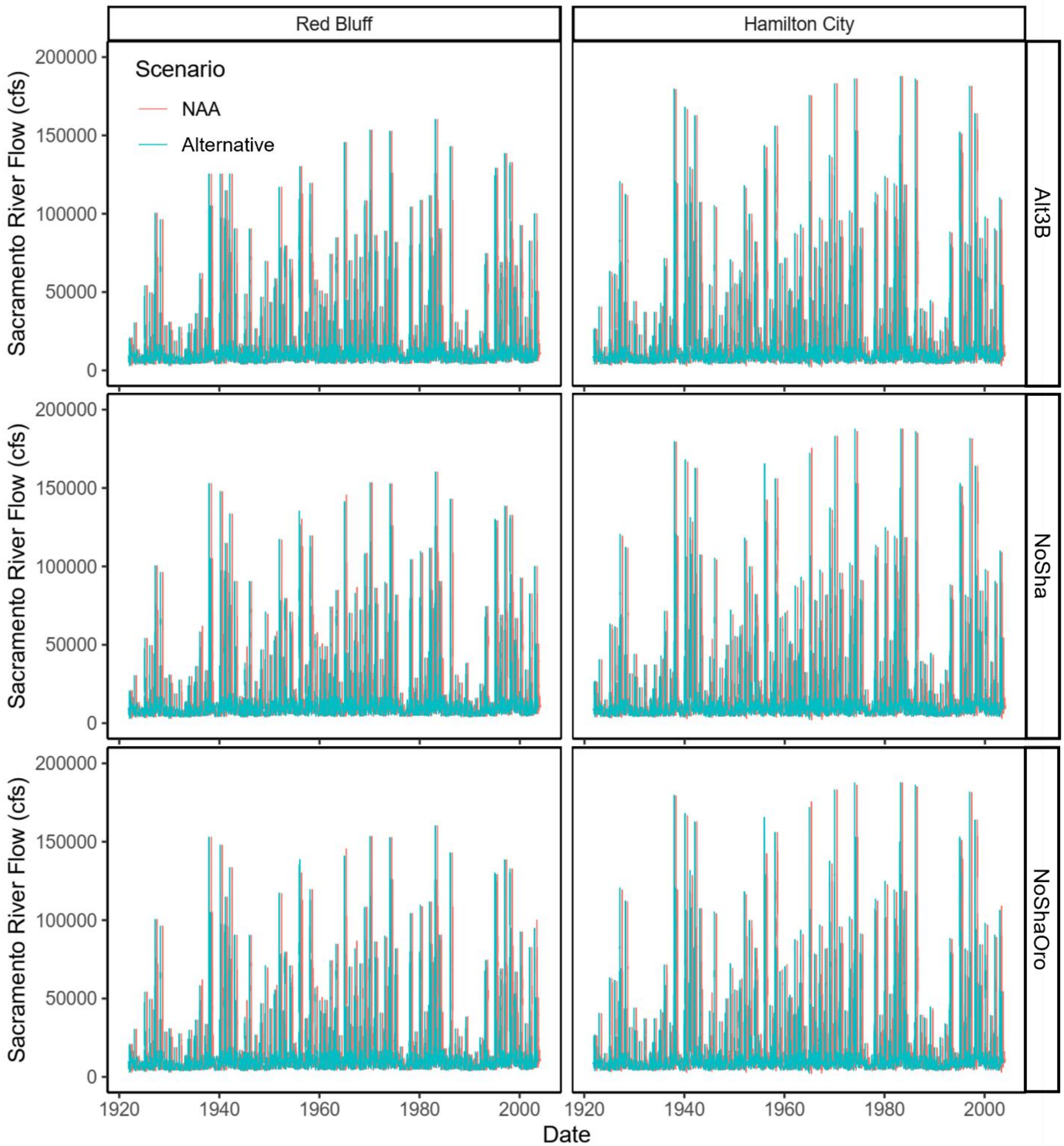

Figure 4-54. Upper Sacramento River Daily Operations Model (USRDOM)-simulated daily Sacramento River flows at Red Bluff (left) and Hamilton City (right) under Alt3B (top), NoSha (middle) and NoShaOro (bottom) in green versus the No Action Alternative (NAA); pink) during 1922 - 2003. NAA curves are shifted right by 150 days for visibility. USRDOM data provided by Sites Authority (2023).

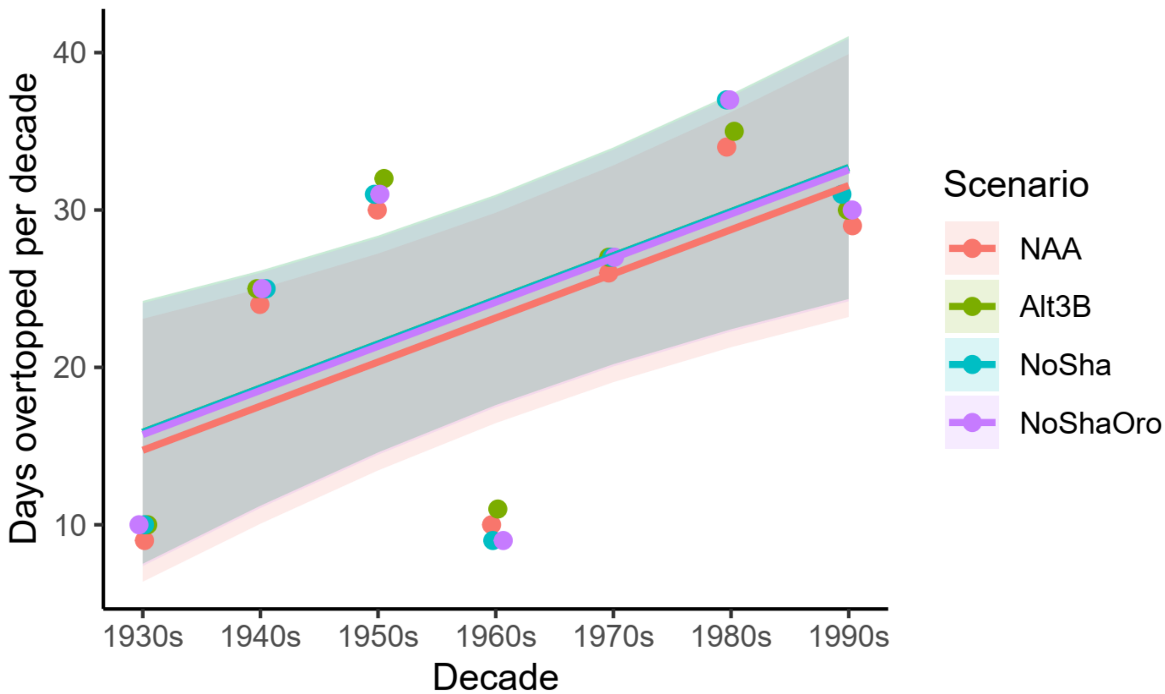

Figure 4-55. Number of days of screen-overtopping flows (>100,000 cfs) per decade at Hamilton City under the No Action Alternative (NAA); pink) versus the Alt3B operational scenario (green), as simulated by Upper Sacramento River Daily Operations Model (USRDOM). The 1920s and 2000s are excluded because they are not complete decades in the simulated time series. Fitted model details are in Table 4-6. Confidence bands and some fitted lines overlap. Points are left-right jittered for visibility. USRDOM data provided by Sites Authority (2023).

Table 4-6. Summary of a linear model of days the Hamilton City fish screen was overtopped per decade as a function of decade under the NAA and Alt3B. Asterisk (*) indicates a significant effect at α = 0.05. Intercept indicates the predicted number of overtopping events during the 1920s. $SE_{residual}$ = 8.54; $F_{2,11}$ = 3.04; P_{model} = 0.038; R^2 = 0.35

Effect	Estimate	$SE_{estimate}$	t-value	P-value
Intercept	11.93	4.57	2.61	0.016
Decade	2.80	0.81	3.47	0.002
Scenario: Alt3B	1.14	4.57	0.25	0.80
Scenario: NoSha	1.14	4.57	0.25	0.80
Scenario: NoShaOro	1.00	4.57	0.22	0.83

Conclusions

Overtopping of both RBFS and HCFS is expected to be rare under all operational scenarios and the NAA; USRDOM suggests that overtopping may never occur at Red Bluff under any operational scenarios, and that overtopping frequency would be similar at Hamilton City under NAA, Alt3B, NoSha, and NoShaOro operational scenarios. When overtopping occurs at Hamilton City, only a small fraction of Sacramento River flow, and thus a small fraction of CHNWR and CHNSR, will pass over the fish screen. Due to the infrequency of overtopping events and the relatively small proportion of CHNWR and CHNSR lost per overtopping event, the risk of taking CHNWR and CHNSR due to stranding behind the fish screens is currently minimal under both the Alt3B operational scenario and the NAA.

4.1.2. Water Temperature

Changes in water temperature due to Project diversions, releases, and/or exchanges could cause harm to or kill winter-run Chinook Salmon and spring-run Chinook Salmon in the Sacramento River.

Thermal stress is defined as any temperature change that significantly alters biological function and lowers the probability of survival of fish present (McCullough 1999). Chinook Salmon are most sensitive to temperature during spawning and egg incubation (Martin et al. 2017; NMFS 2014), and juveniles and adults can tolerate somewhat warmer temperatures if there is adequate food supply and water quality (e.g., Michel et al. 2021; Nobriga et al. 2021). Water temperature reaching or exceeding 70 °F (21 °C) blocks migration (Hallock et al. 1970) and can be lethal for CHNWR and CHNSR adults (McCollough 1999) and juvenile Chinook Salmon (Michel et al. 2021, Nobriga et al. 2021) in the Sacramento River Basin. Sub-lethal effects of increased water temperatures can also indirectly cause mortality, as fish are more susceptible to disease (Dietrich et al. 2014), contaminants (Mehta 2017; Dietrich et al. 2014) and predation (Nobriga et al. 2021).

Survival studies of juvenile Chinook Salmon have found that survival declines steeply when temperatures exceed 68 °F (20 °C) (Kjelson and Brandes 1989; Michel et al. 2021; Nobriga et al. 2021). A recent study in the Sacramento River found that mortality for migrating Chinook Salmon smolts was six times higher in temperatures exceeding 68 °F (20 °C) (Michel et al. 2023). Lower stream flows and warming water temperatures reduce the spatial and temporal extent of rearing and migration habitat as well as functionally disconnect the migratory corridor, which truncates migration and reduces life history and genetic diversity of populations (Munsch et al. 2019; Sturrock et al. 2019; Michel et al. 2021). This risk is particularly important to consider as it relates to CHNSR, as juveniles from different core populations exhibit distinct outmigration timing (Thompson et al. 2024) and could be disproportionally affected by a truncated migration period.

4.1.2.1. Water Temperature in the Sacramento River due to Changes in Flow

The water temperature analysis for Sacramento River in the ITP Application (Sites Authority 2023) used daily modeled water temperature outputs from the HEC-5Q model for four locations on the Sacramento River (Figure 4-56). The ITP Application (Sites Authority 2023) compared modeled water temperatures for the Alt3B operational scenario to the NAA to determine the frequency (days) and magnitude (°F) that the project would exceed one or more water temperature index values for each life stage, race/species. Results were then averaged by month and water year types. The temperature differences between the operational scenarios and NAA were considered biologically significant in the ITP Application (Sites Authority 2023) when the temperature differences meet both of the following two criteria: (1) the difference in frequency of exceedance was greater than 5%, and (2) the difference in average daily exceedance was greater than 0.5 °F.

While the ITP Application (Sites Authority 2023) focused on changes in temperature between Keswick Dam (RM 302) and Hamilton City, CDFW analyzed temperature changes for a larger portion of the Sacramento River where changes in flows due to diversion might affect water temperatures (Figure 4-56). Michel et al. (2023) found a strong relationship between flow and temperature between March and October, and that the effects of flow on temperature increase with distance downstream from Keswick Dam. Higher flow releases decrease water travel time and increase thermal mass, which slows the heating of water as it moves downstream (Daniels and Danner 2020; Michel et al. 2023). Michel et al. (2023) found that managing flows to maintain temperatures below 20 °C (68 °F) at Wilkin’s Slough (RM 120) could be most effective between early April and early June, and between the end of August and the end of October, periods that coincide with important migratory periods for CHNWR and CHNSR.

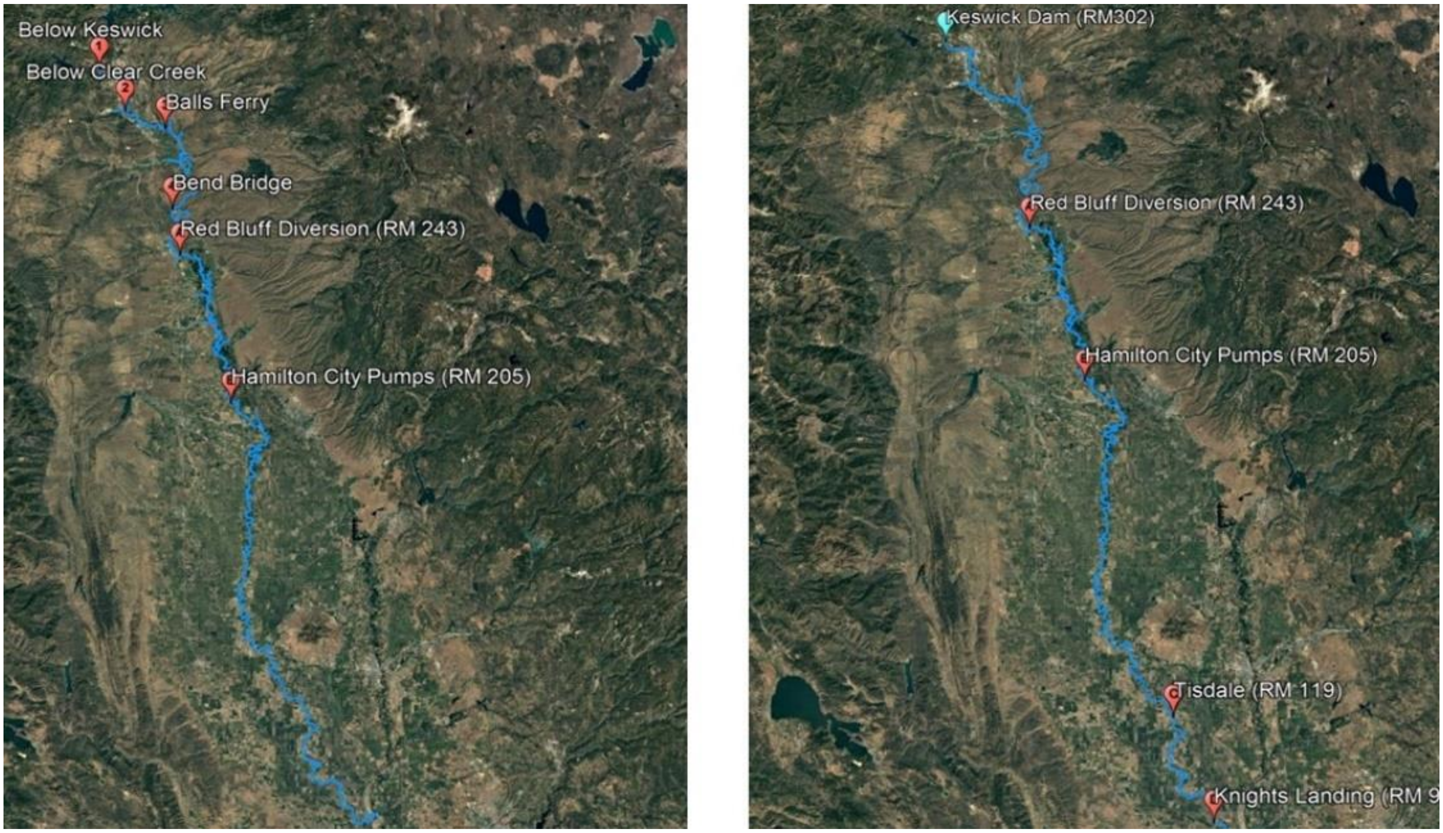

Figure 4-56. Locations used for Sacramento River Temperature Analysis in the ITP Application (Sites Authority 2023; Left) and in CDFW's Sacramento River Temperature Analysis (Right). Note that effects on egg-to-fry survival are analyzed in section 4.1.4.2.

To analyze the effects on temperature caused by changes in flow in the Sacramento River due to operations of the Project, CDFW compared the NAA to Alt3B, NoSha, and NoShaOro operational scenarios. Similar to the analysis in the ITP Application (Sites Authority 2023), CDFW considered a 0.5 °F change in temperature as biologically significant and compared the number of days the daily average or maximum temperature (from HEC-5Q) exceeded a biological or regulatory threshold (Table 4-7).

The following locations were considered in this analysis:

- Sacramento River at Red Bluff (RM 243)
- Sacramento River at Hamilton City (RM 205)
- Sacramento River at Tisdale Weir (RM 119, 1 RM upstream of Wilkins Slough)
- Sacramento River at Knights Landing (RM 90)

The HEC-5Q model files provided in the ITP Application (Sites Authority 2023) were used to re-run temperature simulations for NAA, Alt3B, NoSha, and NoOro operational scenarios. CDFW made only one update to the model files, which was changing the river water temperature output interval from one day to six hours to provide an estimate for maximum daily temperature to compare with biological temperature thresholds that use daily maxima rather than averages.

Table 4-7. Temperature Criteria used to compare each operational scenario to the No Action Alternative.

Location	Temperature	Rationale/ Reference	Winter-run Chinook Salmon Timing	Spring-run Chinook Salmon Timing
Red Bluff	56 °F (13.3 °C)[A] 60 °F (15.5 °C)[M] 66 °F (18.9 °C)[M]	Order 90-5[1] Juvenile Rearing[2] Adult Migration[3]	Year-round August–February November–June	Year-round Year-round February–September
Hamilton City	60 °F (15.5 °C) [M] 66 °F (18.9 °C) [M]	Juvenile Rearing[2] Adult Migration[3]	August–February November–June	February–April February–September
Tisdale Weir	60 °F (15.5 °C) [M] 66 °F (18.9 °C) [M] 70 °F (21.1 °C) [M]	Juvenile Rearing[2] Adult Migration[3] Barrier/Lethal[4]	August–May November–June August–June	December–June January–June December-June
Knights Landing	60 °F (15.5 °C) [M] 66 °F (18.9 °C) [M]	Juvenile Rearing[2] Adult Migration[3]	August–May November–June	December–June January–June

[A] Criterion based on the daily average temperature; analysis uses daily averages

[M] Criterion based on the 7-day average of the daily maximum; analysis uses daily maxima

[1] State Water Resources Control Board Order 90-5 (SWRCB 1990)

[2] Upper bounds of the stressful range based on NMFS 2014 and Boles et al. 1988

[3] Thermal avoidance threshold based on Hallock et al. 1970

[4] Thermal blockage threshold based on Hallock et al. 1970

CDFW used two criteria for analyzing temperature impacts to Chinook Salmon:

1. The Project increases or decreases temperature past a biological threshold (Table 4-7).
2. The Project increases or decreases temperature by more than 0.5°F within a stressful range (Figure 4-57).

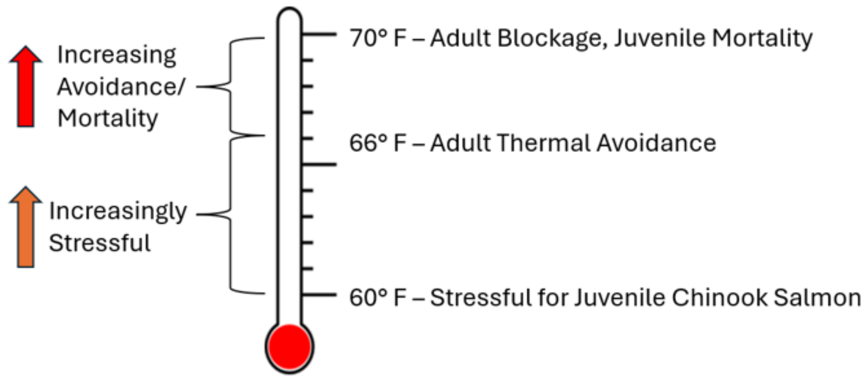

Figure 4-57. CDFW considered exceedance of temperature thresholds at 60ºF, 66ºF and 70ºF and increases greater than 0.5 °F to analyze the effects of the project on temperature for listed fish species,

CDFW compared the number of days meeting these criteria for Alt3B, NoSha, and NoShaOro operational scenarios to the NAA and summarized the results as the mean and maximum for each month and water year type (Appendix B1**)**. Results of this analysis show mostly small average changes in the number of days the Project causes an exceedance related to the NAA, with Alt3B generally showing greater average increases in exceedances than NoSha and NoShaOro operational scenarios. The maximum changes in days between the NAA and the Alt3B operational scenario were found to be large (at times 100% of the month) and variable (see Appendix B1), suggesting very large differences in a proportion of the years.

To further evaluate the temperature impacts of the Project, CDFW compared the differences in exceedance days for each year in the period of record. This additional analysis focused on changes in temperature at Tisdale, as this location is frequently temperature limited, water temperature at this location is affected by flow (Michel et al. 2021), and because CDFW's initial temperature analysis showed it as a location with large changes in temperature between the scenarios. Because there did not appear to be large differences in temperature between NoSha and NoShaOro operational scenarios, CDFW focused on the differences between the NAA and the Alt3b and NoSha operational scenarios. CDFW compared the number of temperature exceedance days as well as the average flow for each month from for the years 2003–2022, the full time series in the HEC-5Q model. Only the months from April–June and August–October are presented, as these are the months when flow can affect water temperatures most in this reach (Michel et al. 2021). During these periods, CHNWR and CHNSR adults and CHNSR juveniles (April through mid-June) and CHNWR juveniles (mid-August through October) are likely to be present in this reach (Table 4-7).

Results showed large changes in flow and temperature in some months and years due to Project operations, with the Alt3B operational scenario having the largest and most frequent decreases in flow and increases in water temperature. For example, in May of Critical water year types, 5 of 12 (42%) years are predicted to have a biologically significant increase (defined as a 0.5 °F increase in >5% of days) in temperature within a temperature range that is stressful for CHNWR and CHNSR. During those same years and months, 3 of 12 (25%) years are predicted to have a significant (>5% of days) increase in the number of days exceeding 66 °F, and 3 of 12 (25%) years are predicted to have a significant increase in the number of days exceeding 70 °F (Table 4-8). This is a dramatic difference from the NoSha operational scenario, which had no change in temperature exceedance days from the NAA for the same months and years (Table 4-9).

Table 4-8. May flow (cfs) and temperature (°F) exceedances at Tisdale under No Action Alternative (NAA) and Alternative 3B (Alt3B) for critically dry water year types. Changes in days >5% are bolded in red (increase) and green (decrease). Changes in flow >5% are bolded in red (decrease) and green (increase).

Water Year	May Average Flows (cfs) NAA	May Average Flows (cfs) Alt3B	Change in Days >60°F Alt3B	Days >60°F AND >0.5°F change	Change in Days >66°F Alt3B	Days >66°F AND >0.5°F change	Change in Days >70°F 3B	Days >70°F AND >0.5°F change
1924	4,972	4,952	0	**4**	1	2	0	0
1929	7,233	**6,286**	0	**31**	**7**	**26**	0	0
1931	4,741	4,725	0	**-2**	0	-1	-1	0
1933	7,440	7,507	0	0	-1	0	0	0
1934	6,922	6,928	0	**-2**	**-2**	-2	-1	0
1976	6,430	**5,634**	0	**27**	**2**	**27**	**5**	**10**
1977	5,137	**4,656**	0	0	1	0	0	0
1988	6,748	**5,846**	0	**28**	**4**	**20**	**3**	**5**
1990	7,043	7,035	0	0	0	0	0	0
1991	4,676	4,650	0	0	1	0	0	0
1992	6,600	**5,721**	0	**29**	0	**29**	**15**	**28**
1994	4,765	4,594	0	0	0	0	0	0

Table 4-9. May flow (cfs) and temperature (°F) exceedances at Tisdale under the No Action Alternative (NAA) and No Shasta Exchange Alternative (NoSha) for critically dry water year types.

Water Year	May Average Flows (cfs) NAA	May Average Flows (cfs) NoSha	Change in Days >60°F under NoSha	Days >60°F AND >0.5°F change	Change in Days >66°F under NoSha	Days >66°F AND >0.5°F change	Change in Days >70°F NoSha	Days >70°F AND >0.5°F change
1924	4,972	4,984	0	0	0	0	0	0
1929	7,233	7,232	0	0	0	0	0	0
1931	4,741	4,723	0	0	0	0	0	0
1933	7,440	7,516	0	0	0	0	0	0
1934	6,922	6,929	0	0	0	0	0	0
1976	6,430	6,420	0	0	0	0	0	0
1977	5,137	5,133	0	0	0	0	0	0
1988	6,748	6,748	0	0	0	0	0	0
1990	7,043	7,027	0	0	0	0	0	0
1991	4,676	4,649	0	0	0	0	0	0
1992	6,600	6,619	0	0	0	0	-1	0
1994	4,765	4,594	0	0	0	0	0	0

In the fall (August–October), Alt3B and NoSha operational scenarios show significant reductions (0.5 °F decrease in >5% of days) in water temperatures in September and October of some years, although many of those reductions are not biologically significant (e.g., water temperatures with Project operations exceed lethal thresholds under both NAA and each operational scenario). Temperature impacts of Project operations and exchanges with Shasta appear to be more variable from mid-August–October, with some months and years showing temperature benefits and some showing temperature impacts (Appendix B1).

Although HEC-5Q operates at a 6-hour time-step, the version of the model provided in the ITP Application (Sites Authority 2023) uses monthly average flow data (cfs) from CalSim II. This modeling assumption averages out sub-monthly changes in the hydrograph, and therefore doesn't consider the effects of the highest and lowest Sacramento River flows on temperature.

Conclusions

CDFW's temperature analysis found that, depending on exchanges with Shasta and Oroville reservoirs, the Project could result in significantly different flows and water temperatures in the Sacramento River during periods of CHNWR and CHNSR migration. Project operations have the potential to increase temperatures to stressful or lethal levels from March through mid-June and mid-August through mid-October, and these impacts are most frequent and largest when there are exchanges between Sites and Shasta reservoirs.

CDFW's temperature analysis shows that temperature impacts would be greatest in the reach of the Sacramento River near Tisdale Weir and Wilkins Slough and could therefore impact CHNWR and CHNSR populations in the Sacramento Basin upstream of the Feather River confluence most severely. Temperature impacts could occur in all water year types; however, temperature exceedances in spring months (March–June) would be more frequent in drier year types, and temperature exceedances in the fall months (August–October) would be more frequent in wetter year types. Because of their unique outmigration strategy, lower flows and higher temperatures in the spring would likely have a disproportionate impact on late smolt CHNSR outmigrants from Mill and Deer creeks, negatively impacting juvenile life-history expression and resiliency of these imperiled CHNSR lineages. Lower flows and higher temperatures near Tisdale from August through October would primarily impact CHNWR outmigrants.

These differences were not seen in the ITP Application (Sites Authority 2023) analyses or in the FEIR (Reclamation and Sites Authority 2023) because those analyses did not evaluate water temperatures downstream of Hamilton City, and flow is not as strongly related to water temperature at those upstream locations (Michel et al. 2023). Because water temperatures vary so greatly between the Alt3B, NoSha, and NoOro operational scenarios, temperature impacts related to changes in Sacramento River flow can be minimized through coordinated operations of Sites with Shasta Reservoir and the CVP.

4.1.2.2. Water Temperature Effects of Releases to the Sacramento River at KLOG

The ITP Application (Sites Authority 2023) evaluated temperature effects of water released from the Sites Reservoir using two models: (1) A CE-QUAL-W2 model that simulates water temperatures both within and released from the Sites Reservoir, and (2) a release blending model that estimates temperature effects of Sites Reservoir releases to the TCC, GCID Main Canal, CBD, and the Sacramento River just downstream of the CBD. Descriptions of these models are included in Appendix 6D of the FEIR (Reclamation and Sites Authority 2023), and models were provided to CDFW as part of the ITP Application (Sites Authority 2023).

CDFW notes that the two models used for temperature analysis have not been validated, and the monitoring data needed for model validation will not be available before construction and operation of the reservoir. For this reason, there is extremely high uncertainty associated with model outputs and their ability to inform analyses of the Project's impacts on downstream water temperature.

The CE-QUAL-W2 model includes several assumptions and model parameters that may be unrepresentative of Project conditions and must be validated using monitoring data after Sites Reservoir is constructed and operational. First, CE-QUAL-W2 modeling of Sites Reservoir incorporates base meteorological input data that may not represent conditions in the Reservoir location, as noted below:

1. The 2035 central tendency climate-adjusted meteorological data used in the model are based on data from the California Irrigation Management Information System (CIMIS) station located in Durham, California, which is approximately 35 miles northeast of the Reservoir site and at a lower elevation, with a surrounding environment different from that of the Reservoir site.

2. The 2007–2018 CIMIS Durham Station dataset was adjusted and repeated to simulate meteorological conditions from 1922–2003. This is unlikely to be an accurate representation of the meteorological conditions at the Reservoir site for the 82-year simulation period, which does not overlap temporally with nor show the same variability and year-to-year meteorological patterns as the meteorological data.

Second, CDFW notes several assumptions about how flow and temperature were modeled for Sites Reservoir using CE-QUAL-W2 that increase the uncertainty of the results:

1. CE-QUAL-W2 assumes lateral homogeneity, which is best suited for relatively long, narrow waterbodies (e.g., canals or river channels). The model must be validated to ensure that this assumption is appropriate for the Sites Reservoir.

2. The inflow temperature between the diversion locations (Red Bluff and Hamilton City) and Sites Reservoir is assumed to be constant. However, the diverted water would travel more than 40 miles down the open, shallow Tehama-Colusa and Glenn-Colusa Canals, where its temperature would likely change substantially, especially in warmer months.

The ITP Application (Sites Authority 2023) modeled the temperature of water released from Sites Reservoir and its effects on water temperature in the Sacramento River downstream of the release location (KLOG) using a water temperature blending model. CDFW identified two major shortcomings of this approach. First, the blending model can only provide monthly average temperature estimates; however, impacts to protected species could result from daily or sub-daily changes in water temperature. Second, for all channels and canals covered by this model, the temperature change per river mile for each month is based on water temperature change in the Sacramento River main channel. As changes in water temperature in a channel are directly affected by conditions such as water depth, velocity, and shading, it may be inappropriate to use water temperature changes derived from the Sacramento River for agricultural canals that are generally much shallower, less shaded, and will exhibit dramatically different flows.

Because of the high uncertainty around the temperature modeling for releases, CDFW used a mass balance approach to investigate the impact of various release temperatures to the Sacramento River, and how they may result in meeting or exceeding temperature criteria for CHNWR and CHNSR. The analysis used HEC-5Q modeled temperature and flow data for Sacramento River at Knights Landing (Alt3B scenario) and assumed Project releases at KLOG of 1,000 cfs and 4,000 cfs. Sites Authority indicated total discharges to the Sacramento River at KLOG may be approximately 4,000 cfs, which includes a maximum of 1,000 cfs from the Dunnigan pipeline and up to 3,000 cfs from other sources (J. Spranza personal communication July 2024).

The temperature in the river after mixing was calculated as:

Equation 6.

$$T_{Mixed} = \frac{Q_{CBD}T_{CBD} + Q_{SR}T_{SR}}{Q_{CBD} + Q_{SR}}$$

where, T_{Mixed} is the temperature of the Sacramento River just downstream of the outfall of the Sites Reservoir releases; Q_{CBD} is the flow rate in the CBD due to Sites releases; T_{CBD} is the temperature of the water in the CBD from Sites releases prior to mixing with the Sacramento River; Q_{SR} is the flow rate in the Sacramento River just upstream of the outfall of Sites releases into the river; and T_{SR} is the temperature of the Sacramento River just upstream of the outfall of Sites releases into the river prior to mixing. For the mass balance temperature analysis, CDFW used the HEC-5Q temperature modeling results at Knights Landing (Alt3B operational scenario) for Q_{SR} and T_{SR} from the ITP Application (Sites Authority 2023).

An interactive data tool was produced to visualize the potential impact on river temperatures over a range of possible release temperatures (Figure 4-58). Whether the Sites releases will increase river temperatures, particularly around critical biological thresholds, will depend on the temperature of the water being released and the total release volume.

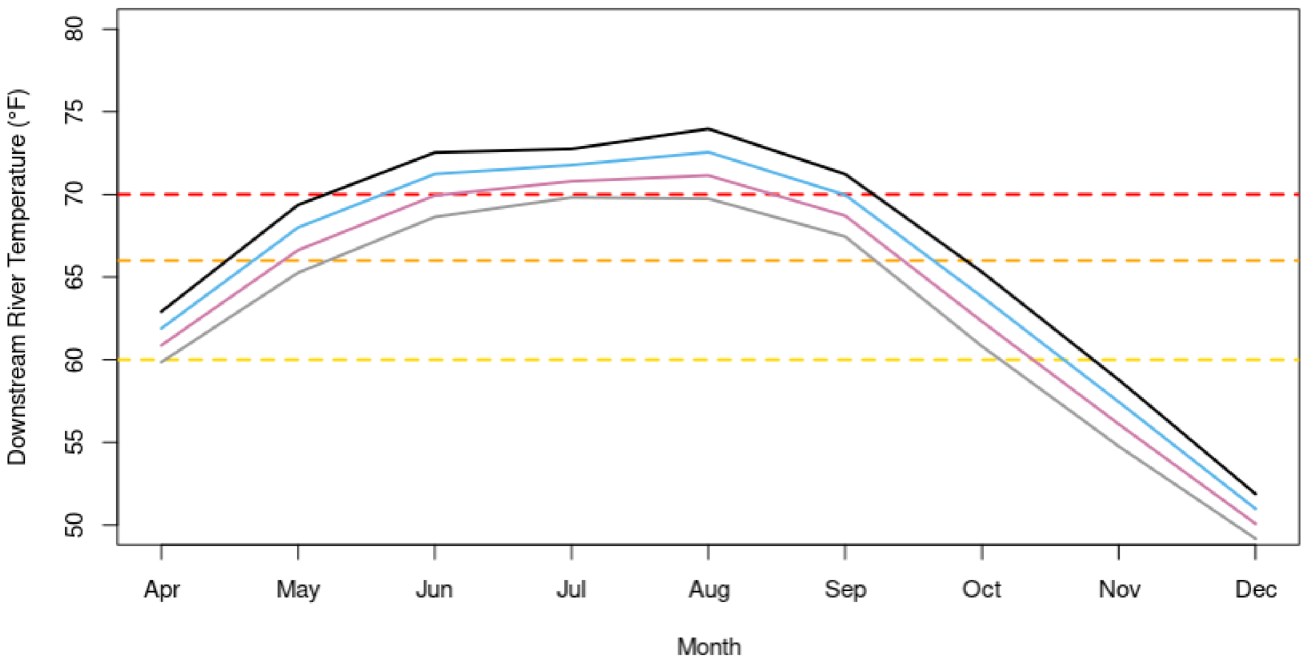

Figure 4-58. An example frame from the interactive tool for exploring the potential impacts of releases on Sacramento River temperatures by month. This example assumes monthly median river flow and temperature from Project HEC-5Q model at the Knights Landing node. Horizontal dashed lines mark important biological thresholds for juvenile rearing and migration (yellow, 60 °F), adult migration (orange, 66 °F), and Chinook Salmon survival (red, 70 °F) (see Section 4.1.2.1 for details on these thresholds). Each solid line represents the Sacramento River temperature after mixing with Sites releases at different temperatures of released water: grey = 50 °F (bottom line), pink = 60 °F (bottom middle), blue = 70 °F (top middle), black = 80 °F (top line). All scenarios assume a release flow rate of 1,000 cfs.

Since the water temperatures of releases into the river are currently poorly understood, we can rearrange Equation 6 to estimate what the temperature of reservoir releases would need to be in order to keep the river at or below critical temperature thresholds based on biological limits. Rearranging Equation 6 to calculate the maximum temperature of release water to achieve a target temperature results in Equation 7.

Equation 7.

$$T_{CBD} = \frac{(Q_{CBD} + Q_{SR})T_{Mixed} - Q_{SR}T_{SR}}{Q_{CBD}}$$

where T_{Mixed} is the target temperature of the river after mixing with Sites releases.

CDFW analyzed the release temperature that would result in Sacramento River temperatures equal to the biological thresholds of 60°, 66° and 70° F, assuming KLOG releases of 1,000 cfs (Table 4-10) and 4,000 cfs (Table 4-11). These calculated values were then compared to historical water temperatures in the Sacramento River and CBD to determine if future releases could reasonably be expected to occur under the Project that would exceed biological thresholds.

Assuming that the temperature of Project releases could be similar to historical temperatures, if the range of calculated release temperature for a threshold overlapped with a range of historical temperatures observed in the CBD and/or Sacramento River during any given month, CDFW concluded that there is a potential for releases at KLOG to increase or decrease Sacramento River temperatures past a biological threshold.

Results of the mass balance analysis suggest that during April, May, and September, KLOG releases of 1,000 cfs could cause temperature thresholds to be exceeded if the water temperature of releases is greater than water temperature in the Sacramento River (Table 4-10). From June through August, though monthly average Sacramento River water temperatures near KLOG often exceed lethal temperatures for Chinook Salmon, and CHNSR and CHNWR are not likely to be present when that happens. Releases up to 1,000 cfs at KLOG would be unlikely to increase temperatures over biological thresholds from October through March, as Sacramento River temperatures and flow are, on average, able to balance a 1,000 cfs discharge with temperatures up to 85.9 °F.

The analysis showed that KLOG discharges of 4,000 cfs would be more likely than 1,000 cfs discharges to cause temperature thresholds for CHNWR and CHNSR to be exceeded if release temperatures are warmer than river temperatures. Results of the mass balance analysis indicate that KLOG releases of 4,000 cfs could, on average, increase monthly average Sacramento River temperatures above biological thresholds in April, May, September, and October (Table 4-11). The broad ranges of calculated release temperatures suggest that releasing 4,000 cfs of warmer water also has the potential to increase river temperatures into the stressful range for juvenile rearing and migration in March, above the lethal threshold during the months of June through August, and into the stressful range for juvenile rearing in November (Table 4-11).

Table 4-10. Historical water temperatures (°F) in the Colusa Basin Drain (CBD; Column A) and Sacramento River (Column B) and calculated release temperatures that would result in 60 °F, 66 °F, and 70 °F in the Sacramento River below Knights Landing Outfall Gates (KLOG, Columns C–E)). Values are calculated using Equation 6 from daily flow and temperatures from Project HEC-5Q model output and assuming a 1,000 cfs release at KLOG. Monthly mean temperatures are in bold, and the range of daily temperatures for the period of record are in parentheses. Red text indicates that the range of calculated release temperatures overlaps the range of historical water temperatures in the CBD and/or Sacramento River for the period of record, and orange shaded cells indicate that the mean monthly temperature is also within that range. Release temperatures in those ranges could cause temperatures in the Sacramento River to increase or decrease across the biological threshold.

Month	A. Historical Temperature in the Colusa Basin Drain at KLOG[4] (°F)	B. Historical Temperature in the Sacramento River at Wilkins Slough[5] (°F)	C. Calculated 1,000 cfs Release Temperature to achieve 60 °F (°F)	D. Calculated 1,000 cfs Release Temperature to achieve 66 °F (°F)	E. Calculated 1,000 cfs Release Temperature to achieve 70 °F (°F)
Jan	**48.8** (41.0–55.4)	**49.2** (42.9–54.8)	**264** (99.8–470)	**365** (137–639)	**433** (161–752)
Feb	**52.9** (43.3–61.3)	**51.6** (44.5–57.4)	**261** (63.5–457)	**375** (99.8–622)	**450** (124–734)
Mar	**57.7** (45.0-67.3)	**55.4** (44.5–66.1)	**170** (21.9–401)	**271** (79.5-574)	**338** (108–689)
Apr	**63.1** (53.1–76.1)	**61.5** (51.2–70.1)	**70.4** (-24.5–311)	**147** (40.7–477)	**198** (71.6–588)
May	**69.9** (61.5–80.2)	**66.9** (55.8–75.4)	**11.6** (-77.7–122)	**62.1** (6.0–250)	**95.8** (32.0–343)
Jun	**76.0** (61.2–85.5)	**71.3** (63.3–80.1)	**-18.9** (-148–57.9)	**30.0** (-29.9–163)	**62.6** (8.7–242)
Jul	**79.6** (72.9–88.0)	**72.5** (66.0–80.4)	**-41.9** (-146–15.1)	**16.2** (-64.3–57.6)	**55.0** (-10.0–107)
Aug	**76.6** (70.3–83.1)	**70.6** (64.2–79.0)	**-20.0** (-85.1–18.5)	**23.4** (-23.1–57.8)	**52.4** (10.4–92.9)
Sep	**72.2** (65.1–79.2)	**67.3** (60.1–78.3)	**-7.0** (-91.0–53.0)	**42.4** (-24.4–131)	**75.3** (19.1–189)
Oct	**64.6** (55.8–72.9)	**61.4** (51.8–70.5)	**43.8** (-80.3–124)	**85.9** (26.1–231)	**114** (57.5–301)
Nov	**55.0** (44.8–62.6)	**54.5** (46.6–61.5)	**98.2** (20.4–307)	**151** 81.2–463	**186** 99.0–572
Dec	**47.7** (40.5–58.1)	**49.5** (41.5–56.6)	**208** (84.3–432)	**295** 116–598	**353** 138–708

[4] https://wdl.water.ca.gov/WaterDataLibrary/StationDetails.aspx?Station=A0294710
[5] https://cdec.water.ca.gov/dynamicapp/staMeta?station_id=WLK

Table 4-11. Historical water temperatures (°F) in the Colusa Basin Drain (CBD; Column A) and Sacramento River (Column B) and calculated release temperatures that would result in 60 °F, 66 °F, and 70 °F in the Sacramento River below Knights Landing Outfall Gates (KLOG columns C-E). Values are calculated from Equation 6 using daily flow and temperatures Project HEC-5Q model output and assuming a 4,000 cfs release at KLOG. Monthly mean temperatures are in bold, and the range of daily temperatures for the period of record are in parentheses. Red text indicates that the range of calculated release temperatures overlaps the range of historical water temperatures in the CBD and/or Sacramento River for the period of record, and orange shaded cells indicate that the mean monthly temperature is also within that range. Release temperatures in those ranges could cause temperatures in the Sacramento River to increase or decrease across the biological threshold.

Month	A. Historical Temperature in the Colusa Basin Drain at KLOG (°F)	B. Historical Temperature in the Sacramento River at Wilkins Slough (°F)	C. Calculated 4,000 cfs Release Temperature to achieve 60 °F (°F)	D. Calculated 4,000 cfs Release Temperature to achieve 66 °F (°F)	E. Calculated 4,000 cfs Release Temperature to achieve 70 °F (°F)
Jan	**48.8** (41.0–55.4)	**49.2** (42.9–54.8)	**110** (69.9–162)	**140** (83.7–209)	**160** (92.8–241)
Feb	**52.9** (43.3–61.3)	**51.6** (44.5–57.4)	**110** (60.9–159)	**143** (74.4–205)	**165** (83.5–236)
Mar	**57.7** (45.0-67.3)	**55.4** (44.5–66.1)	**87.5** (50.5–145)	**117** (69.4–193)	**137.1** (79.6–225)
Apr	**63.1** (53.1–76.1)	**61.5** (51.2–70.1)	**62.6** (38.9–123)	**86.2** (59.7–169)	**102** (70.4–200)
May	**69.9** (61.5–80.2)	**66.9** (55.8–75.4)	**47.9** (25.6–75.5)	**65.0** (51.0–112)	**76.4** (60.5–138)
Jun	**76.0** (61.2–85.5)	**71.3** (63.3–80.1)	**40.3** (7.9–59.5)	**57.0** (42.0–90.2)	**68.2** (54.7–113)
Jul	**79.6** (72.9–88.0)	**72.5** (66.0–80.4)	**34.5** (8.6–48.8)	**53.6** (33.4–63.9)	**66.2** (50.0–79.3)
Aug	**76.6** (70.3–83.1)	**70.6** (64.2–79.0)	**40.0** (23.7–49.6)	**55.4** (43.7–64.0)	**65.6** (55.1–75.7)
Sep	**72.2** (65.1–79.2)	**67.3** (60.1–78.3)	**43.2** (22.3–58.3)	**60.1** (43.4–82.1)	**71.3** (57.3–99.7)
Oct	**64.6** (55.8–72.9)	**61.4** (51.8–70.5)	**55.9** (24.9–76.1)	**71.0** (56.0–107)	**81.0** (66.9–128)
Nov	**55.0** (44.8–62.6)	**54.5** (46.6–61.5)	**69.6** (50.1–122)	**87.3** (69.8–165)	**99.1** (77.3–195)
Dec	**47.7** (40.5–58.1)	**49.5** (41.5–56.6)	**97.0** (66.1–153)	**123** (78.6–199)	**140** (86.9–230)

Conclusions

Given: (1) there is considerable uncertainty around water temperatures of Project releases to the Sacramento River at KLOG; (2) it is not possible for temperature models for Sites Reservoir to be calibrated and validated prior to construction and operation of the Project; (3) water temperatures in the Sacramento River near the discharge location frequently approach or exceed biological thresholds for CHNSR and CHNWR; (4) CDFW's mass balance analysis showed that releasing 1,000 cfs–4,000 cfs at KLOG could increase Sacramento River water temperatures past a biological threshold for juvenile or adult Chinook Salmon; (5) adult and juvenile CHNSR and CHNWR salmon are often in the Sacramento River near KLOG during the time periods of Project releases, and (6) increasing water temperatures above biological thresholds during critical periods of fish presence is known to harm or kill CHNWR and CHNSR, the proposed releases from the Sites Reservoir to the Sacramento River have the potential to take CHNWR and CHNSR.

4.1.3. Water Quality in the Sacramento River and Yolo Bypass

Changes in water quality due to Project releases could cause mortality or changes to behavior, physiological health, swimming ability, or growth that can impact survival of winter-run Chinook Salmon and spring-run Chinook Salmon in the Sacramento River or Yolo Bypass.

The Project proposes to release water from Sites Reservoir into the Sacramento River at the KLOG and/or the Yolo Bypass. The capacity of the Dunnigan Pipeline will limit the maximum Project releases to the CBD to 1,000 cfs; however, Sites Authority indicated total discharges to the Sacramento River at KLOG may be approximately 4,000 cfs, which includes a maximum of 1,000 cfs from the Dunnigan pipeline and up to 3,000 cfs from other sources (J. Spranza personal communication July 2024). The Project would release maximum of approximately 464 cfs into the Yolo Bypass during August through October. The water quality of these discharges may impact CHNSR and CHNWR juveniles and adults nearby, as well as those migrating or rearing in the Sacramento River by exposing them to low DO levels, elevated pesticide, and metal concentrations, as well as harmful algae and their toxins.

As a result of releases from the Project, water quality is likely to be degraded at the Yolo Bypass and KLOG discharge points due to (1) the characteristics of the water when it leaves the reservoir, (2) changes that occur during transit, and (3) the transport of water that mobilizes constituents prior to discharge.

The Final Environmental Impacts Report (FEIR) (Reclamation and Sites Authority 2023) and the ITP Application (Sites Authority 2023) identify some of the water quality impacts anticipated by the first two mechanisms. The North Delta Food Subsidy (NDFS) study led by DWR provides insight into the water quality impacts that may occur due to the third mechanism (Davis et al. 2021). The NDFS pulse flows ranged between 239 to 750 additional daily cfs (approximately 3-32 additional TAF) sourced from a mix of agricultural and/or Sacramento River water routed through the CBD and Yolo Bypass Toe Drain Canal (Toe Drain). Hydrodynamic modelling, along with the collection of a suite of water quality parameters sampled at multiple locations along the CBD, KLRC Slough and Toe Drain from Rominger Bridge (upstream) to the Cache Slough Complex (downstream) allowed for an evaluation of water quality effects and the likely mechanisms for those effects.

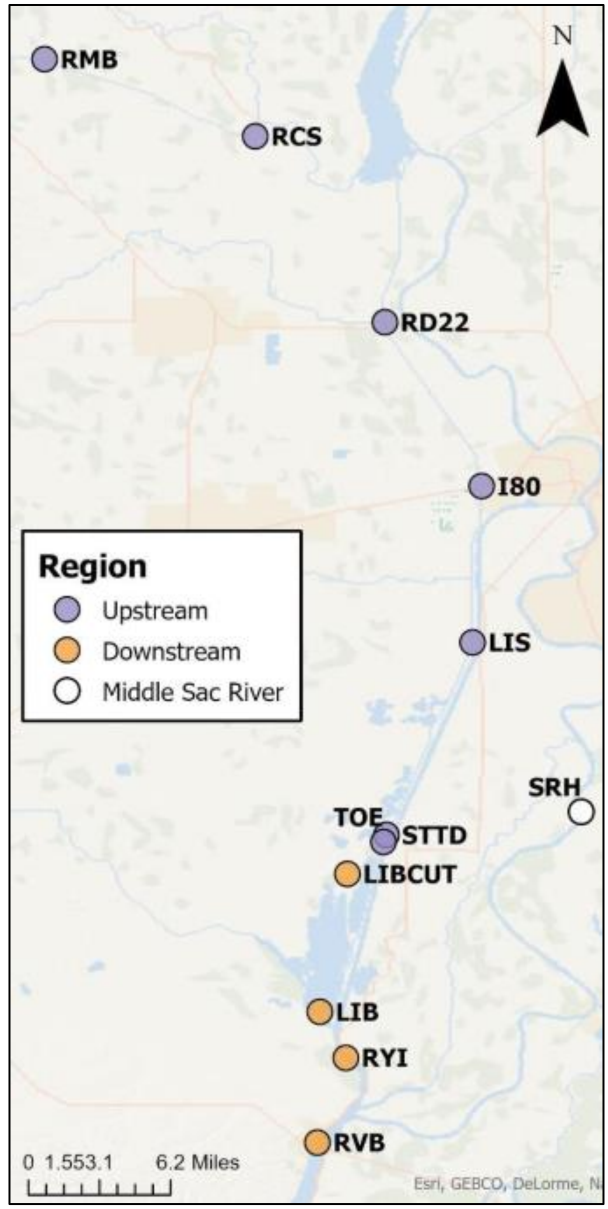

Figure 4-59. Map of water quality monitoring stations for the North Delta Food Subsidy pulse flows, from Davis et al. 2021.

An important overarching finding from the hydraulic modelling and water quality data collected during the NDFS study was that elevated flows in the CBD moved masses of water and their constituents downstream (Figure 4-59). The additional flows from proposed Sites Reservoir discharges, which are expected to be larger than the NDFS pulses, may also transport contaminated or poor-quality water from upstream locations[6] into the Yolo Bypass or through KLOG and into the Sacramento River.

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[6] Upstream monitoring stations referenced in the NDFS study were Colusa Basin Drain at Rominger Bridge (RMB, °38.812214, °-121.774258), Ridge Cut Slough (RCS, 38.793556°, -121.725349°), Yolo Bypass Toe Drain at Road 22 (RD22, 38.676367°, -121.643972°), Yolo Bypass Toe Drain at Lisbon Weir (LIS, 38.474781° -121.588226°), Yolo Bypass Toe Drain at the Rotary Screw Trap (STTD, 38.353383°, -121.643181°), and Yolo

4.1.3.1. Dissolved Oxygen (DO)

Discharges from the Project have the potential to mobilize water with low dissolved oxygen, transporting it to areas where it may cause harm to winter-run Chinook Salmon and spring-run Chinook Salmon.

The FEIR (Reclamation and Sites Authority 2023) notes that decreases in reservoir DO levels are expected during initial filling due to decomposition of organic matter, and that decreases will recur regularly from the late spring through fall due to stratification and the algae die-off. It is unclear how low DO will be when water discharged from the reservoir.

Inadequate DO can cause multiple sub-lethal impacts or mortality to Chinook Salmon. Sublethal impacts that influence survival include impaired development, reduced growth, altered behavior, and reduced swimming ability (Table 4-12). DO concentrations of approximately 6 mg/L cause impairment and DO concentrations of 4 mg/L cause severe impairment (USEPA 1986). Acute mortality for Chinook Salmon begins at DO concentrations of 3 mg/L (USEPA 1986). Swimming performance is impacted for juveniles at 6.5-7.0 mg/L (Davis et al. 1963), which can reduce their ability to escape predators and forage for food (Newcomb et al. 2010), affecting survival. Metabolism and feeding decreases at approximately 7-8 mg/L (Jobling 1993), and is likely linked to observed decreases in growth rate at approximately 6-7 mg/L. At lower DO concentrations, growth rate reductions can be severe, with one study finding a 16% reduction at 5 mg/L, 29% reduction at 4 mg/L and 47% reduction at 3 mg/L (USEPA 1986). Juvenile Chinook Salmon size at ocean entry can be a significant factor influencing survival (Zabel and Achord 2004; Woodson et al. 2013), underscoring the importance of juvenile growth rate during the freshwater portion of their lifecycle.

Bypass Toe Drain at Liberty Island Near Courtland, CA (TOE, 38.349167°, -121.644722°). Downstream monitoring stations referenced in the NDFS study included Liberty Cut at Little Holland Tract near Courtland (LIBCUT, 38.32885°, -121.6675306°), Cache Slough at Liberty Island Near Rio Vista (LIB, 38.242100°, -121.684900°), Cache Slough at Ryer Island (RYI, 38.212800°, -121.669200°), and Sacramento River at Rio Vista Bridge (RVB, 38.159737°, -121.686355°).

Table 4-12. Lethal and sublethal dissolved oxygen thresholds for Chinook Salmon and other salmonids.

Impairment	Dissolved Oxygen Concentration	Reference
Acute Mortality	3 mg/L	USEPA 1986
Severe Impairment	4 mg/L	USEPA 1986
Moderate Impairment	5 mg/L	USEPA 1986
Reduced swimming performance	6.5-7 mg/L	Davis et al. 1963
Reduced growth rate	6-7 mg/L	USEPA 1986
Reduced metabolism/feeding	7-8 mg/L	Jobling 1993

Dissolved Oxygen in the Yolo Bypass

The NDFS study found that pulse flows appeared to move low DO water from upstream locations to monitoring stations immediately downstream in the Yolo Bypass (Figure 4-60), causing DO to drop (Figure 4-61). Daily average DO levels dropped below 6 mg/L on 67% of days during the pulse flow. In comparison, 18% of days decreased below 6 mg/L before the pulses, and 16% after. The NDFS study also found that larger flow pulses caused sudden DO drops to levels below 4-5 mg/L (Davis et al. 2021), when severe impairment occurs (Table 4-12). Sudden DO drops are of particular concern as mass mortality of Chinook Salmon has been observed during such events, evidenced in the 2021 fish kill in nearby Putah Creek (Rabidoux et al. 2022).

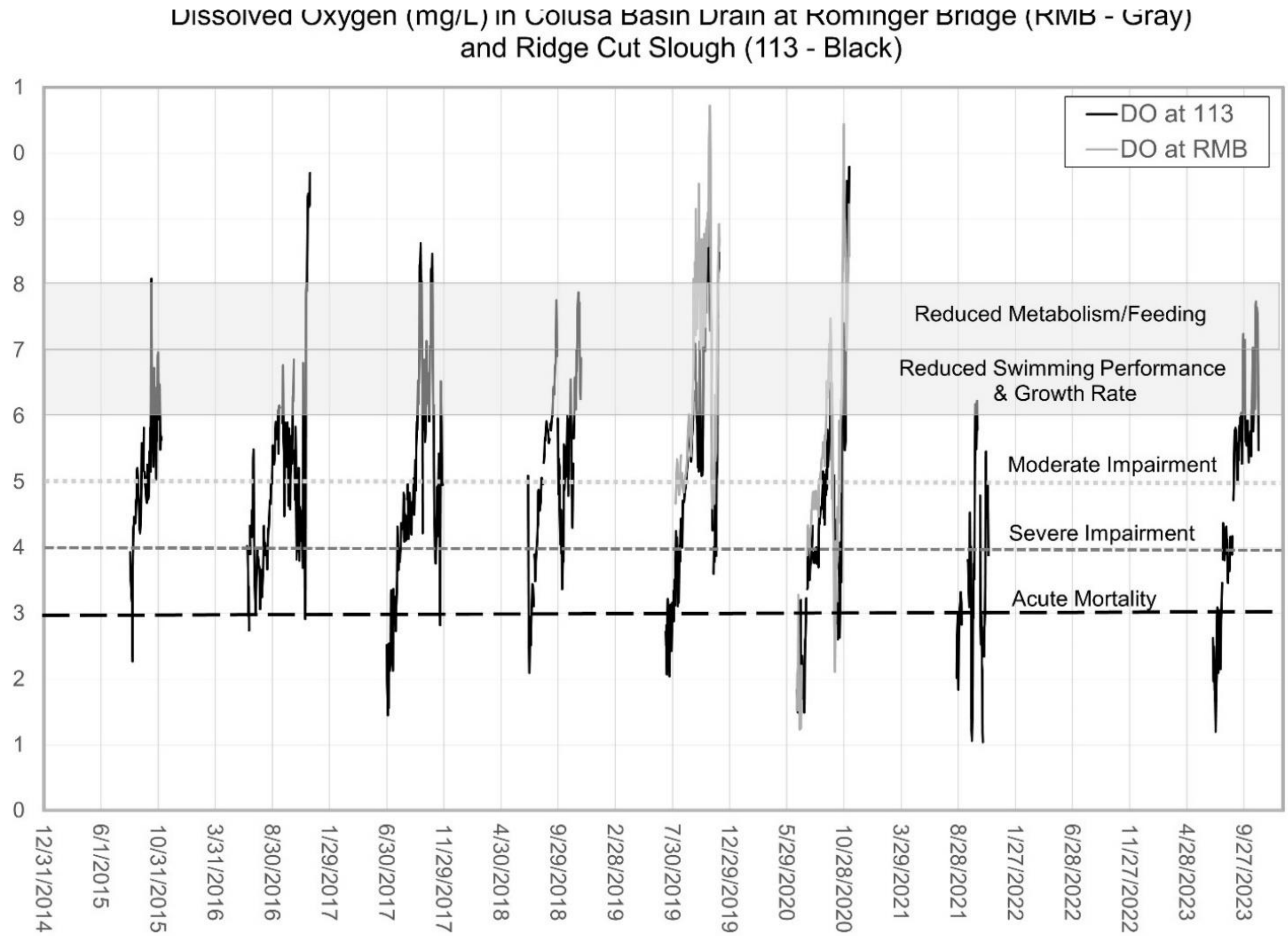


Figure 4-60. Dissolved oxygen concentrations measured in Colusa Basin Drain at Rominger Bridge (RMB) and Ridge Cut Slough (RCS) located a short distance from Knights Landing Outfall Gates.

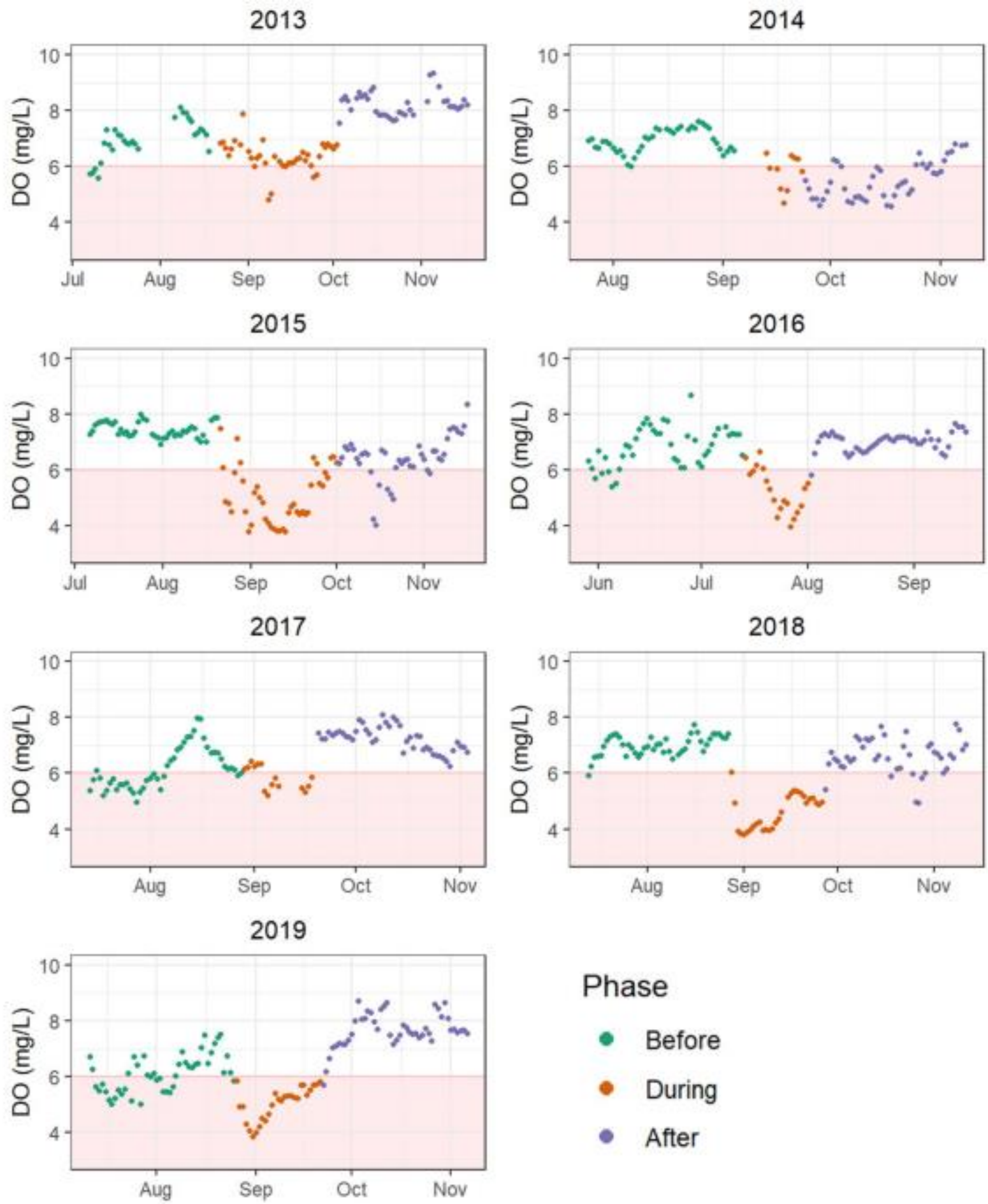


Figure 4-61. Dissolved oxygen levels observed at Lisbon Weir (LIS) before, during and after pulse flows conducted during the North Delta Food Subsidy Study, from Davis et al. 2021.

Dissolved Oxygen in the Sacramento River

Changes to DO in the Sacramento River as a result of Project discharges are a function of flow in the Sacramento River and the volume and DO of the release water. DO levels of water released at KLOG will depend on the DO of water already in the CBD that may be pushed out by Project discharges, the DO of water that is released from Sites Reservoir, and changes that occur to that water as it travels down the CBD to the KLOG. Because specific DO levels and flows were unclear in the ITP Application (Sites Authority 2023), CDFW used a mass balance approach similar to temperature in Section 4.1.2.2 to estimate DO levels on the Sacramento River downstream of KLOG that may be expected as result of Project discharges.

The mass balance formula used to estimate the resulting DO on the Sacramento River downstream of KLOG resulting from Project discharges is:

Equation 8:

$$DO_{SacDown} = \frac{Q_{CBD}\ DO_{CBD} + Q_{SacUp} DO_{SacUp}}{Q_{CBD} + Q_{SacUp}}$$

Where $DO_{SacDown}$ is the DO in the Sacramento River downstream of KLOG, Q_{CBD} is the flow through the Colusa Basin Drain, DO_{CBD} is the dissolved oxygen in the Colusa Basin Drain, Q_{SacUp} is the flow on the Sacramento River upstream of KLOG, and DO_{SacUp} is the dissolved oxygen in the Sacramento River upstream of KLOG.

Separate estimates were examined for a 1,000 cfs and 4,000 cfs discharge at KLOG, based on Project estimate of total flows through the CBD and released at KLOG (J. Spranza pers. comm. 7/22/24). CDFW's analysis assumed a consistent DO of 7.5 mg/L on the Sacramento River upstream of KLOG (DO_{SacUp}); this value is based on the lowest DO measurements taken by the USFWS Delta Juvenile Fish Monitoring Program between 2010 and 2023 at Reels Beach, approximately 6.5 km upstream of KLOG. This represents a conservative approach to assessing risk, as it represents the lower range of resulting DO that could be expected on the Sacramento River downstream of KLOG. DO data from the Ridge Cut Slough (RCS) monitoring station, located approximately 1 km from KLOG ("RCS", DWR Water Data Library station number A0D84761435), was used to represent oxygen in CBD (DO_{CBD}) or flow upstream of KLOG on the Sacramento River (Q_{SacUp}), CDFW used data from 2013 to 2023 at Sacramento River Below Wilkins Slough from (DWR CDEC station name - "WLK", latitude 39.009895°, longitude -121.824692°). The results are displayed in Figures 4-62 and 4-63.

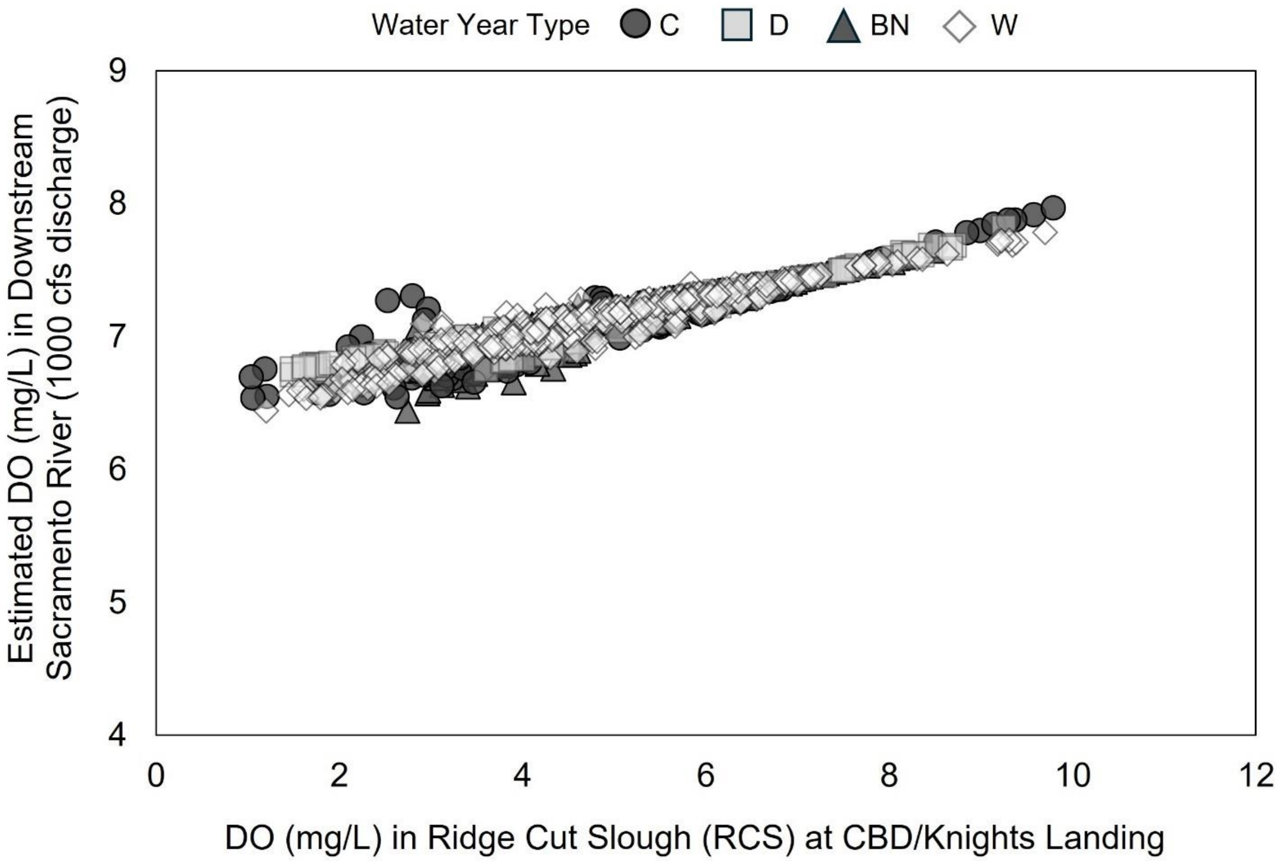


Figure 4-62. Estimated dissolved oxygen (DO) on the Sacramento River downstream of Knights Landing Outfall Gates (KLOG), assuming 1,000 cfs discharge from KLOG and a DO of 7.5 mg/L on the Sacramento River upstream of KLOG, in relation to DO on the Sacramento River in Ridge Cut Slough at Colusa Basin Drain (CBD)/Knights Landing. Water year types were classified using the Sacramento Valley Index and noted as Wet (W), Below Normal (BN), Dry (D), and Critical (C). There were no years with above normal water year types in this dataset.

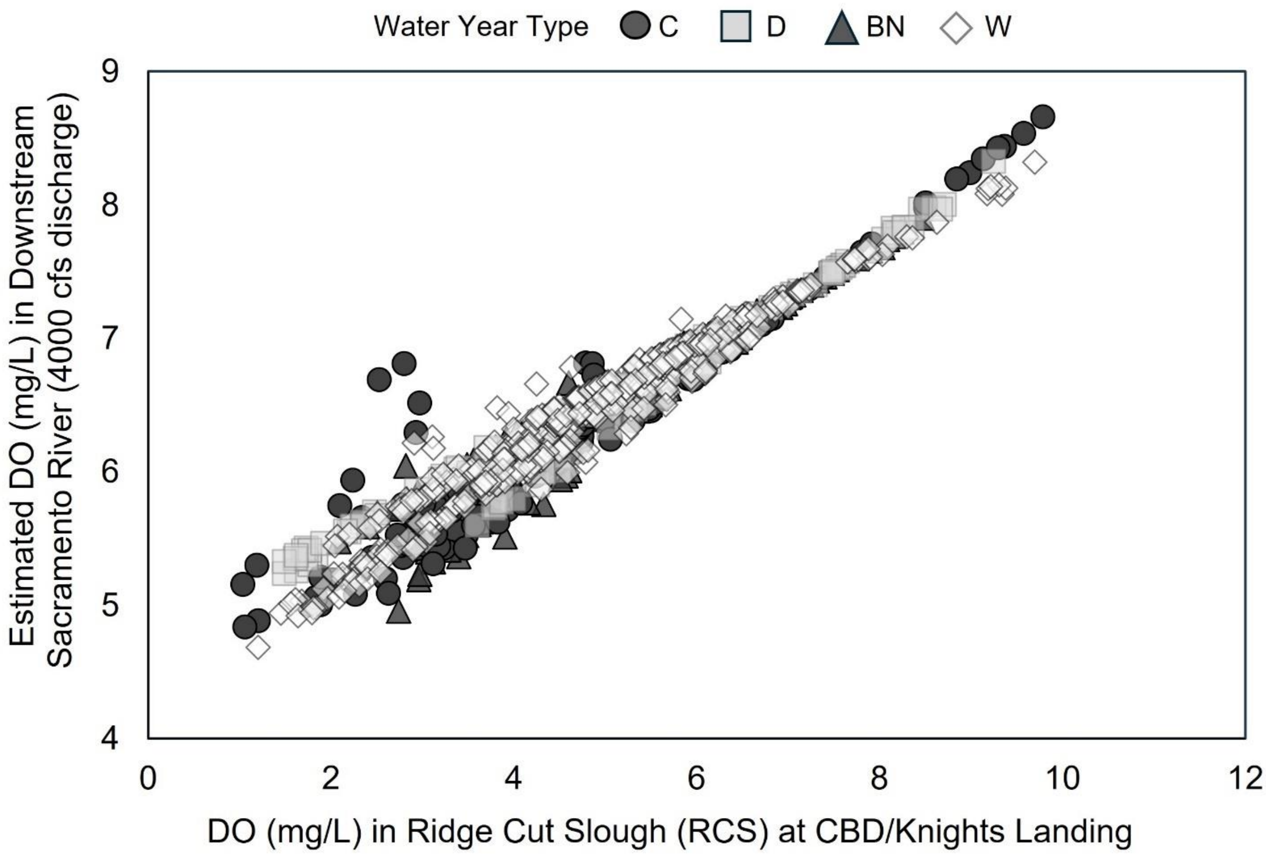


Figure 4-63. Estimated dissolved oxygen (DO) on the Sacramento River downstream of Knights Landing Outfall Gates (KLOG), assuming 4,000 cfs discharge from KLOG and a DO of 7.5 mg/L on the Sacramento River upstream of KLOG, in relation to DO on the Sacramento River in Ridge Cut Slough at Colusa Basin Drain (CBD)/Knights Landing. Water year types were classified using the Sacramento Valley Index and noted as Wet (W), Below Normal (BN), Dry (D), and Critical (C). There were no years with above normal water year types in this dataset.

Conclusions

DO levels in the KLRC (RCS monitoring station) adjacent to KLOG and in the Toe Drain downstream of KLOG are often below levels that cause lethal and sublethal impacts to Chinook Salmon (Figures 4-60 and 4-61). The NDFS pulse flow studies suggest that low DO water may be pushed into the Yolo Bypass or Sacramento River by discharges from Sites Reservoir. Given that: 1) DO concentrations at the RCS monitoring station are often well below levels that cause mortality and sub-lethal impairment to salmon (Figure 4-60); 2) the volumes and flows of discharges from Sites Reservoir will at times be larger than those implemented during the NDFS study; 3) specific DO concentrations in water that will be discharged from the reservoir are unclear; and 4) adult and juvenile CHNSR and CHNWR have been regularly observed immediately downstream of KLOG, as well as in the larger Sacramento River Basin and Yolo Bypass during proposed discharge periods, there is a potential for low DO impacts to CHNSR and CHNWR.

Based on the results of CDFW's mass balance analysis, Project discharges are unlikely to cause DO on the Sacramento River downstream of KLOG to drop below levels that cause impairment to salmon (5 mg/L) once they are fully mixed. However, some uncertainty remains. DO on the Sacramento River downstream of KLOG may drop below 5 mg/L if, 1) flows through CBD are larger than 4,000 cfs, 2) DO of water flowing out of KLOG is goes below approximately 2 mg/L, or 3) DO on the Sacramento River upstream of KLOG drops below 7.5 mg/L. In addition, adult CHNWR and CHNSR have been attracted to outflows at KLOG in the past (USBR and DWR 2012) and have been observed congregating immediately below the outfall gates. DO levels in the CBD near KLOG are frequently between 1 and 4 mg/L (Figure 4-60), levels that cause severe impairment and acute mortality in salmon (Table 4-12). Fish that are attracted to KLOG outflows and congregate below the outfall gates could be subject to direct contact with very low DO water that may be pushed out before it has a chance to mix with the Sacramento River. Because of these uncertainties and risks, it will be important to monitor and study the relationship between DO and Project discharges in the CBD, at KLOG immediately downstream of the outfall gates, as well as in downstream locations in the Sacramento River.

4.1.3.2. Pesticides

Discharges from the Project could transport water with high levels of contaminants, transporting it to areas where it may cause harm to winter-run Chinook Salmon and spring-run Chinook Salmon.

The ITP Application (Sites Authority 2023) notes that the proposed reservoir should contain low to no concentrations of pesticides but recognized that the Project's flow inputs to the contaminated CBD and KLRC could move pesticides downstream. Sites (2023) noted the potential for pesticide transport to the Yolo Bypass and Cache Slough Complex.

The NDFS study found that the sampling sites at upstream locations immediately above and within the Yolo Bypass had the highest numbers and concentrations of pesticides in the water and suspended sediment. These sampling locations included the RCS monitoring station located approximately 10 km north of the WWFCF, and the Road 22 monitoring station (RD22) in the Toe Drain located approximately 5 km south of the WWFCF (Figure 4-59). RD22 and RCS had the highest average number of pesticides detected per sample (20 and 16, respectively), and the highest total concentrations of pesticides (Figure 4-64). Sixty-one percent of samples collected from RD22 had at least one pesticide above United States Environmental Protection Agency (USEPA) aquatic life benchmarks, and 36% of samples from RCS contained pesticides at concentrations above the USEPA aquatic life benchmarks (Davis et al. 2021, Orlando et al. 2020).

The highest pesticide concentrations in water and zooplankton were found during the NDFS pulse flows, in comparison to periods before and after. The NDFS pulse flows also moved upstream water masses downstream to habitats of the Cache Slough Complex, indicating that contaminants could also be transported (Davis et al. 2021).

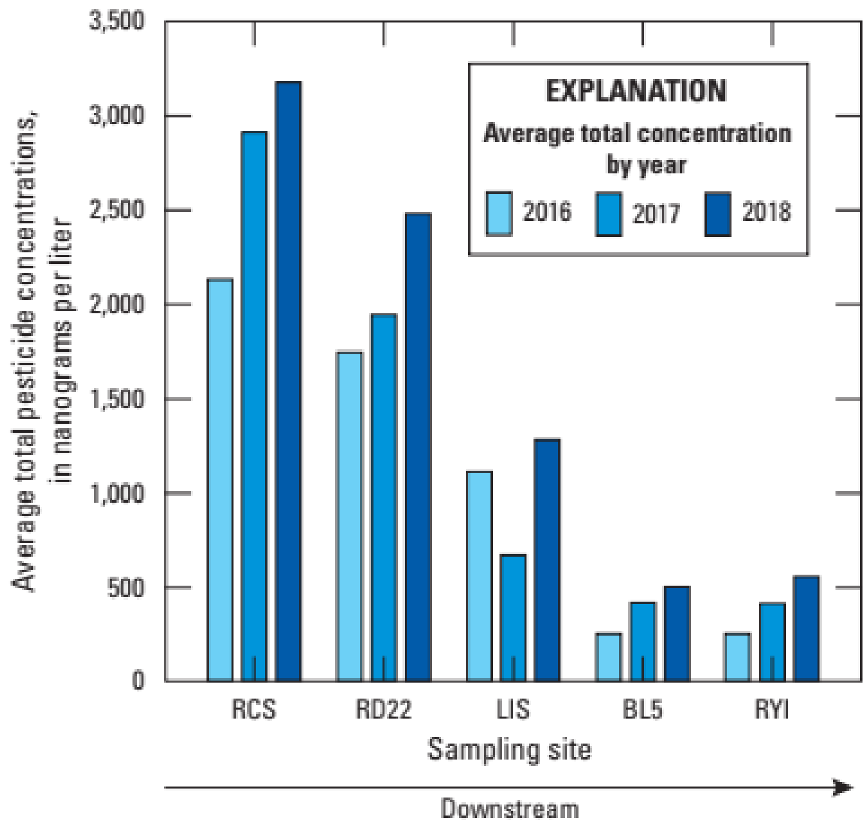


Figure 4-64. Average total pesticide concentrations sampled during the North Delta Food Subsidy study by sampling site and year from Orlando et al. (2020). Ridge Cut Slough is located immediately upstream of the Knights Landing Outfall Gates.

Though not all of the pesticides found at RD22 and RCS have been evaluated for lethal and sub-lethal toxicity to Chinook Salmon, many have been found to have physiological and behavioral impacts at relatively low concentrations (e.g., bifenthrin, fipronil, chlorpyrifos). Warmer temperatures and pesticide mixtures can amplify effects. For example, short term exposure to organophosphate and carbamate classes of insecticides decreases juvenile Chinook Salmon growth such that size at ocean entry is reduced (Baldwin et. al. 2009) which is a significant factor influencing fish survival (Zabel and Achord 2004; Woodson et al. 2013). Consumption of food containing bifenthrin or a mixture of bifenthrin and fipronil causes decreased swimming performance, important for eluding predators (Magnuson et al. 2022). Food containing low concentrations of pesticides, including several detected at RCS, has been found to result in reduced swimming performance at 19 °C, neuroendocrine system impacts at 14 °C, and olfactory impairment at 14 °C (Fuller et al. 2022; Magnuson et al. 2023). Olfactory and swimming impairment can reduce survival, as juvenile salmon rely on these abilities to detect and evade predators.

Conclusions

Given that: (1) The NDFS study found very high numbers and concentrations of pesticides in and around the KLOG and the WWFCF; (2) the NDFS study found that flow inputs transported water and constituents, including pesticides, from upstream locations downstream; (3) CHNSR adults have been captured in the Yolo Bypass in October; (4) some CHNWR juveniles are present in the Delta and lower Sacramento River Basin from August-October; (5) adult and juvenile CHNSR and CHNWR salmon have been regularly observed immediately downstream of KLOG, as well as in the larger Sacramento River Basin during proposed discharge periods and (6) several of the pesticides found during the NDFS study have known impacts on Chinook Salmon, the proposed releases from the Sites Reservoir to the Yolo Bypass and Sacramento River have the potential to impact CHNWR and CHNSR.

4.1.3.3. Metals/Metalloids

Sites Reservoir will constitute a new source of metal and metalloid contaminants that may be transported and released to areas that are impaired for mercury. Discharges may cause harm to winter-run Chinook Salmon and spring-run Chinook Salmon in the Sacramento River and Yolo Bypass.

The FEIR (Reclamation and Sites Authority 2023) notes that metals and metalloids, including mercury/methylmercury, copper, aluminum, iron, manganese, arsenic, nickel, selenium, and lead, may contaminate water directly in Sites Reservoir, and may be released in discharges to the CBD. Concentrations in the proposed reservoir are anticipated to be elevated in comparison to the Sacramento River due preexisting concentrations in water diverted from the Sacramento River, existing sources within the proposed reservoir footprint, and evapoconcentration in the reservoir. The specific concentrations of metals and metalloids upon discharge are unclear, but the FEIR (Reclamation and Sites Authority 2023) notes that they may be higher than ambient concentrations in the Sacramento River.

Mercury is a contaminant of particular concern for the Delta and Yolo Bypass. The Delta is on the Clean Water Act 303(d) list for waters impaired by mercury, and the Delta Mercury Control Program (DMCP) directs the DWR to reduce methylmercury outputs from out of compliance areas including the Yolo Bypass (OWW and OWMTMW 2020). The DMCP also requires that inputs to the

Yolo Bypass be reduced (CA RWQCB Central Valley Region, 2010). Currently, the methylmercury load to the Yolo Bypass is estimated to be 100 g/year, and target load allocation is 22 g/year (OWW and OWMTMW, 2020). Elevated methylmercury concentrations are common in newly flooded reservoirs for up to 10 years after filling, and Sites Authority expects mercury levels in the proposed reservoir to be double the long-term average for up to the first decade (Reclamation and Sites Authority 2023). Any additional mercury or methylmercury inputs from Project-related releases would further impair the Yolo Bypass.

Table 4-13. Lethal and sub-lethal metal/metalloid impacts to Chinook Salmon and related salmonids.

Metal or Metalloid	Concentration	Impact	Species	Reference
Copper	19-26 µg/L	Mortality	Juvenile Chinook Salmon	Chapman et al. 1978, Porter et al. 2023
Copper	1.9 µg/L	Reduced growth	Juvenile Chinook Salmon	Hecht et al. 2007
Copper	2 µg/L	Impaired predator detection and avoidance behavior	Juvenile Coho salmon	Sandahal et al. 2007
Copper	10-25 µg/L	Interrupts spawning migration	Adult Chinook Salmon	Hecht et al. 2007
Copper	25-50 µg/L	Olfactory damage and impairment	Chinook Salmon	Hansen et al. 1999
Selenium	5.3 µg/g in feed	Reduced growth	Juvenile Chinook Salmon	Hamilton et al. 1990
Selenium	9.6 µg/g in feed	Reduced survival	Juvenile Chinook Salmon	Hamilton et al. 1990
Mercury	10 mg/L	Reproductive impairment	Atlantic Salmon	Crump and Trudeau 2009
Methylmercury	40 mg/L	Reproductive impairment	Atlantic Salmon	Crump and Trudeau 2009
Methylmercury	4 mg/kg in feed	Liver damage, with impacts to metabolism, inflammation, oxidative stress and cell structure	Atlantic Salmon	Nostbakken et al. 2012
Aluminum	45 µg/L	Mortality	Juvenile Atlantic Salmon	Kroglund et al. 2008

Metal or Metalloid	Concentration	Impact	Species	Reference
Aluminum	38 µg/L	Gill impairment, impaired swimming speed	Juvenile Rainbow Trout	Wilson et al. 1994
Lead	13 µg/L	Reduction in red blood cell count, volume, iron content, enzyme activity.	Juvenile Rainbow Trout	Hodson 1978
Lead	7 µg/L	Physical abnormalities	Juvenile Rainbow Trout	Davies et al. 1976
Lead	10 µg/L	Reduced egg cell development	Adult Rainbow Trout	Ruby et al. 2000
Nickel	8.1-10.9 mg/L	Mortality	Juvenile Rainbow Trout	Nebeker et al. 1985
Nickel	11.6 mg/L	Acute respiratory toxicity	Adult Rainbow Trout	Pane et al. 2005

Metals, particularly heavy metals, are of concern for fish broadly because they do not degrade, bioaccumulate in organisms, and affect physiology (Kumar et al. 2024). Physiological effects can result in altered behavior, reduced growth and reduced survival. Of the metals noted as likely contaminants in Sites Reservoir (Sites Authority 2023), heavy metals include mercury, copper, arsenic, and lead. While this effects analysis is not a comprehensive review of metal and metalloid effects, some examples of impacts that can reduce survival and reproductive output for Chinook Salmon and other closely related salmonids are listed in Table 4-13.

Conclusions

Given that 1) Sites Reservoir will likely contain elevated concentrations of metals and metalloids that have lethal and sublethal effects on adult and juvenile Chinook Salmon and closely related salmonids at a range of concentrations; 2) it is unclear what the specific concentrations of metals will be upon discharge from the reservoir or after water transits through the CBD and into the Sacramento River or Yolo Bypass; 3) adult CHNSR have been captured at the WWFCF in October; and 4) juvenile CHNWR are present in the lower Sacramento River system during August-October, 3) CHNWR and CHNSR are likely to be located immediately downstream of the KLOG and in the adjacent Sacramento River during the period of proposed discharges, there is a potential for impacts to CHNWR and CHNSR from exposure to metals due to Project releases.

4.1.3.4. Harmful Algal Blooms

Operations of the Project could increase potential for harmful algal blooms, which may harm winter-run Chinook Salmon and spring-run Chinook Salmon in the Sacramento River and Yolo Bypass.

The FEIR (Reclamation and Sites Authority 2023) states that nutrient levels and warm temperatures in the proposed reservoir could facilitate the formation of HABs, particularly in drier water years when most releases would be made. The FEIR (Reclamation and Sites Authority 2023) acknowledges that harmful algae could be released from the reservoir and notes that dilution with the Sacramento River would negate negative effects. However, it is not clear whether HABs would be transported or increase as proposed releases move down the CBD and into the Yolo Bypass.

HABs are the largest cause of mortality to aquacultured salmon in British Columbia, Canada (Haigh and Esenkulova 2014). There is evidence that wild Chinook Salmon suffer similar physiological impacts from HABs as do farmed individuals, including feeding decreases, and damage to the gills and liver (Esenkulova et. al. 2022). *Microsystis*, a HAB genus frequently found in the Delta region (Bouma-Gregson et al. 2024), has also been found to cause liver damage to Chinook Salmon within 6 hours of exposure (Shartau et al. 2022).

Conclusions

Adult CHNSR have been captured at the WWFCF in October, and juvenile CHNWR are present in the lower Sacramento River system from August-October. CHNWR and CHNSR adults are likely to be attracted to outflows at KLOG, and CHNWR and CHNSR are regularly sampled immediately downstream from the outfall gates during the months proposed for reservoir discharges. If HABs or their toxins are present in discharges, there is a potential that they could impact CHNWR and CHNSR in the vicinity of KLOG, before dilution with the Sacramento River occurs. While it is likely that harmful algae and HABs will occur in Sites Reservoir, there is a low likelihood that algae or their toxins could be transported to the Sacramento River or Yolo Bypass and where they could come in contact with CHNWR or CHNSR.

4.1.4. Eggs, Fry and Juveniles: Survival, Rearing and Juvenile Production in the Sacramento River above Red Bluff

Project diversion and release locations are all downstream of Red Bluff, and therefore CHNWR and CHNSR spawning, egg incubation, and juvenile rearing upstream would not be directly affected by Project diversions or releases. Changes in flow and water temperature that affect habitat, survival, and juvenile production in this reach are due to changes in releases from Shasta

Reservoir related to CVP operational flexibility and exchanges with Sites Reservoir or directly with Project participants.

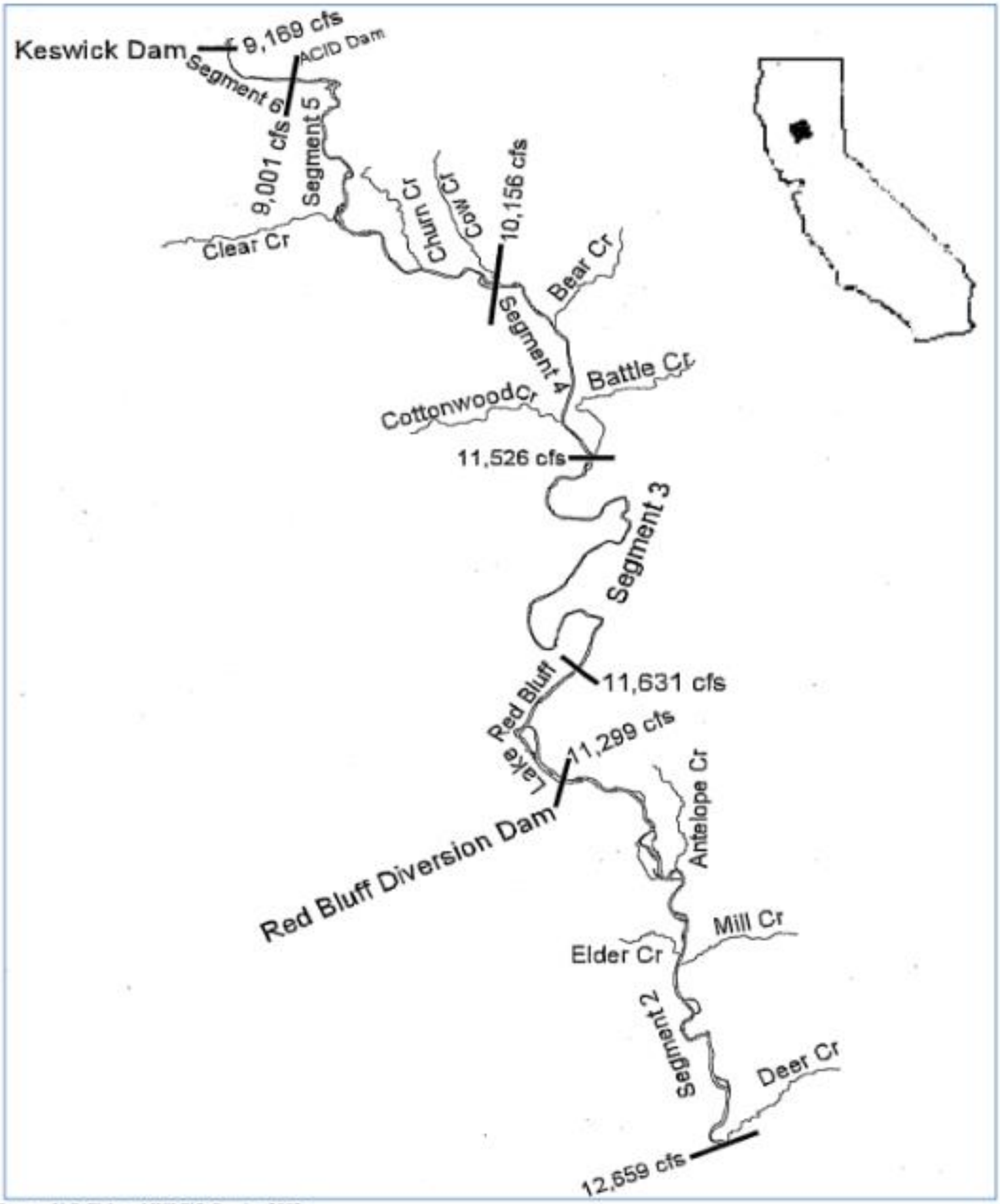
4.1.4.1. Upper Sacramento River Spawning Weighted Usable Area (WUA)

Changes in Shasta Reservoir operations due to Sites operational exchanges will cause changes in upper Sacramento River flow, potentially impacting the quality and availability of winter-run and spring-run Chinook salmon spawning habitat.

Weighted usable area (WUA) is a tool that can be used to evaluate the relationship between microhabitat complexity and flow within a stream (Bovee et al. 1998). It is typically calculated using the sum of the stream surface area within a study site, weighted by multiplying the area by the suitability criteria such as velocity, depth, substrate, and/or cover (Payne, 2003). The resulting model output is a dimensionless habitat index that is often related to habitat suitability and survival of aquatic taxa during rearing and spawning. However, the utility of a habitat suitability index strongly depends on the quality of the measured input data used in the calculations (Beecher et al. 2010; Gard 2009; Payne 2003).

The ITP Application (Sites Authority 2023) analyzed changes in spawning area WUA for CHNWR and CHNSR in three river segments in the upper Sacramento River (USFWS 2003; figure 4-65). Sites used monthly CalSim II modeled flow from water years 1922-2002 and a relationship between flow and spawning area developed by USFWS (2003) to estimate maximum available spawning WUA, generating WUA time series for the NAA and the Alt3B operational scenario for each of the three river segments. Spawning WUA was then calculated separately for CHNWR and CHNSR based on their spawn timing, with mean monthly WUA from April through July representing CHNWR and mean monthly WUA from August through September representing CHNSR.

The CHNWR spawning WUA analysis showed a mean increase of 0.262% in spawning WUA for the Alt3B operational scenario compared to the NAA (Table 4-14). For CHNSR spawning (August–October), there was mean difference of -1.084% in spawning WUA between the Alt3B operational scenario and the NAA across all three modeled reaches. CDFW found little difference between the long-term means of the Alt3B and NAA time series; however, differences were highly variable over time and across segments, with the standard deviations ranging from 4.02% to 8.62% (Figure 4-66 and Figure 4-67). Thus, while there were no long-term mean differences in WUA between Alt3B and the NAA, substantial month-to-month variation due to operational changes can be expected under the Project. The strongest observable pattern was a decrease in WUA under Alt3B, relative to the NAA, across all three modeled segments, with the largest decrease, -2.08%, in Segment 6 during CHNSR spawning months (Table 4-14).



Source: U.S. Fish and Wildlife Service 2003a.

Figure 4-65: Modeled Stream Segments for winter-run Chinook Salmon and spring-run Chinook Salmon spawning weighted usable area (WUA). Segments 4-6 were used in these analyses with CalSim II modeled flow from 1922-2002 paired with USFWS WUA curves. Source: USFWS (2003).

Table 4-14. Mean and standard deviation (SD) of annual percent change in winter-run and spring-run Chinook Salmon spawning weighted usable area (WUA) for Alt 3B relative to the NAA in Sacramento River Segments 4-6. Data provided by Sites (2023).

Sacramento River Segments	Winter-run Mean (%Diff)	Winter-run SD (%Diff)	Spring-run Mean (%Diff)	Spring-run SD (%Diff)
Segment 4	1.53	4.03	-0.37	7.67
Segment 5	0.49	4.52	-0.79	6.03
Segment 6	-1.23	6.29	-2.08	8.63

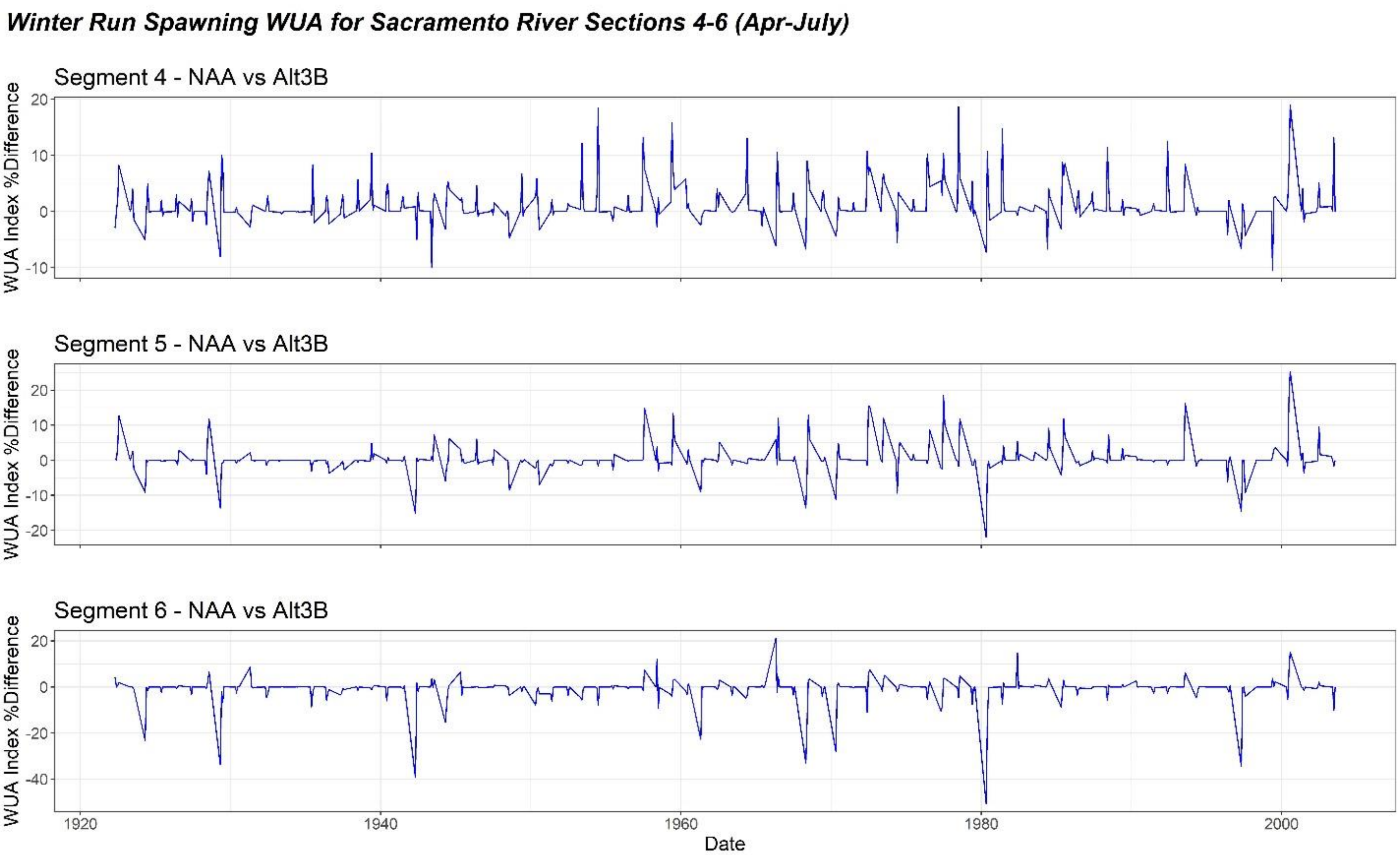


Figure 4-66. Sacramento River winter-run Chinook Salmon spawning weighted usable area (WUA) for spawning months (Apr-July).

To evaluate whether there were any long-term trends in the differences in spawning WUA between the NAA and the Alt3B operational scenario, CDFW used a time-series regression to evaluate if one time series could predict another. Results showed no significant difference between the time series, suggesting that Alt3B did not provide any significant long-term benefit or detriment to CHNWR and CHNSR spawning habitat. However, some months in some years showed substantial decreases in spawning WUA, especially for CHNSR, showing the potential for large reductions in spawning habitat availability during some years under Project operations.

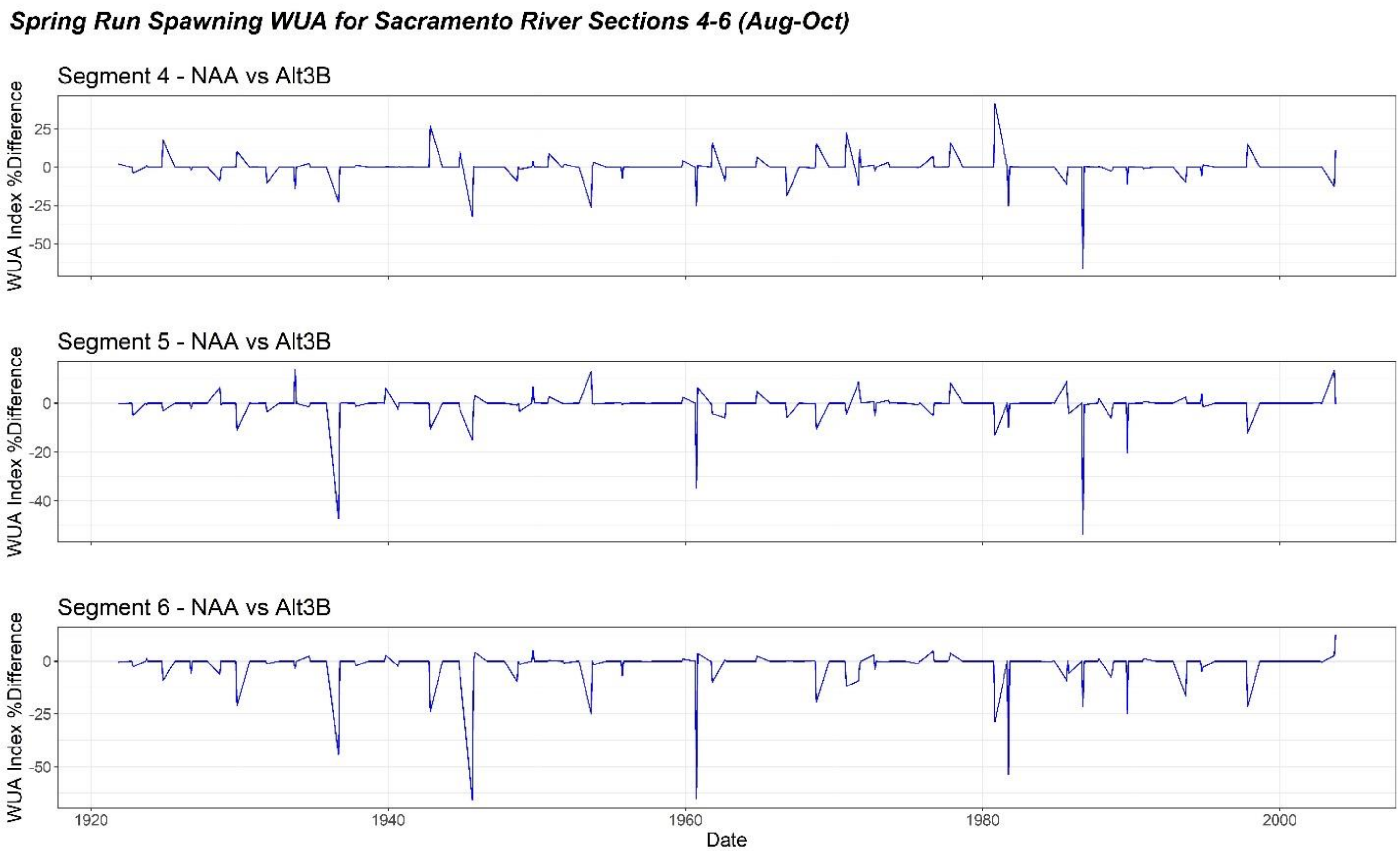


Figure 4-67. Sacramento River spring-run Chinook Salmon spawning WUA for spawning months (Aug-Oct)

CDFW's evaluation of the WUA modeling and its effectiveness across multiple published studies demonstrate limitations in its utility and a potential for misleading model interpretation. While some studies have found WUA to be a useful index in predicting spawning habitat use and survival of different fish species, an equivalent number have found it to be ineffective (Payne, 2003). When evaluating salmonid habitat usage and survival, WUA often fails to accurately predict where juveniles will rear due to alternative life-histories and complex behavioral strategies (Beecher et al., 2010; Irvine et al. 1987; Shirvell 1989). Additionally, WUA may not take into consideration changes in habitat due to inundation new areas such as gravel bar, side-channels, and riparian banks, leading to predicted decrease in habitat suitability instead of an increase. WUA methodology tends to be more effective in smaller watersheds where habitat can be more thoroughly ped and topographic changes are tracked through time (Payne 2003).

Conclusions

Given the results of the analysis in the ITP Application (Sites Authority 2023), CDFW's subsequent analysis, and review of the WUA index more generally, CDFW cannot draw definite conclusions on the effects of the Alt3B operational scenario as compared to the NAA. While the possibility exists of large changes in area of spawning habitat, as expressed by the large standard deviation range and negative peaks in the calculated difference time series, there are no significant differences between the two modeled flow scenarios.

4.1.4.2. Temperature Dependent Mortality

Changes in Shasta Reservoir operations due to Sites operational exchanges could cause changes in upper Sacramento River water temperatures, affecting survival of winter-run Chinook salmon eggs.

The DO content in water flowing through the gravel substrate of a redd, which sustains CHNWR eggs, decreases as water temperature increases. Warm, anoxic conditions can cause egg mortality and reduced egg-to-fry survival (Martin et al. 2020). This analysis aims to isolate the thermal component of egg mortality from other factors such as density-dependent mortality and redd dewatering. Both the Martin et al. (2017) model and the Anderson (2018) model start by calculating the lifetime of a redd, based on the days required to reach a specified cumulative degree-days threshold. While both models estimate mortality as a linear function that increases with temperature beyond a certain threshold, each model relies on different assumptions.

Using historical data, Martin et al. (2017) used an egg mortality regression model for CHNWR in the Sacramento River to identify 11.9 °C as a critical water temperature threshold for egg mortality. The study noted a discrepancy between laboratory and field estimates of egg mortality, attributing this difference to varying flow velocities in laboratory and field settings. Martin et al. (2017) then proposed a model to estimate temperature-dependent egg mortality in the field, calibrating its parameters using in situ CHNWR population data collected from 1996 to 2015.

Anderson (2018) refined the model by Martin et al. (2017) with two key changes: focusing on a five-day critical period just before hatching, instead of the entire redd lifespan, and using a different equation to estimate hatching dates. Analysis of field data from 2002 to 2015 showed that this critical period provided the best fit. Both models assume a linear relationship between mortality and temperature, with zero mortality below an 11.9 °C threshold. However, the Anderson model uses a steeper slope (0.5 compared to 0.024) to reflect the higher mortality impact within the shorter critical period. The method for calculating total mortality by summing daily survivals remains consistent with the Martin et al. (2017) model.

The ITP Application (Sites Authority 2023) applied the Martin and Anderson models to modeled HEC-5Q Sacramento River temperatures for the NAA and the Alt3B, NoSha, and NoShaOro operational scenarios. The analysis assumed the same spatiotemporal distribution of redds each year based on averaged location and timing from CDFW aerial surveys from 2007-2014). Simulated redds were subjected to mortality calculations and weighted by their distribution to estimate total seasonal mortality. This approach did not assume a total number of redds, as density-dependent mortality was not considered. The results reflect the percentage of the seasonal CHNWR egg population in the upper Sacramento River estimated to have experienced temperature-dependent mortality. Because a large percentage of modeled redds survive into October, and because the HEC5Q simulation ends in September, 2003, egg mortality was estimated only for the water years 1922-2002 (Table 4-15).

Table 4-15. Monthly average temperature dependent mortality (%), estimated using the Martin (2017) model, for winter-run Chinook Salmon for the No Action Alternative (NAA) and change in temperature dependent mortality between NAA and the Project scenario (Alt3B, NoSha, and NoShaOro). Results are based on HEC5Q modeled temperatures from Water Years 1922-2002 and averaged by water year type.

Month	Water Year Type	NAA	ALT 3B – NAA	NoShaOro – NAA	NoSha – NAA
May	All	0.31%	0.01%	0.00%	0.00%
May	Above Normal	0.14%	0.02%	0.00%	0.00%
May	Below Normal	0.13%	0.12%	0.01%	0.01%
May	Critical	0.85%	-0.12%	-0.07%	-0.09%
May	Dry	0.21%	0.02%	0.00%	0.00%
May	Wet	0.27%	0.00%	0.03%	0.03%
June	All	2.99%	0.20%	0.06%	0.07%
June	Above Normal	0.36%	0.12%	0.00%	0.00%
June	Below Normal	0.33%	0.40%	0.00%	0.00%
June	Critical	11.37%	0.78%	0.29%	0.34%
June	Dry	1.90%	-0.19%	-0.12%	-0.11%

Month	Water Year Type	NAA	ALT 3B – NAA	NoShaOro – NAA	NoSha – NAA
June	Wet	2.34%	0.11%	0.12%	0.12%
July	All	5.61%	0.44%	-0.01%	0.01%
July	Above Normal	0.70%	0.23%	-0.02%	-0.02%
July	Below Normal	1.05%	-0.14%	-0.17%	-0.14%
July	Critical	23.17%	3.75%	0.22%	0.30%
July	Dry	4.46%	-0.73%	-0.24%	-0.22%
July	Wet	2.75%	0.13%	0.13%	0.13%
August	All	7.15%	-0.33%	-0.09%	-0.13%
August	Above Normal	0.96%	0.20%	-0.02%	-0.02%
August	Below Normal	1.25%	-0.09%	-0.16%	-0.13%
August	Critical	31.81%	-1.44%	-0.38%	-0.70%
August	Dry	4.89%	-0.74%	-0.21%	-0.18%
August	Wet	3.03%	0.12%	0.13%	0.13%
September	All	9.86%	-0.88%	-0.12%	-0.11%
September	Above Normal	1.39%	-0.13%	-0.03%	-0.03%
September	Below Normal	2.44%	-0.57%	-0.14%	-0.11%
September	Critical	45.14%	-4.33%	-0.46%	-0.46%
September	Dry	6.77%	-0.75%	-0.19%	-0.16%
September	Wet	3.18%	0.13%	0.05%	0.05%
October	All	10.23%	-0.93%	-0.10%	-0.09%
October	Above Normal	1.95%	-0.57%	0.00%	0.00%
October	Below Normal	2.65%	-0.71%	-0.13%	-0.10%
October	Critical	46.28%	-4.08%	-0.40%	-0.44%
October	Dry	7.19%	-0.79%	-0.13%	-0.08%
October	Wet	3.21%	0.13%	0.05%	0.05%

Month	Water Year Type	NAA	ALT 3B – NAA	NoShaOro – NAA	NoSha – NAA
November	All	10.31%	-0.93%	-0.10%	-0.09%
November	Above Normal	2.07%	-0.56%	-0.01%	0.00%
November	Below Normal	2.71%	-0.70%	-0.13%	-0.10%
November	Critical	46.29%	-4.08%	-0.40%	-0.44%
November	Dry	7.23%	-0.79%	-0.13%	-0.08%
November	Wet	3.34%	0.13%	0.05%	0.05%

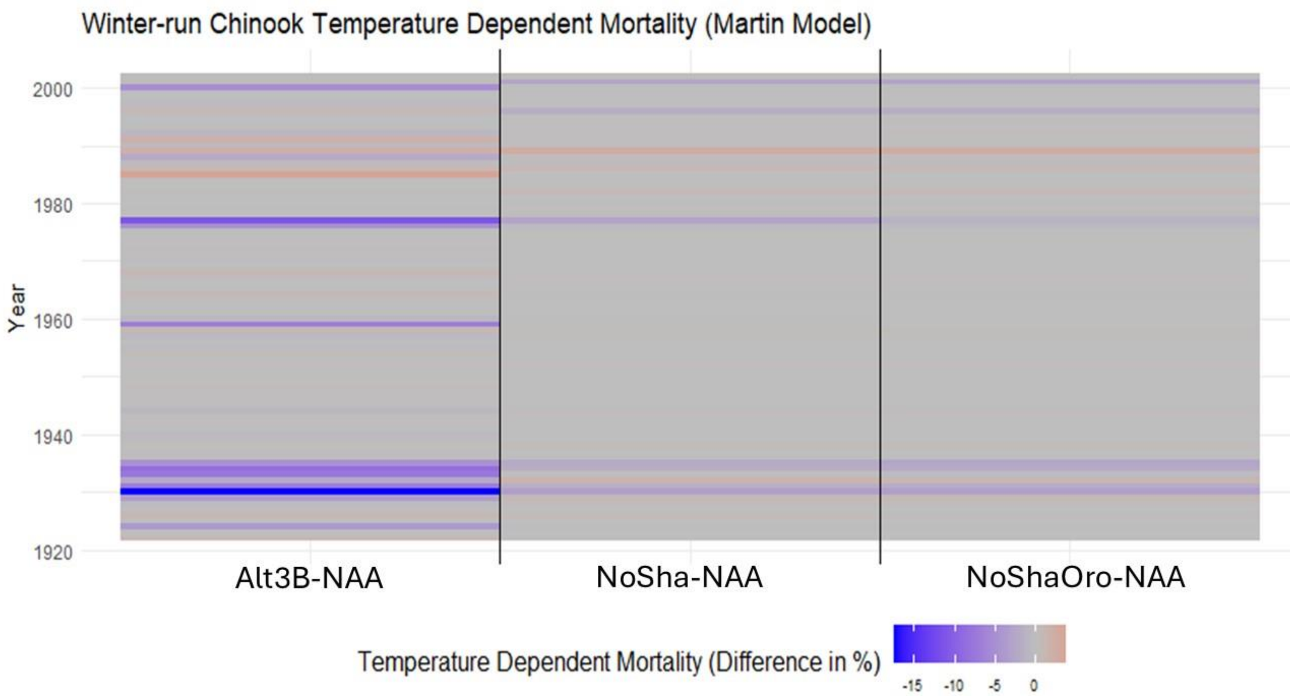


Figure 4-68. A heatmap showing the difference in winter-run Chinook Salmon redd temperature dependent mortality for water years 1922-2003 using HEC5Q Sacramento River Temperatures and Martin model parameters. Each operational scenario (i.e. Alt3B, NoSha, NoShaoOro) is shown as a difference to the No Action Alternative (NAA).

Compared to the NAA, Alt3B showed changes in annual CHNWR egg-to-fry survival ranging from decreases of 3.80% to increases of 17.54% based on the Martin (2017) model (Figure 4-68). In comparison, changes in temperature dependent mortality for the operational scenarios that do not include exchanges with Shasta Reservoir (i.e., NoSha and NoShaOro) showed changes in CHNWR egg-to-fry survival from -2.64% to 3.43% (Figure 4-68). The Anderson (2018) model yielded similar results (Figure 4-69). Alt3B showed changes in egg-to-fry survival of CHNWR ranging from -0.65 to +10.45 compared to the NAA. Changes in egg-to-fry survival for the NoSha and NoShaOro operational scenarios ranged from -1.60 to +3.29 (Figure 4-69).

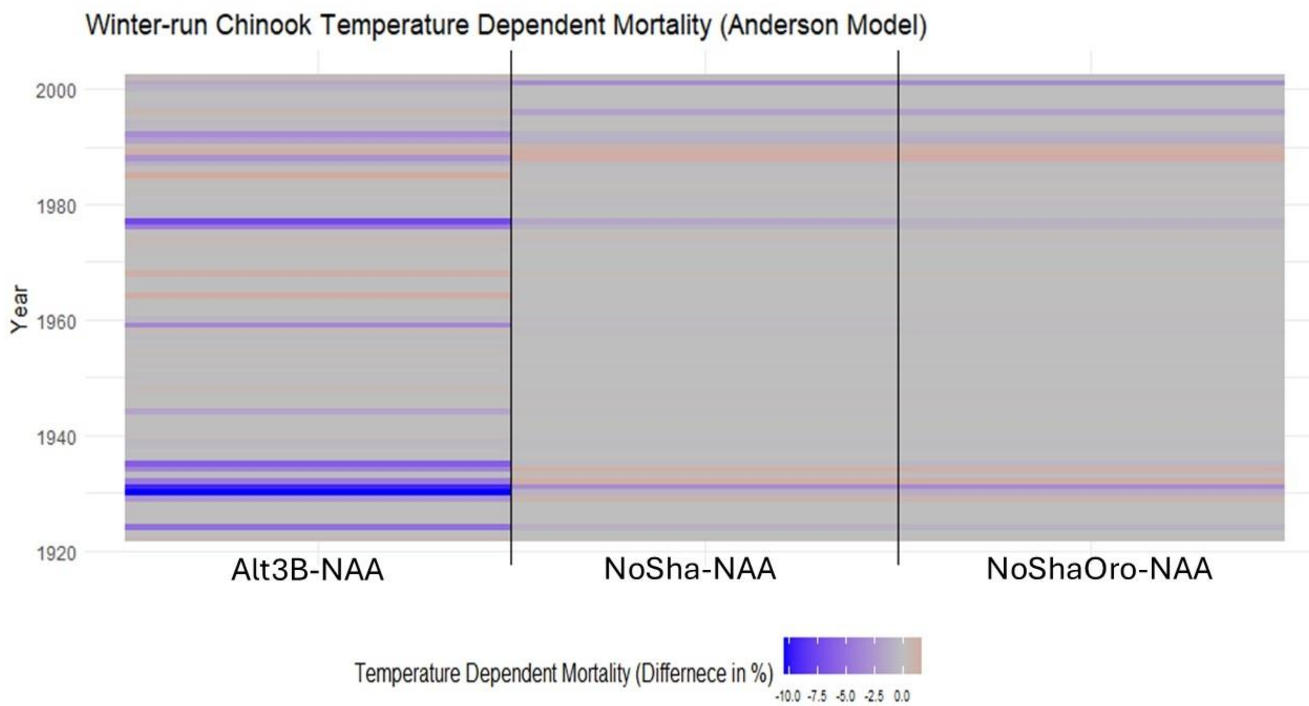


Figure 4-69. A heatmap showing the difference in winter-run Chinook Salmon redd temperature dependent mortality for water years 1922-2003 using HEC5Q Sacramento River Temperatures and Anderson model parameters. Each operational scenario (i.e. Alt3B, NoSha, NoShaoOro) is shown as a difference to the No Action Alternative (NAA).

Conclusions

Modeled effects of Project operations on the temperature dependent mortality in CHNWR redds were mixed, and differed between Alt3B, which includes operational exchanges with Shasta Reservoir, and the NoSha and NoShaOro operational scenarios, which do not. Exchanges with Shasta Reservoir for temperature benefits (Alt3B operational scenario) are predicted to increase CHNWR survival due to greater cold-water availability during some Critical and Dry water years, but only small changes in temperature dependent mortality are predicted under the NoSha and NoShaOro operational scenarios.

4.1.4.3. Redd Dewatering

Changes in Shasta Reservoir operations due to Sites operational exchanges may reduce upper Sacramento River flows during winter-run and spring-run Chinook Salmon egg incubation, causing redd dewatering and egg mortality.

Redd dewatering can occur when rapid decreases in flow leave shallow redds exposed, causing egg and alevin mortality (USFWS 2006). These dewatering events typically happen in shallow gravel bar and riffle habitats that have geomorphological features that increase risk of exposure. When evaluating dewatering, shallow redds (those in water shallower than approximately 2 ft) are the most vulnerable due to the managed flow regime in the upper Sacramento River, where summer flows can be as high as 14,000 cfs and can drop as low as 3,500 cfs in the fall (D. Killam personal communication 2024). Both CHNWR and CHNSR are vulnerable to redd dewatering if large flow changes occur after spawning and before emergence (Jarrett and Killam 2015; USFWS 2003).

The approach used in the ITP Application (Sites Authority 2023) analysis of redd dewatering in the Sacramento River utilized the functional relationships developed by the USFWS (USFWS 2006), which compare water elevation at a spawning flow with that at a minimum dewatering flow during the following 90-day period. A flaw of Projects analysis is that it averages out the daily flow fluctuations and potential redd dewatering over a monthly period, which discounts large daily fluctuations in flow that can lead to redd mortality (Tables 4-16 and 4-17).

CDFW conducted a similar analysis for redd dewatering using the same expanded tables from USFWS (2006) for the Sacramento River from Keswick Dam to Battle Creek; however, CDFW calculated the number of dewatered redds and the summary statistics differently. CDFW's analysis sought to identify the largest change in flow during the spawning and incubating period, corresponding to the maximum possible number of redds that could be dewatered due to project operations each year under the NAA and the Alt3B, NoSha, and NoShaOro operational scenarios. As there is no dewatering relationship table for CHNSR in USFWS (2006), fall-run (CHNFR) dewatering tables were used to estimate CHNSR redd dewatering using flows, timing, and spawning distributions from CHNSR.

CDFW used USRDOM daily flow for Below Keswick Dam and Clear Creek confluence to represent spawning flows for CHNWR and CHNSR, respectively, for the NAA, Alt3B, NoSha, and NoShaOro operational scenarios. CHNWR spawning was assumed to occur between Keswick Dam and Battle Creek from April through July, with the highest proportion of redds present from May through July. CHNSR spawning was assumed to occur in the same reaches from August to October, peaking in September.

Modeled seasonal changes to CHNWR redd dewatering ranged from 29% higher to 27.7% lower under Alt3B, relative to the NAA (Figure 4-70). Change in dewatering potential for CHNSR redds is predicted to range from +16.4% of redds to -28.9% under Alt3B, relative to the NAA (Figure 4-71). Differences between NAA and NoSha and NoShaOro operational scenarios were minimal for CHNWR and CHNSR and are summarized in Tables 4-16 and 4-17.

Based on USFWS (2006), flow reductions of as little as 250 cfs can potentially dewater up to 0.8% of CHNWR or CHNSR redds when spawning flows are around 3,500 cfs. Under higher spawning flow conditions of approximately 12,000 cfs, redd dewatering becomes increasingly likely as Keswick releases are reduced to baseflow conditions (approximately 3,500 cfs-5,000 cfs).

Table 4-16. Monthly average redd dewatering (%) for winter-run Chinook Salmon (i.e., redds built during the months of April-July) for the No Action Alternative (NAA) and change in redd dewatering (%) between NAA and each project scenario. Percent change from the NAA is shown in parentheses. Results are based on USRDOM daily modeled flows from Water Years 1922-2002 and averaged by water year type.

Month	Water Year Type	No Action Alternative	ALT3B–NAA	NoShaOro–NAA	NoSha–NAA
April	Wet	18.1	0 (-0.1%)	-0.1 (-0.3%)	-0.1 (-0.3%)
April	Above Normal	9.3	0.2 (2.7%)	0.1 (1.4%)	0 (0.1%)
April	Below Normal	2.3	0.1 (3.6%)	0.1 (3.5%)	0.1 (3.6%)
April	Dry	1.5	0.1 (5.7%)	0.1 (5.4%)	0.1 (5.3%)
April	Critical	1.2	0 (1.9%)	0.1 (5.5%)	0.1 (5.2%)
April	All	8.0	0.1 (0.7%)	0 (0.5%)	0 (0.3%)
May	Wet	2.4	-0.1 (-5%)	0 (0.9%)	0 (0.9%)
May	Above Normal	2.2	0.4 (16.4%)	0 (-0.1%)	0 (0%)
May	Below Normal	1.3	-0.1 (-10%)	0.1 (6%)	0.1 (6.9%)
May	Dry	1.5	-0.4 (-23.7%)	0 (2.7%)	0 (2.9%)
May	Critical	2.7	-0.8 (-31.2%)	0 (1.5%)	0 (1.5%)
May	All	2.0	-0.2 (-10.9%)	0 (1.8%)	0 (1.9%)
June	Wet	2.8	-0.4 (-13.1%)	-0.4 (-13.6%)	-0.4 (-13.6%)
June	Above Normal	5.4	-2.3 (-43.1%)	-0.1 (-2.6%)	-0.1 (-2.6%)
June	Below Normal	16.2	-2.1 (-13.2%)	0.6 (3.6%)	0.3 (2.2%)

Month	Water Year Type	No Action Alternative	ALT3B–NAA	NoShaOro–NAA	NoSha–NAA
June	Dry	20.8	-0.7 (-3.5%)	0.8 (3.9%)	0.7 (3.6%)
June	Critical	14.0	-3.1 (-21.9%)	0 (0%)	-0.2 (-1.4%)
June	All	11.2	-1.4 (-12.6%)	0.1 (1.2%)	0.1 (0.5%)
July	Wet	18.0	-0.2 (-1.1%)	-0.5 (-2.7%)	-0.5 (-2.7%)
July	Above Normal	21.8	-4.2 (-19.4%)	0.2 (1.1%)	0.2 (1%)
July	Below Normal	32.5	-1 (-3.2%)	1.3 (4.1%)	0.8 (2.3%)
July	Dry	28.5	-1.3 (-4.7%)	0.5 (1.9%)	0.5 (1.7%)
July	Critical	17.0	-1.4 (-8.5%)	0.1 (0.5%)	0.2 (1%)
July	All	23.3	-1.3 (-5.5%)	0.2 (1%)	0.1 (0.6%)

Table 4-17. Monthly average redd dewatering (%) for spring-run Chinook Salmon (i.e., redds built during the months of August-October) for the No Action Alternative (NAA) and change in redd dewatering (%) between NAA and each project scenario. Percent change from the NAA is shown in parentheses.

Month	Water Year Type	NAA	ALT3B–NAA	NoShaOro–NAA	NoSha–NAA
August	Wet	21.4	0.2 (0.9%)	0.2 (1.1%)	0.2 (1.1%)
August	Above Normal	23.8	-4.2 (-17.8%)	1.8 (7.5%)	1.8 (7.6%)
August	Below Normal	28.9	-1.8 (-6.1%)	1.2 (4.2%)	0.5 (1.8%)
August	Dry	25.6	0.1 (0.5%)	0.9 (3.5%)	1 (3.8%)
August	Critical	16.8	1.6 (9.4%)	0.8 (4.7%)	0.6 (3.8%)
August	All	23.3	-0.5 (-2.2%)	0.8 (3.6%)	0.7 (3%)
September	Wet	18.2	0.5 (2.5%)	0.8 (4.6%)	0.8 (4.6%)
September	Above Normal	21.2	-1.4 (-6.7%)	1.1 (5%)	1.1 (5%)
September	Below Normal	6.5	-0.4 (-6.7%)	-0.2 (-2.3%)	-0.3 (-4%)
September	Dry	5.0	-0.2 (-4.3%)	-0.3 (-6.7%)	-0.2 (-4.4%)
September	Critical	6.3	1.4 (21.5%)	0.2 (2.5%)	0.2 (2.5%)
September	All	11.8	0.1 (0.4%)	0.3 (2.8%)	0.3 (2.9%)

Month	Water Year Type	NAA	ALT3B–NAA	NoShaOro–NAA	NoSha–NAA
October	Wet	9.5	0.2 (1.6%)	-0.2 (-1.8%)	-0.3 (-2.8%)
October	Above Normal	13.7	-0.4 (-2.7%)	-0.4 (-3.1%)	-0.4 (-3.1%)
October	Below Normal	10.1	0.2 (1.9%)	-0.4 (-4%)	-0.3 (-2.8%)
October	Dry	11.1	1.2 (11%)	0.7 (6.3%)	0.8 (7.3%)
October	Critical	11.1	-0.9 (-7.9%)	-0.2 (-1.7%)	-0.2 (-2.1%)
October	All	10.7	0.2 (1.7%)	-0.1 (-0.5%)	0 (-0.4%)

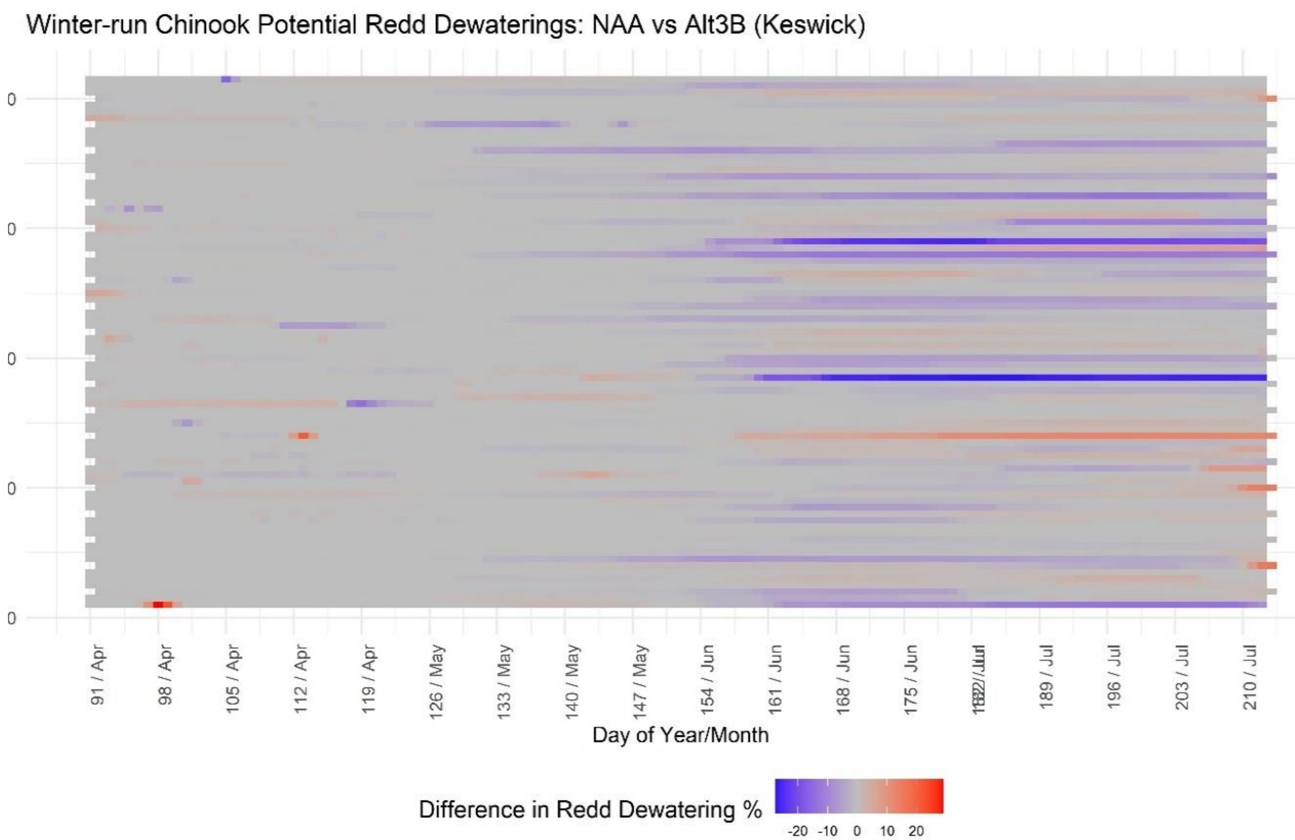


Figure 4-70. Heatmap showing the percent (%) change in daily potential for redd dewatering for winter-run Chinook Salmon (i.e., redds built during the months of April-July) for the Alt3B operational scenario compared to the NAA for Water Years 1922-2003.

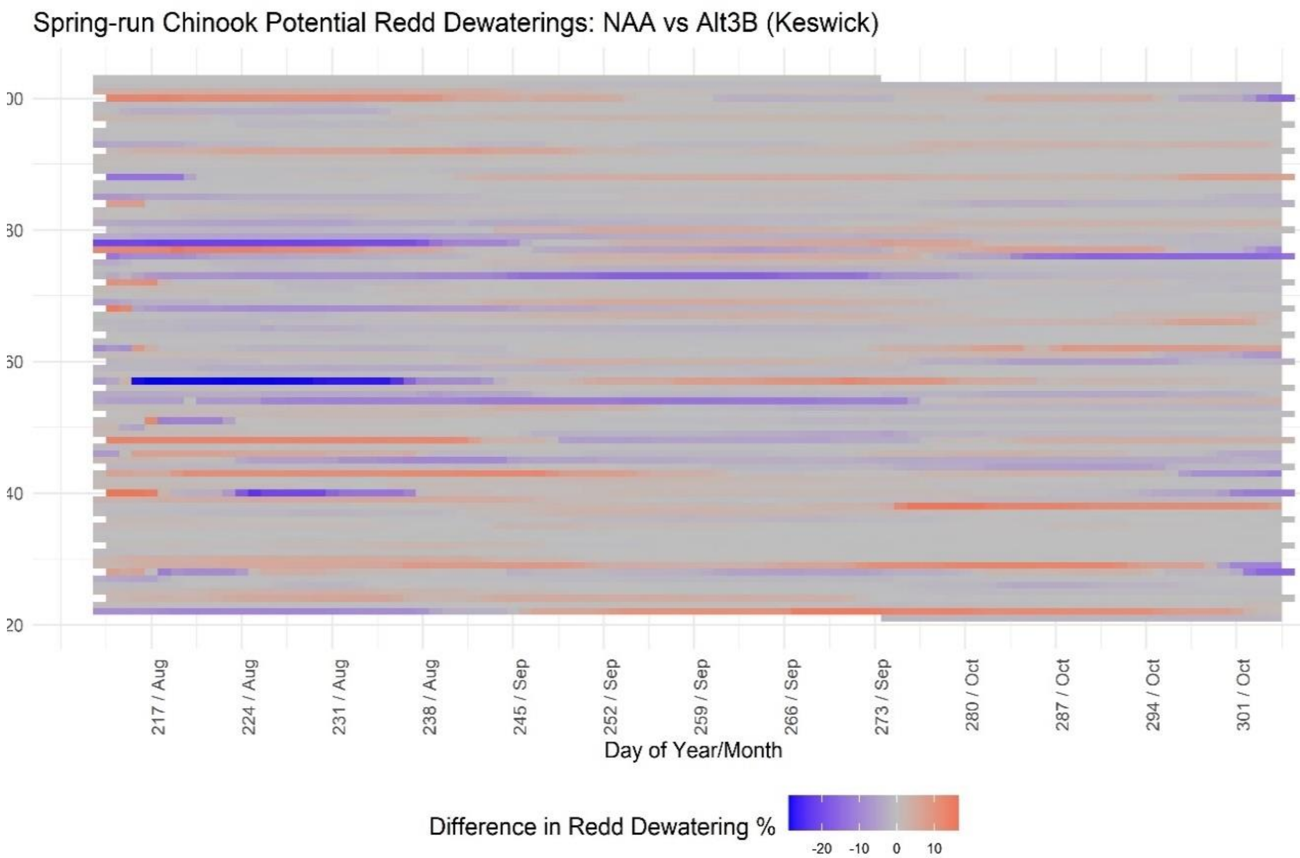


Figure 4-71. Heatmap showing the percent (%) change in daily potential for redd dewatering for spring-run Chinook Salmon (i.e., redds built during the months of August-October) for the Alt3B operational scenario compared to the NAA for Water Years 1922-2003.

Conclusions

The redd dewatering analysis and literature review conducted by CDFW indicate that Project operational exchanges with Shasta Reservoir and/or CVP operational flexibility under Alt3B may lead to both increases and decreases in redd dewatering, depending on annual fluctuations in hydrological conditions. Averaged over the USRDOM simulation period (1922-12003), the modeled Alt3B operational scenario would result in small increases in redd dewatering for CHNSR and small decreases in redd dewatering for CHNWR.

4.1.4.4. Redd Scouring/Entombment

Changes in flow due to changes in Shasta Reservoir operations with Sites operational exchanges may move spawning gravel during the egg incubation period, scouring redds and causing mortality of eggs and alevin.

Redd scouring or entombment can occur when rapid increases in flow mobilize sediments and lead to the destruction of redds and their incubating eggs and alevin (May et al. 2009). There are limited data to show how much flow is needed to mobilize sediments and damage redds, but the few available sources show a range for the Sacramento River of 24,000 to 50,000 cfs (Cain and Monohan 2008). The analysis in the ITP Application (Sites Authority 2023) used 40,000 cfs as the threshold for gravel mobilization, a relatively conservative estimate based on past work from the American River (Ayres Associates 2001). USRDOM daily flow estimates for existing conditions and the Project were used to compute the proportion of days at three locations (below Keswick Dam, Clear Creek confluence, and Battle Creek confluence) on which the Sacramento River exceeded 40,000 cfs. CHNWR redds are assumed to be present in this section of the river from April–October, with the highest proportion of the redds being present from May–September. CHNSR redds are assumed to be present from August–January, with a peak in September–December.

Conclusions

Results showed 0.0-0.1% differences in redd scouring, based on the percentage of days during the egg incubation period with flows greater than 40,000 cfs. Given the outcome of this analysis and on review of redd scouring literature, CDFW concludes that the Project will not substantially change the frequency of CHNWR or CHNSR redd scour or entombment.

4.1.4.5. Upper Sacramento River Rearing Habitat Weighted Usable Area (WUA)

Changes in Shasta Reservoir operations due to Sites operational exchanges will cause changes in flow, potentially impacting the quality and availability of rearing habitat for winter-run and spring-run Chinook Salmon juveniles in the upper Sacramento River.

The ITP Application (Sites Authority 2023) calculated fry and juvenile rearing WUA for CHNWR and CHNSR in the upper reaches of the Sacramento River between Keswick Dam and Battle Creek (USFWS 2005b; Figure 4-72). Sites used monthly CalSim II modeled flow from water years 1922-2002 and a relationship between flow and rearing area developed by USFWS (2005b) to estimate maximum available rearing WUA, generating WUA time series for the NAA and the Alt3B operational scenario for each of the three river segments. Rearing WUA was calculated separately for fry and juvenile rearing for both CHNWR and CHNSR in these three segments (Table 4-18).

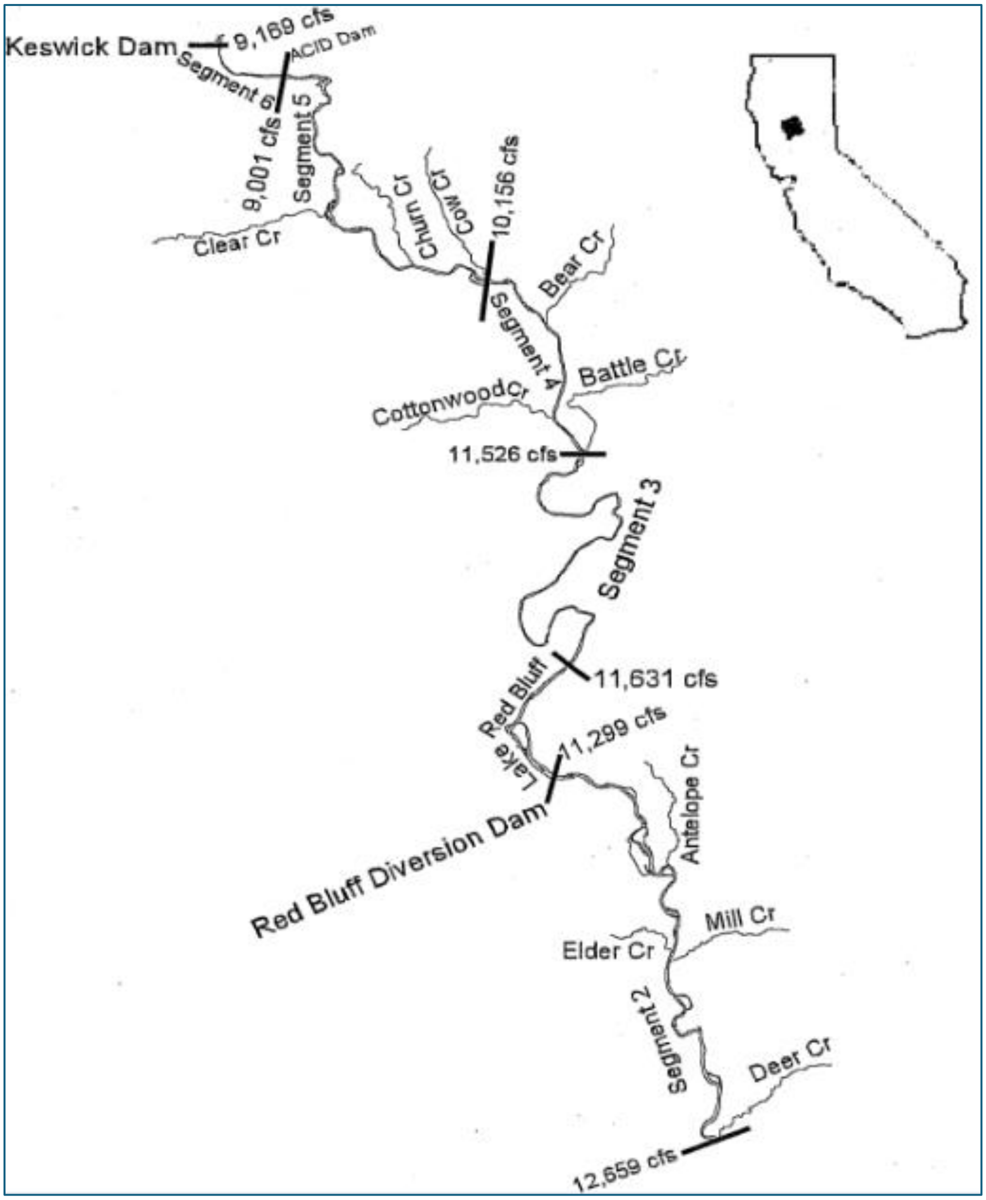


Figure 4-72. Modeled Stream Segments for winter-run Chinook Salmon and spring-run Chinook Salmon rearing weighted usable area (WUA). Segments 4-6 were used in this analysis with CalSim II modeled flow from 1922-2002 paired with USFWS WUA curves. Source: USFWS (2005b).

An important limitation of the rearing habitat analysis provided in the ITP Application (Sites Authority 2023) is that it does not evaluate changes in rearing habitat between the confluence of Battle Creek and the Delta, which represents roughly ~200 RM and contains a great deal of rearing habitat for CHNWR and CHNSR juveniles. Rearing habitats in the Sacramento River between Sites diversion points (Red Bluff at RM 243 and Hamilton City at RM 205.5) and the Knights Landing Outfall Gates (KLOG), where water is returned to the Sacramento River for delivery, are likely to be most affected by operations of the Project, yet there is currently very little understanding of potential changes to rearing habitat in this part of the river.

The ITP Application (Sites Authority 2023) analysis found little difference in long-term mean rearing WUA for either CHNWR or CHNSR between the Alt3B and the NAA for the reach between Keswick Dam and the confluence with Clear Creek. The mean differences across all three modeled reaches was an increase of 0.105% for Alt3B over the NAA for CHNWR fry and juveniles (Table 4-18, Figures 4-73 and 4-74) and an increase 0.308% for CHNSR fry and juveniles (Table 4-18, Figures 4-75 and 4-76). CDFW used a time-series regression to test for long-term trends and found no significant difference between the time series, suggesting that the Project would not provide any significant long-term benefit or detriment to CHNWR or CHNSR rearing WUA. Percent differences were highly variable over time and across segments, with standard deviations ranging from 2.18% to 10.2% (Table 4-18, Figures 4-73 through 4-76), suggesting that operational changes may have impacts on WUA on a shorter (e.g., monthly or seasonally) time scale.

Table 4-18. Mean and standard deviation (SD) of the annual percent change in winter-run and spring-run Chinook Salmon fry and juvenile rearing weighted usable area (WUA) for Alt 3B relative to the NAA in Sacramento River Segments 4-6. Data provided by Sites (2023).

Sacramento River Segments	Winter-run Fry Mean (%Diff)	Winter-run Fry SD (%Diff)	Spring-run Fry Mean (%Diff)	Spring-run Fry SD (%Diff)	Winter-run Juvenile Mean (%Diff)	Winter-run Juvenile SD (%Diff)	Spring-run Juvenile Mean (%Diff)	Spring-run Juvenile SD (%Diff)
Segment 4	0.121	2.766	0.070	4.246	0.161	3.439	1.114	10.237
Segment 5	-0.176	4.397	-0.122	4.877	0.023	2.178	0.118	3.520
Segment 6	0.060	5.264	0.462	4.851	0.440	5.358	0.207	5.300

Winter Run Fry Rearing WUA for Sacramento River Sections 4-6

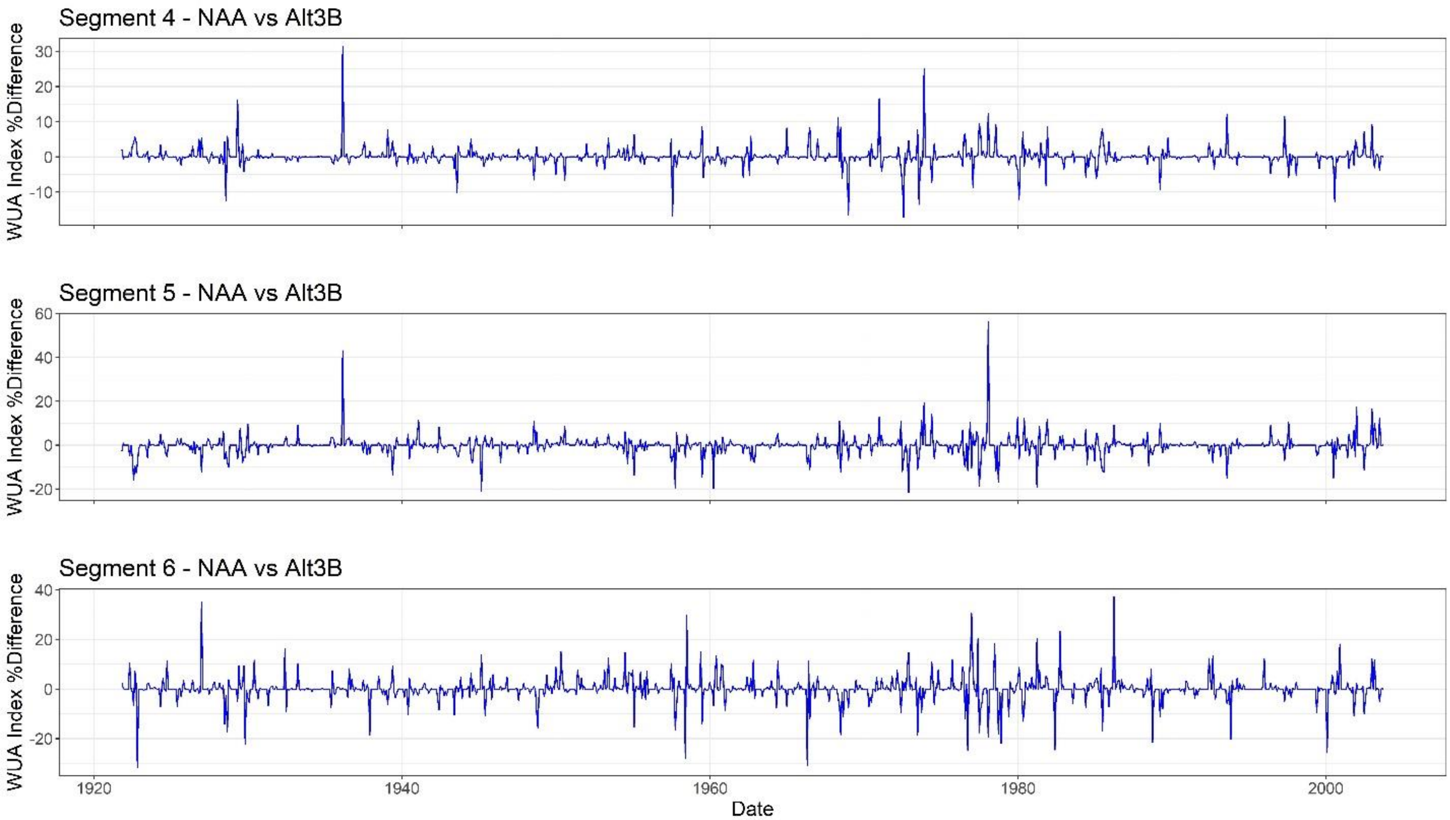


Figure 4-73. Sacramento River winter-run Chinook Salmon fry rearing weighted usable area (WUA).

Winter Run Juvenile Rearing WUA for Sacramento River Sections 4-6

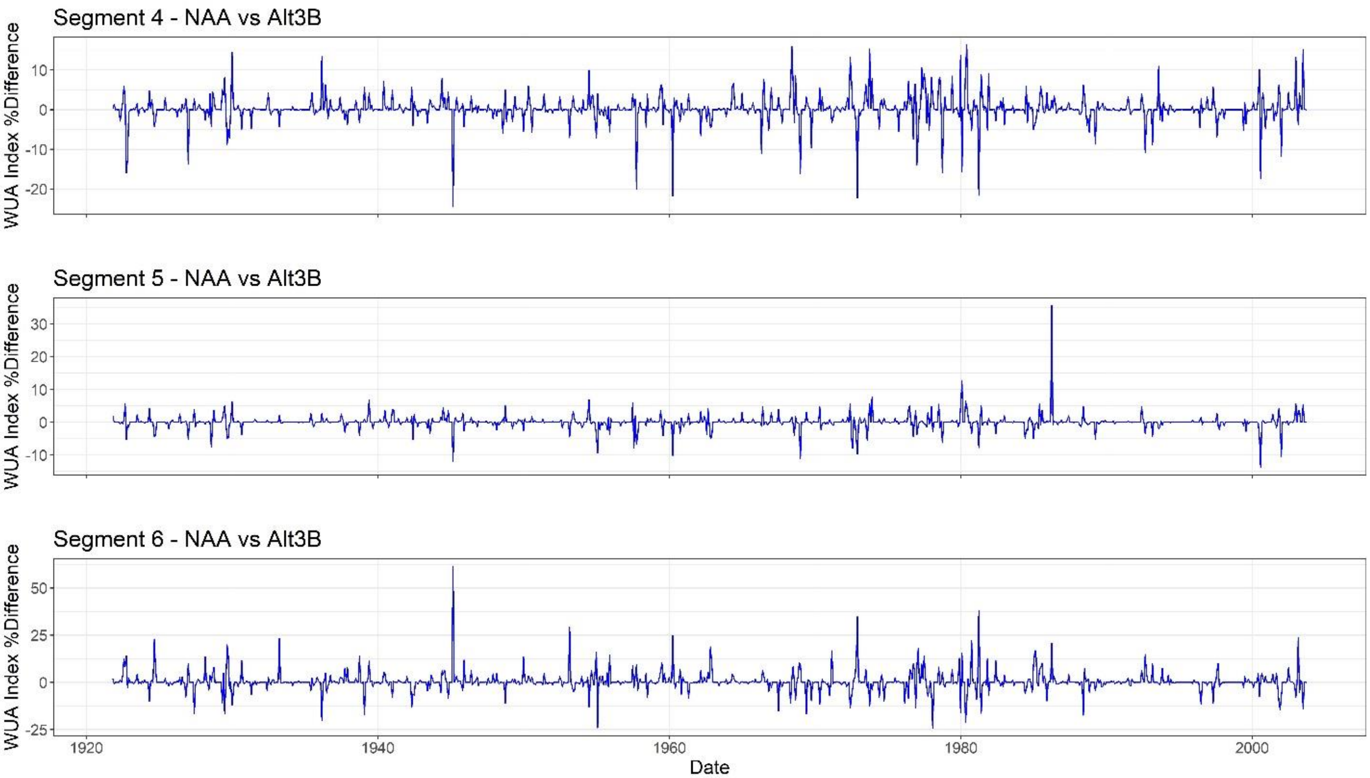


Figure 4-74. Sacramento River winter-run Chinook Salmon juvenile rearing weighted usable area (WUA).

Spring Run Fry Rearing WUA for Sacramento River Sections 4-6

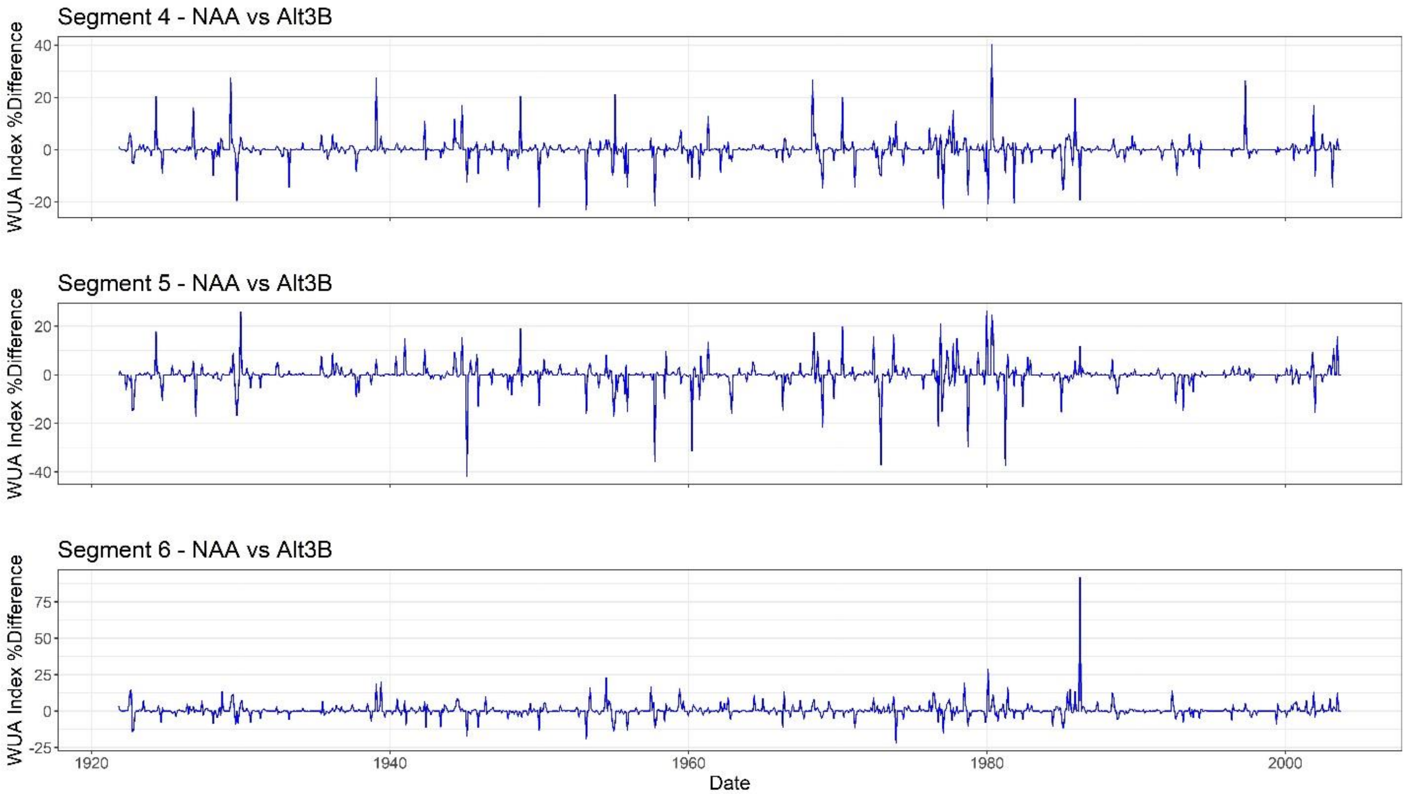


Figure 4-75. Sacramento River spring-run Chinook Salmon fry rearing weighted usable area (WUA).

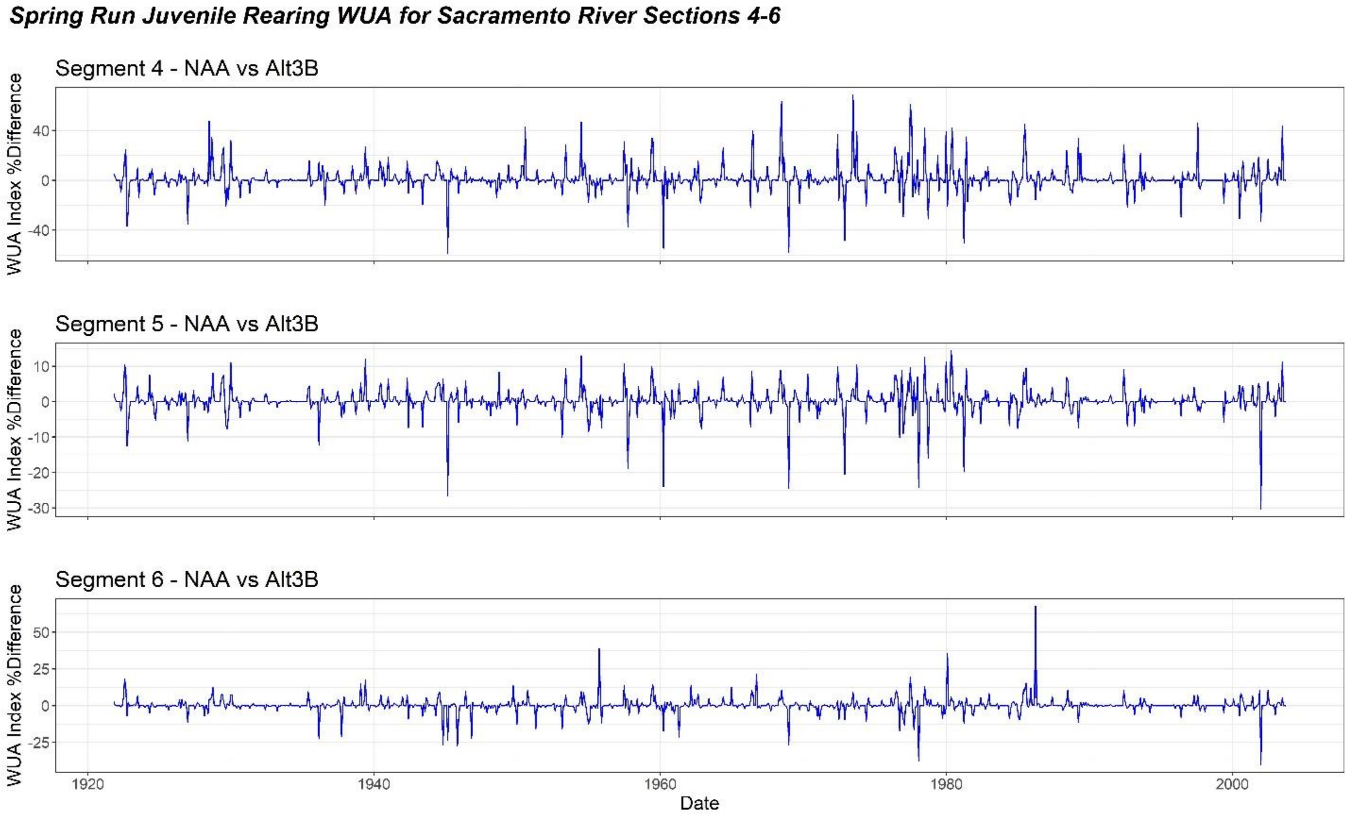


Figure 4-76. Sacramento River spring-run Chinook Salmon juvenile rearing weighted usable area (WUA).

CDFW's acknowledges the limitations of the WUA approach and urges caution when interpreting the results. While WUA can sometimes be a useful index, it is not consistently effective at predicting habitat use and survival of different fish species (Payne 2003). Rearing WUA analyses often fail to accurately predict where juveniles will rear due to alternative life-histories and complex behavioral strategies (Beecher et al. 2010; Irvine et al. 1987; Shirvell 1989). Beecher et al. (2010), found that WUA results were inconsistent with their empirical measurements of Coho salmon smolt production, as WUA supported lower summer base flows providing more favorable habitat while monitoring data showed that lower summer flows led to lower overall survival of the population. The WUA approach often does not consider changes in habitat size due to inundation of new areas such as gravel bars, side-channels, and riparian banks. This can result in WUA analyses that incorrectly conclude that suitable habitat decreases with increasing flows when the opposite is true. Additionally, WUA does not consider habitat use of juveniles exhibiting all life history strategies, as in the Coho example from Beecher et al. (2010). Coho salmon and many other salmonids express multiple behavioral strategies while rearing, including territorial, non-territorial, and floater individuals. While the WUA analysis of Beecher et al. (2010) correctly predicted the distribution of territorial individuals, these fish only make up a small portion of the population therefore cannot be used to accurately predict juvenile survival and habitat use for the population as a whole.

Conclusions

Based on the WUA analysis in the ITP Application (Sites Authority 2023), CDFW's WUA analysis, and CDFW's review of the WUA index as a rearing habitat indicator in general, CDFW cannot draw definite conclusions on the effects of the Project on rearing habitat in the Sacramento River upstream of Clear Creek. While it is possible that Project operations may result in substantially less suitable habitat in some months of some years, as expressed by the large standard deviation and negative peaks in the calculated difference time series, there were no significant differences between the two modeled flow scenarios. This could suggest that natural variation and flow management can both increase and decrease the amount of suitable habitat available in this reach. Additionally, the analyzed reach is only a small portion of the Sacramento River. Migration and rearing behavior of CHNWR and CHNSR fry and pre-smolt juveniles are currently poorly understood in the Sacramento River, and more information is needed about juvenile rearing in the reach between Red Bluff and the Delta.

4.1.4.6. Juvenile Stranding

Changes in Shasta Reservoir operations due to Sites operational exchanges could reduce flows and disconnect side channels during juvenile rearing, stranding winter-run Chinook Salmon and spring-run Chinook Salmon juveniles and leading to mortality.

Juvenile stranding occurs when rapid decreases in flow leave fish trapped in isolated pools that can eventually dry up (USFWS 2006). These stranding events typically happen in both in-channel and off-channel habitats with geomorphological features that cause pools to disconnect from the main channel. Compared to other Chinook Salmon life stages, fry are the most vulnerable to stranding due to their decreased swimming abilities and preference for shallower habitats less than 1 m deep. Both CHNWR and CHNSR are vulnerable to stranding as rapid drops in flow can occur at any time of year due to natural and anthropogenic hydrologic fluctuations (Dudley 2019; Jarrett and Killam 2015).

The ITP Application (Sites Authority 2023) evaluated risk of juvenile stranding in the Sacramento River from Keswick Dam to Battle Creek using functional relationships developed by the USFWS (2006). Project analysis uses an expanded table that compares water elevation at an initial flow with that at a minimum flow during the following 90-day period. In this section of the Sacramento River from Keswick Dam to Battle Creek, there are 107 potential stranding sites identified by the USFWS (2006), with 12 sites being split channels. An index table of flow relationships and the potential numbers of juveniles are used to make the calculations between flow stages and time periods. USRDOM daily flow estimates for the NAA and the Alt3B operational scenario were used to compute the potential number of stranded juveniles at three locations (below Keswick Dam, Clear Creek confluence, and Battle Creek confluence).

CHNWR juveniles are assumed to be present in this section of the river from July through October, with a higher proportion of fry being present earlier in this period. CHNSR YOY juveniles are present in the Sacramento River from November to February, with these fish typically migrating downstream quickly and at a small size. Based on USFWS (2006), flow reductions of as little as 250 cfs can produce stranding conditions for up to 1,097 fish when flows are around 3,500 cfs. Under flows greater than approximately 15,000 cfs, stranding become less likely due to increased depth at potential stranding sites (USFWS 2006). Results are shown in Figures 4-77 through 4-82.

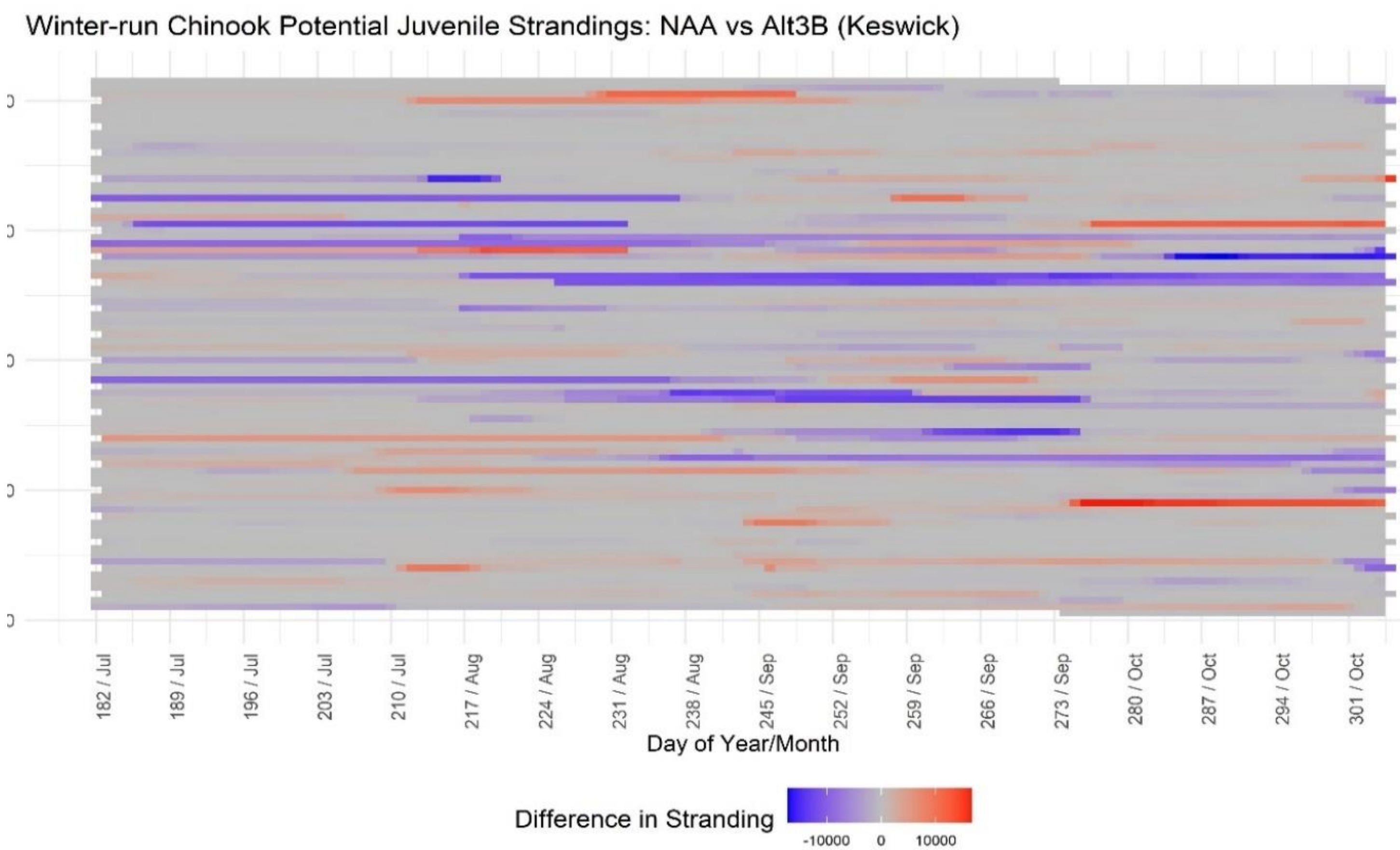


Figure 4-77. A heatmap showing the change in daily stranding potential for winter-run Chinook Salmon (CHNWR) juveniles for the Alt3B operational scenario relative to the NAA for the Sacramento River at Keswick. Results are presented for water years 1922–2003 for months when CHNWR fry would be rearing (July-October). Data from the ITP Application (Sites Authority 2023).

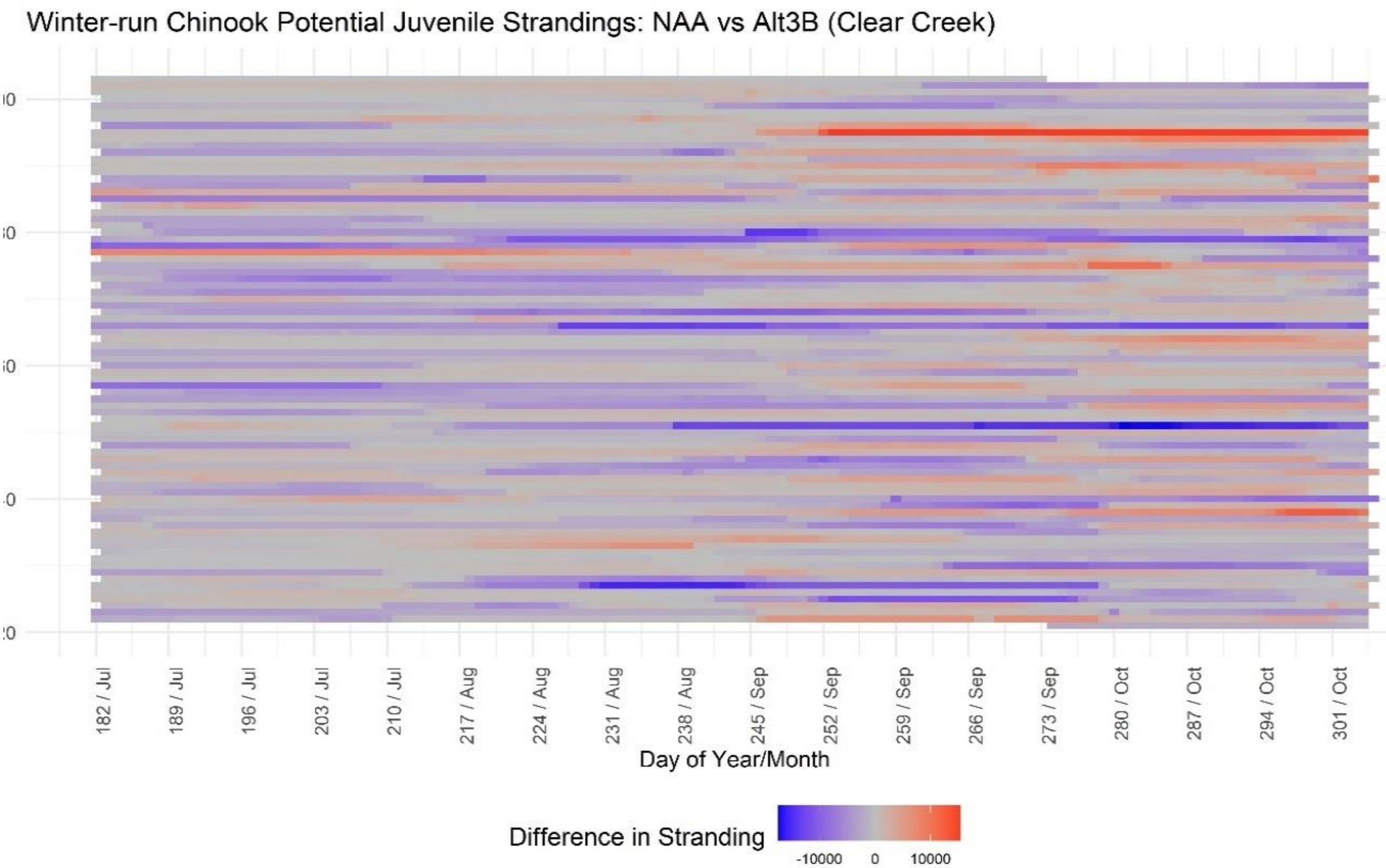


Figure 4-78. A heatmap showing the change in daily stranding potential for winter-run Chinook Salmon (CHNWR) juveniles for the Alt3B operational scenario relative to the NAA for the Sacramento River at Clear Creek). Results are presented for water years 1922–2003 for months when CHNWR fry would be rearing (July-October). Data from the ITP Application (Sites Authority 2023).

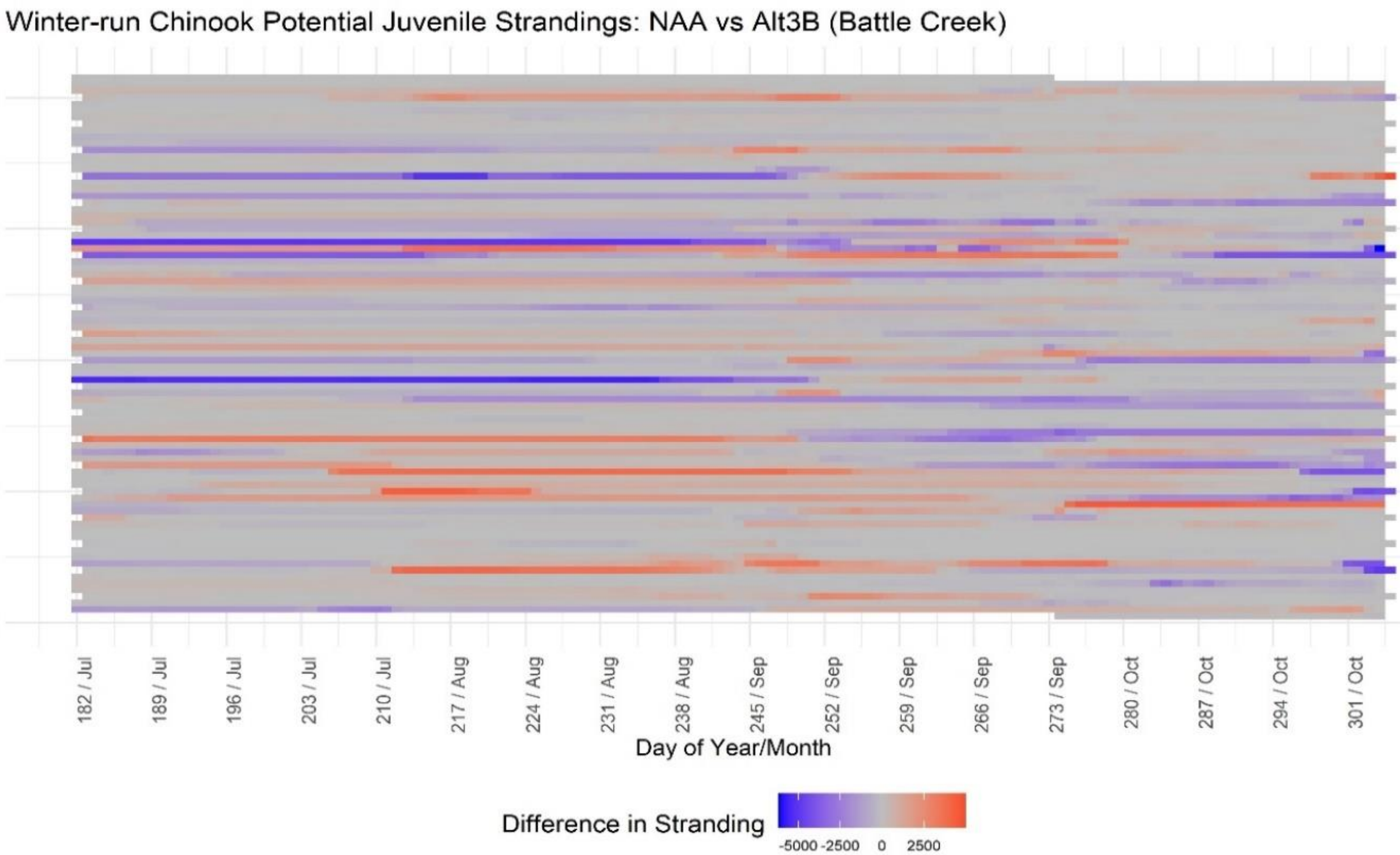


Figure 4-79. A heatmap showing the change in daily stranding potential for winter-run Chinook Salmon (CHNWR) juveniles for the Alt3B operational scenario relative to the NAA in the Sacramento River at Battle Creek). Results are presented for water years 1922–2003 for months when CHNWR fry would be rearing (July-October). Data from the ITP Application (Sites Authority 2023).

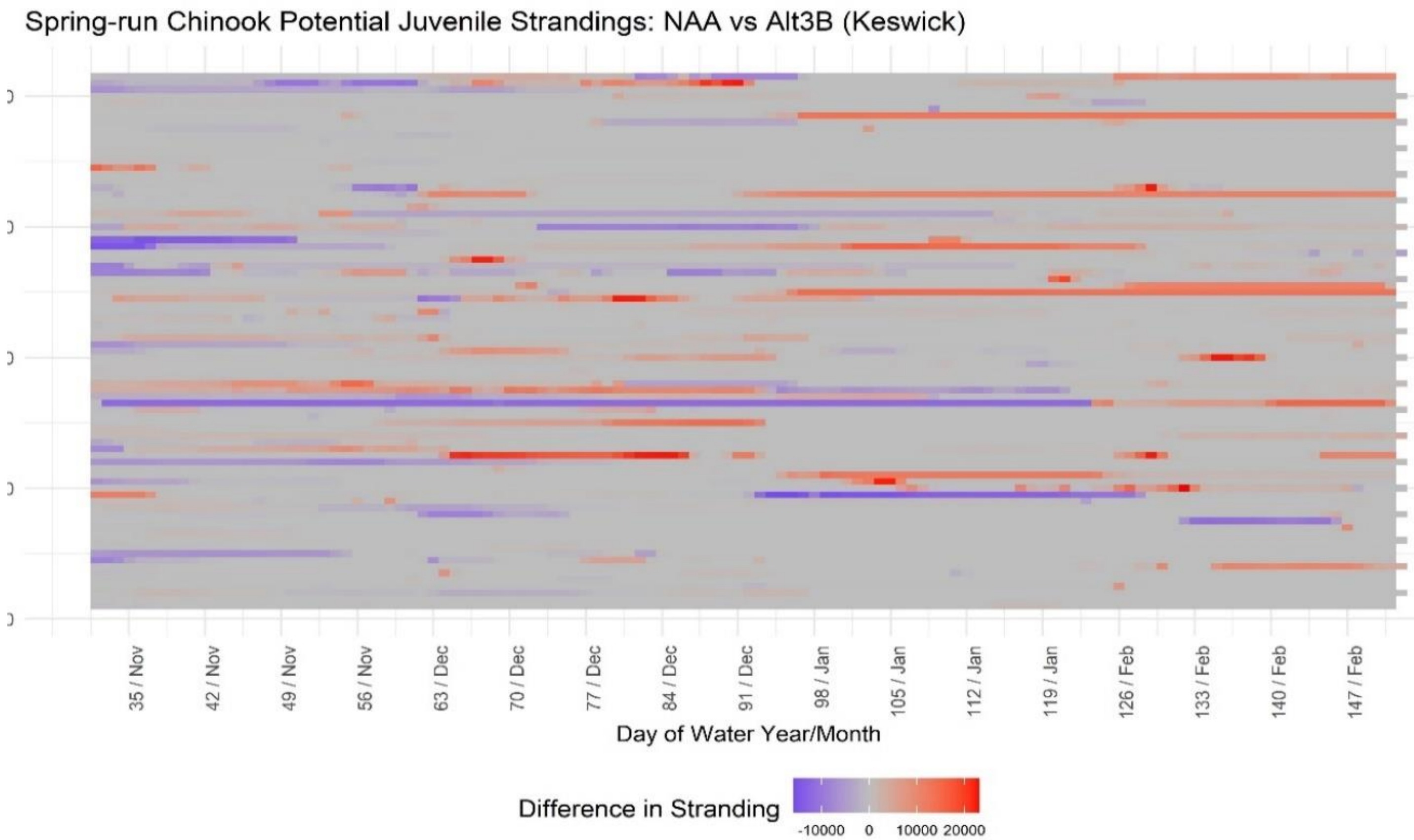


Figure 4-80. A heatmap showing then change in daily stranding potential for spring-run Chinook Salmon (CHNSR) juveniles for the Alt3B operational scenario relative to the NAA in the Sacramento River at Keswick Dam. Results are presented for water years 1922–2003 for months when CHNSR fry would be rearing (November–February). Data from the ITP Application (Sites Authority 2023).

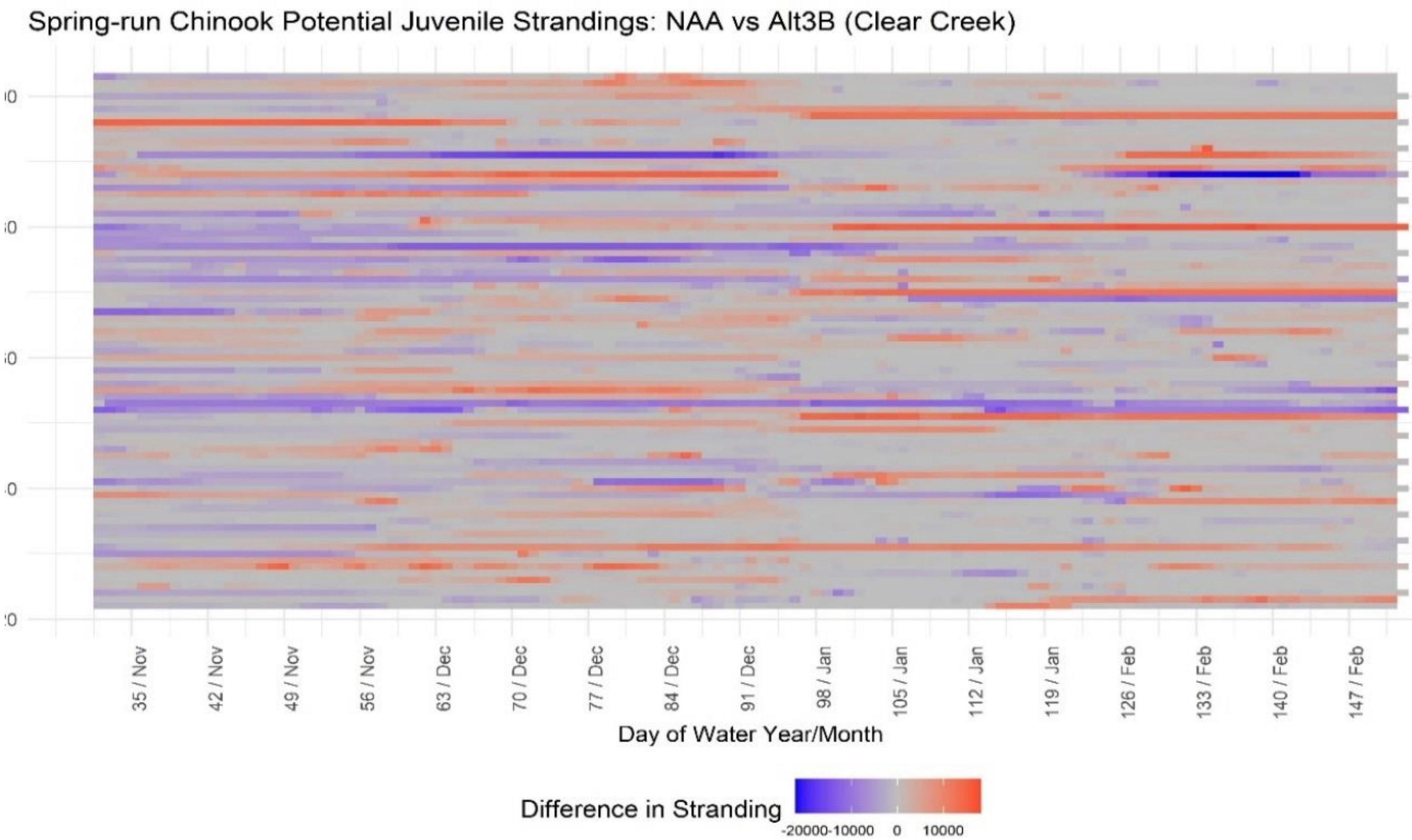


Figure 4-81. A heatmap showing then change in daily potential for stranding for spring-run Chinook Salmon (CHNSR) juveniles for the Alt3B operational scenario compared to the NAA in the Sacramento River at Clear Creek. Results are presented for water years 1922–2003 for months when CHNSR fry would be rearing (November–February). Data from the ITP Application (Sites Authority 2023).

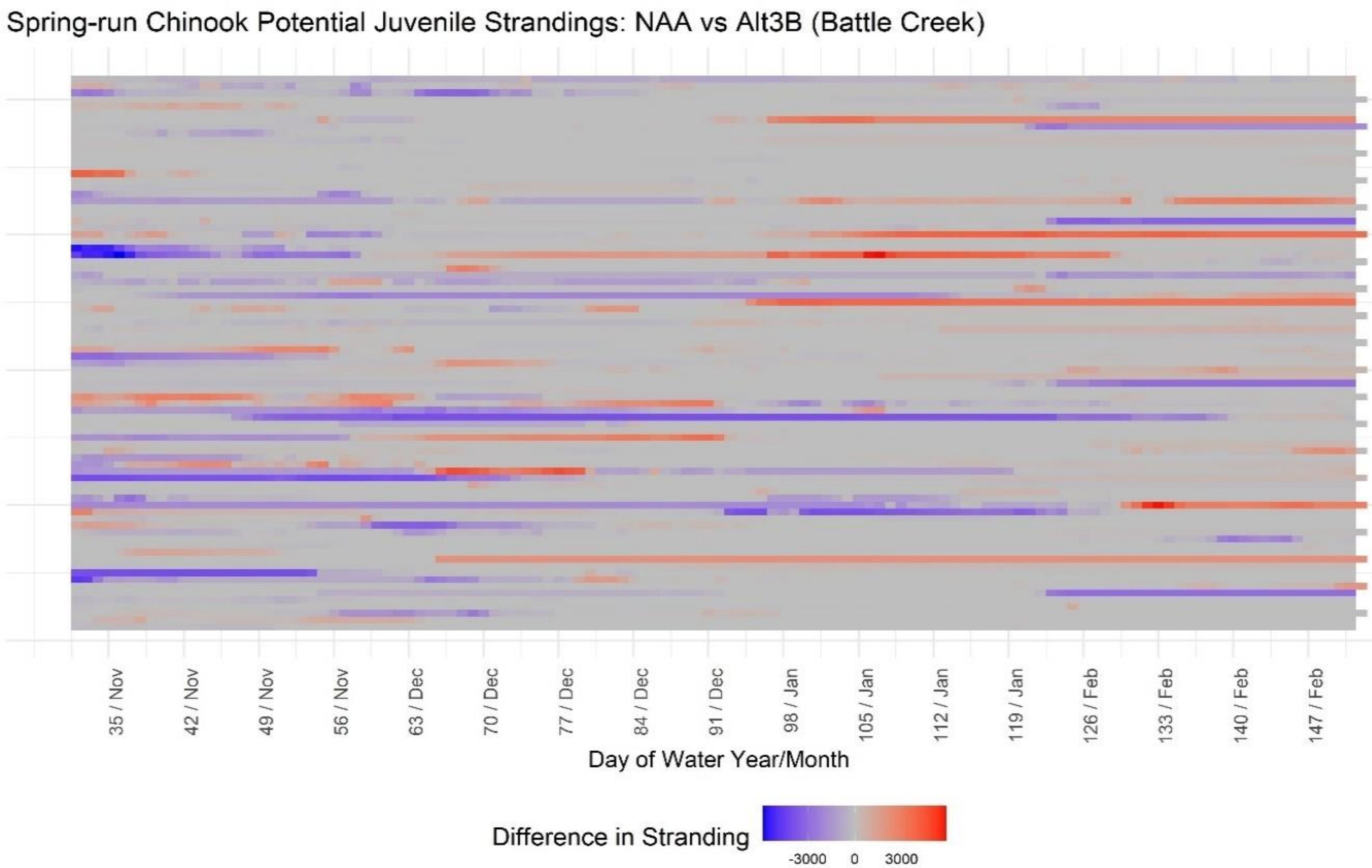


Figure 4-82. A heatmap showing then change in daily potential for stranding for spring-run Chinook Salmon (CHNSR) juveniles for the Alt3B operational scenario compared to the NAA in the Sacramento River at Battle Creek. Results are presented for water years 1922–2003 for months when CHNSR fry would be rearing (November–February). Data from the ITP Application (Sites Authority 2023).

Conclusions

Based on review of Project analysis and peer-reviewed scientific literature on juvenile stranding, CDFW finds mixed conclusions on the effects of the Project on juvenile stranding, with both increases and decreases in stranding potential. A limitation of this analysis is that stranding sites were identified for the USFWS (2006) report, and flood events or restoration projects may have adjusted river geomorphology and stranding sites considerably in the last two decades.

4.1.4.7. SALMOD Model of Juvenile Production

The ITP Application (Sites Authority 2023) evaluated potential changes in early life stage survival and juvenile production of CHNWR and CHNSR in the upper Sacramento River using SALMOD, a salmon survival model produced by the U.S. Geological Survey. SALMOD is a cohort-based model that estimates survival and production of early-life stage salmon as a function of the number of adult spawners present, river flow, and water temperature. The model operates on a weekly timestep, estimating mortality, growth, and life stage transition for each time step. The model ends at the pre-smolt life stage when juvenile fish that have survived disperse downstream prior to emigration. Therefore, the model is primarily useful for estimating survival of early life stages of Chinook salmon, namely eggs and alevin, prior to smoltification and emigration.

The ITP Application (Sites Authority 2023) used SALMOD to compare early life stage survival and juvenile production for the Alt3B operational scenario and the NAA. SALMOD modeling indicated that proposed cold water releases from Shasta by Reclamation under Alt3B have the potential to reduce temperature- and density-dependent mortality in early life-stage Chinook salmon. As the study area for SALMOD is entirely upstream of Sites diversions and releases, SALMOD results capture only the effects of coordinated CVP operations (OpFlex) and exchanges with Shasta.

Results of the ITP Application SALMOD analysis align with findings from other models that estimate the same parameters (e.g., Anderson and Martin models, WRLCM). In summary, a small number of individual years in the analyzed time series experienced water temperatures above the thermal limit for early life stage salmon, which was modeled to cause extremely high mortality in the NAA scenario in those years. In contrast, cold-water releases from Shasta Reservoir under the modeled Alt3B scenario alleviated most of that mortality. These findings are consistent with those obtained using other analyses, which provide additional insights, e.g. into out-migration survival.

Conclusions

Since the area covered by SALMOD is limited to the upper reaches of the Sacramento River above the Project diversion locations, the only impacts that Sites operations can have on this model come from CVP operational flexibility and exchanges. SALMOD is over two decades old and has not been updated to reflect recent advances in science that have updated our understanding of the effects of water temperature on CHNWR and CHNSR early life stage survival (e.g., Martin et al. 2017; Martin et al. 2020; Anderson et al. 2018). Additionally, SALMOD no longer appears to be supported by the USGS, as CDFW's attempts to contact the developers (Bartholow et al. 2004) were unanswered. For these reasons, CDFW puts more weight on the results of other analyses provided in the ITP Application (2023), including the WRLCM and analyses of temperature dependent mortality.

4.1.5. Juvenile Migration Survival vs. Flow from Red Bluff to the Feather River Confluence

Changes in Sacramento River flow as a result of Project operations could reduce flow while CHNWR and CHNSR juveniles are migrating down the Sacramento River, reducing outmigration survival.

Chinook Salmon outmigration survival through the upper Sacramento River (i.e. to the Feather River confluence) was modeled as a function of river flow using acoustic telemetry by Michel et al. (2021). This model was fit using primarily CHNFR and CHNLFR, which in this case are used as a surrogate for CHNWR and CHNSR. A three-threshold model was found to best fit the data where survival is low (3%) at flows less than 4,259 cfs, medium survival (18.9%) at flows 4,259–10,712 cfs, and high survival (50.8%) at flows 10,712–22,872 cfs at Wilkins Slough (Figure 4-83). A third flow threshold predicts reduced survival (around 35%) at very high flows (>23,000 cfs), but the authors suggest that this is likely due to alternative routes available at these high flows compounded with the reduced effectiveness of the detection equipment in these environments (Michel et al. 2021). For this reason, analyses and discussion of survival as a function of flow with regards to the Michel et al. 2021 analysis should assume survival remains at the higher 50% survival for all flows above approximately 10,700 cfs at Wilkins Slough.

The ITP Application (Sites Authority 2023) estimated Project impacts on CHNWR and CHNSR migration survival as a function of river flow using the Michel et al. (2021) threshold survival model and simulated diversions were restricted to only occurring when flows at Wilkins Slough were above 10,700 cfs. The analysis used daily flows from the DDFT, which accounts for the direct effects of diversions on streamflow but does not capture Project-related changes in streamflow due to operational exchanges or releases. Therefore, by definition, the results found no reduction in survival because the Project was simulated to never be responsible for reducing river flows to less than 10,700 cfs at Wilkins Slough. The threshold model creates the possibility for a simple analysis such as this, as well as simple operational criteria. However, the conclusion that the Project would result in 0.0% change in river migration survival relies on Project operations successfully avoiding reducing river flows below the ~10,700 cfs or ~4,259 cfs survival thresholds. If Project operations would result in reductions in flow at Wilkins Slough below either of these thresholds, then some impact to CHNWR and CHNSR survival would be expected. While Project diversions are not anticipated during conditions <10,700 cfs, the Project could still be responsible for reducing flows at Wilkins Slough below either of these critical survival thresholds as a result of exchanges with Oroville and Shasta reservoirs, CVP operational flexibility, or real-time exchanges and transfers. Furthermore, there is some uncertainty around the exact flow thresholds that cause the change in survival (Figure 4-83Figure 4-83). For consistency in discussion, we refer to the flow threshold at 10,712 cfs; however, to account for the uncertainty in this flow threshold, a flow threshold of 10,930 cfs would better protect CHNWR and CHNSR (Michel et al. 2021). Further analysis supporting this is in Section 5.2.1.

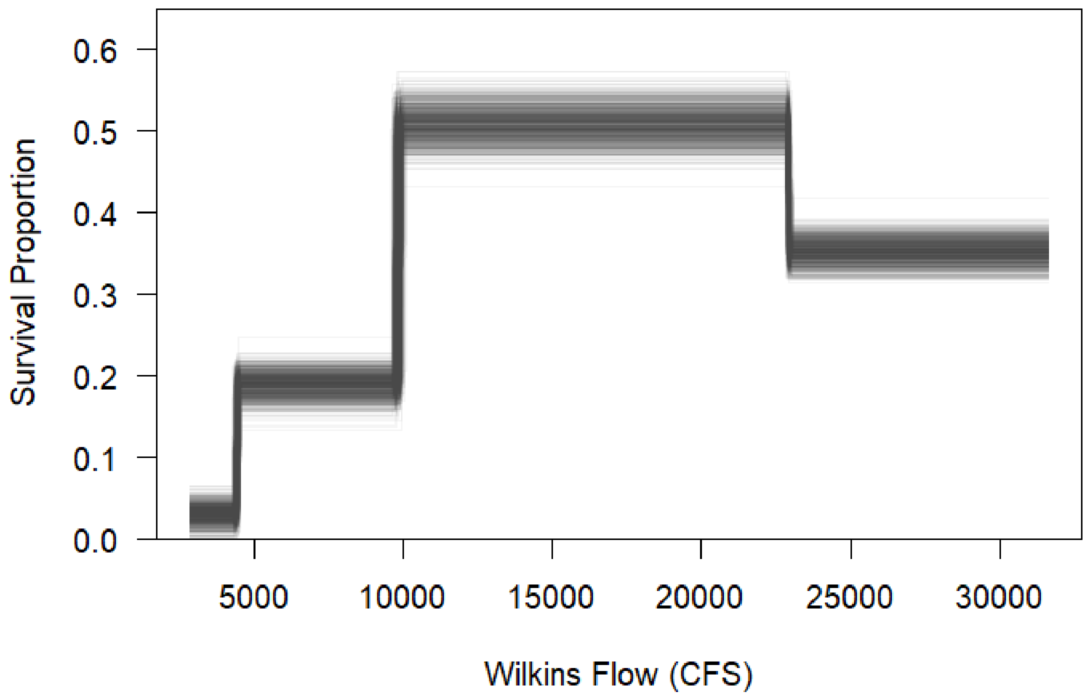


Figure 4-83. Outmigration survival of juvenile Chinook Salmon through the upper Sacramento River as a function of flow at Wilkins Slough from Michel et al. (2021), including model uncertainty. The critical threshold of 10,700 cfs represents the central tendency of the transition point between the 20% survival tier to the 50% survival tier.

CDFW calculated CHNSR and CHNWR juvenile migration survival using the Michel et al. (2021) flow-survival relationship for the NAA, Alt3B, NoSha, and No ShaOro operational scenarios. CDFW modeled an arbitrary starting population of 4,000,000 individual CHNWR and 4,000,000 individual CHNSR. Fish were assumed to begin migration at a date randomly drawn from the seasonal density distribution of daily passage estimates at Red Bluff from SacPas (Columbia Basin Research 2024). CDFW calculated the median travel time for CHNWR and CHNSR from Red Bluff to Fremont Weir, which is 4 km from the Feather River Confluence that was used as the downstream extent in the Michel et al. (2021) study, from Juvenile Salmon Acoustic Telemetry System (JSATS) telemetry data (NMFS 2024). Tagged CHNWR were used to estimate CHNWR travel time, and tagged CHNSR and CHNFR that were released as CHNSR surrogates were used for estimating CHNSR travel time. The median travel time was added to the date of departure to estimate the simulated arrival date at Fremont Weir.

Next, CDFW calculated the mean flow during the migration period of each individual using USRDOM flow from the Below Tisdale Weir station (115-TISDALEWEI-FLOW-REG), which is ~1 km from Wilkins Slough, for the NAA and three operational scenarios. CDFW then assigned survival probabilities to each fish according to the mean flow experienced during migration, following the Michel et al. (2021) flow thresholds. Fish migrating with an average flow <4,259 cfs were assigned a 3% survival rate, fish migrating with an average flow between 4,259-10,712 cfs were assigned a 18.9% survival rate, and fish migrating with an average flow >10,712 cfs were assigned a 50.8% survival rate. Cumulative survival rate was compiled for each brood year (Jul 1 – Jun 30 for CHNWR; Oct 1 – Sep 30 for CHNSR) and compared across scenarios.

The results of CDFW's analysis showed long-term average change in survival ranging from a 1% increase in CHNWR survival under Alt3B to a3% decrease in CHNSR survival under the Alt3B and NoSha operational scenarios. (Table 4-19). There were no obvious trends in survival rates between the NAA and Project operational scenarios across the simulation period, but there were differences in survival rates in individual years (Figure 4-84**)**. Further evaluation of modeled daily flow from Projects USRDOM confirmed that the predicted changes in juvenile migration survival are caused by Project-related flow reduction across both the 10,712 cfs and 4,259 cfs critical flow thresholds during periods of CHNSR migration (Sites Authority 2023). Project diversion criteria protect against changes in migration survival related to Project diversions, so the survival impacts are likely a result of CVP Operational Flexibility, real-time exchanges, and/or exchanges with Shasta or Oroville reservoirs.

Table 4-19. Average upper Sacramento River survival rates (proportion) for CHNWR and CHNSR assuming a flow-survival relationship published by Michel et al. (2021) under project scenarios across all years of provided USRDOM flow data (i.e. 1923-2002). 'NAA' = No Action Alternative; 'Alt3B' = Alt3B; 'NoSha' = Alt1A No Shasta exchanges; 'NoShaOro' = Alt1A No Shasta and No Oroville exchanges. Percent change from the NAA is shown in parentheses.

Run	NAA	Alt3B	NoSha	NoShaOro
CHNSR	0.315	0.307 (-3%)	0.307 (-3%)	0.308 (-2%)
CHNWR	0.195	0.196 (+1%)	0.193 (-1%)	0.194 (-1%)

Figure 4-84. The difference in Upper Sacramento River migration survival according to the Michel et al. 2021 flow-survival relationship under each project scenario relative to No Action Alternative (NAA) for winter-run Chinook Salmon and spring-run Chinook Salmon. Horizontal red line represents no difference between the project and NAA. 'Alt3B' = Alt3B; 'NoSha' = Alt1A No Shasta exchanges; 'NoShaOro' = Alt1A No Shasta and No Oroville exchanges.

While the Michel et al. (2021) model provides a useful estimate of salmon survival through the upper Sacramento River, there are important considerations when extending this model to how Project operations may impact listed CHNWR and CHNSR. This model was fit primarily with CHNFR and CHNLFR that were >80 mm FL. It also does not account for routing and survival through the Sutter Bypass, which may be impacted by Project operations. It is uncertain whether the modeled relationship would hold for natural-origin CHNWR or CHNSR that exhibit different behaviors than the fish used to fit this model, based on differences in rearing behavior, fish size, and migration timing. Analysis by del Rosario et al. (2013) showed that the 50th percentile of natural origin CHNWR passage occurs at Red Bluff in early October and at Knights Landing in

December. In contrast, the smolt-sized fish used by Michel et al. (2021) were released in late March through early June.

A key difference between CHNWR migrating past Red Bluff as fry in September and October versus later smolt migrants is that early migrants are moving downstream to rear, not simply migrating toward the ocean. Tagging and otolith studies have shown the value of this early migration life history strategy (Phillis et al. 2018, Sturrock et al. 2015), with a large proportion of returning adults having reared in habitats other than their natal reaches. Otolith isotope analysis of natural origin CHNWR spawners sampled in 2007–2009 found that approximately half (44–65%) had reared in non-natal habitats, including the American River (17–26%), Lassen tributaries (7–34%), and Feather River and/or the Delta (7–23%) (Phillis et al. 2018). High flow events that back the Sacramento River up into the American River may provide high quality rearing habitat for CHNWR during some years (Phillis et al. 2018, Silva and Bouton, 2015). These juvenile migration and rearing strategies, which are used by approximately half of all CHNWR that will contribute to the next generation, are not included in any current models relating survival and flow.

The Michel et al. (2021) model may better represent the relationship between Sacramento River flow and outmigration survival for some, though not all Central Valley CHNSR. Juvenile CHNSR have diverse outmigration phenotypes, with some young-of-year migrating as fry in October through February, most young-of-year migrating as smolts in March through June, and some migrating as yearlings between October and June of the following year. Outmigration phenotype varies by natal tributary: Cordoleani et al. (2021) used otolith microchemistry to show that Mill Creek and Deer Creek CHNSR have distinct early (fry), intermediate (parr/smolt) and late (smolt/yearling) migration phenotypes. CHNSR hatching in the mainstem Sacramento River likely exhibit similar phenotypic diversity (Figure 4-37). Also using otolith microchemistry, Cordoleani et al. (2024) showed that Butte Creek CHNSR mostly migrate as parr or smolts (median FL at natal exit = 74 mm; median FL at freshwater exit = 83 mm), with few remaining to migrate as yearlings and many rearing in the Butte Creek floodplain in winter and spring. Outmigrating Butte Creek CHNSR typically traverse the Sutter Bypass and enter the Sacramento River near its confluence with the Feather River (Cordoleani et al. 2019). Thus, while potentially affected by changes in Sutter Bypass inundation due to Project operations, Butte Creek CHNSR outmigration survival is unlikely to bear the same relationship to Sacramento River flow as that of the Mill Creek, Deer Creek and mainstem Sacramento River CHNSR.

The CHNFR and CHNLFR released by Michele et al. (2021) in March – June may well approximate the outmigration behavior of young-of-year smolt migrant CHNSR (increasingly the majority: Figure 4-37) originating in Mill Creek, Deer Creek, and the Sacramento River. Central Valley CHNSR begin reaching the minimum size for acoustic tagging (75 – 80 mm FL) around 1 May of their brood year (Johnson and Merrick 2012; Cordoleani et al. 2019; see also Figure 4-46) and those smolts not destined to migrate as yearlings move out of the system quickly in spring. Yearling migrant CHNSR overlap in size with the fish tagged by Michel et al. (2021) as well (Johnson and Merrick 2012; Cordoleani et al. 2019), though only those migrating in March through June would be likely to experience hydrological conditions similar to those experienced by the tagged fish. The CHNFR and CHNLFR released in spring by Michel et al. (2021) may be poor surrogates for early migrant young-of-year CHNSR, which migrate in fall and winter and are typically smaller than 80 mm FL. Early fry-migrant CHNSR are increasingly rare in the Mill Creek, Deer Creek and Sacramento River populations and the dependence of their outmigration survival on Sacramento River flow is poorly understood.

Conclusions

Project operations, including exchanges and diversions at Red Bluff and Hamilton City, have the potential to reduce downstream streamflow and therefore decrease survival of juvenile CHNSR and CHNWR. Current science relating flow to survival of Chinook Salmon is based on data from larger, acoustically tagged juveniles, which representative a fraction of life history diversity found in wild CHNWR and CHNSR. There is a need to better understand migration and rearing behavior and survival of CHNWR and CHNSR fry and pre-smolt juveniles, as well as CHNSR yearlings, to validate or adjust these flow-survival relationships to represent other life history strategies.

4.1.6. Adult Migration in the Sutter and Yolo Bypasses

4.1.6.1. Attraction Flows to the Yolo Bypass

Increases in flows in the Yolo Bypass due to Project releases could attract adult winter-run Chinook Salmon and spring-run Chinook Salmon into the Yolo Bypass, causing increased stress, physical harm, and increased mortality.

Sites proposes reservoir releases to the Yolo Bypass via the CBD and KLRC which will increase flows over existing conditions ranging from approximately 50 cfs to more than 400 cfs during the months of August through October. This may pose a straying and stranding risk for adult CHNSR migrating upstream to spawn due to 1) temporal overlap between releases and fish presence in the area, and 2) the production/augmentation of attraction flows into the Yolo Bypass. CHNSR adults are present in the Sacramento River Basin from March through October (NMFS 2019) which overlaps with the period of proposed releases. Genetically verified CHNSR adults have also been captured at the WWFCF in KLRC Slough in October (Figure 3-4), reaffirming the temporal overlap between fish presence and proposed reservoir releases.

Adult Chinook Salmon moving upstream on their spawning migration can enter the Yolo Bypass system from the Sacramento River via the Cache Slough Complex at the southern downstream end and proceed northward through the Toe Drain, which is wetted year-round. They can then continue northward to KLRC where Wallace Weir and the WWFCF are located. Outside of flooding periods, there is no connection allowing passage back to the Sacramento River at the northern upstream end of the Yolo Bypass. There is no spawning or rearing habitat for CHNSR in the Yolo Bypass, so strays must retreat downstream, exit the Toe Drain and resume their upstream migration on the Sacramento River. Not all fish backtrack successfully. Johnson et al. 2020 found that salmon retreating this way exit the Yolo Bypass with a probability of 58%-87% (credible interval). Presumably, the remainder do not return to their natal waterways to spawn successfully.

The addition of flow from Sites Reservoir releases during the August-October timeframe could potentially create an attraction signal for CHNSR. High flows, increases in flows (e.g. pulses), and differential flow velocities at tributary junctions can attract migrating adult CHNSR, and these factors have been associated with adult salmon straying (Unwin and Quinn 1993, Mesick 2001, Marston et al. 2012). In the Yolo Bypass, it has been hypothesized that migratory fish are drawn into the Yolo Bypass Toe Drain when downstream flows through the Cache Slough Complex exceed those of the Sacramento River (Sommer et al. 2014), which is often pronounced in drier periods and during high tide cycles (Gahan et al. 2016). Increases in adult CHNSR catches were observed during and immediately following the 2019 NDFS flow pulse in the Yolo Bypass, which was conducted at a similar time of year and with a similar volume to pulses proposed in the ITP Application (Sites Authority 2023; Davis et al. 2021). Catches included two genetically identified CHNSR salvaged in October.

The ITP Application (Sites Authority 2023) notes that the fish passage structure at the Fremont Weir and the WWFCF as pathways for straying adult Chinook Salmon to return to the Sacramento River; however, these options are problematic. The Fremont Weir Adult Fish Passage Facility is only passable when the weir overtops and a few days immediately after floodwaters recede. It is not functional at other times, including the period of proposed releases into the Yolo Bypass during August-October. Reliance on the WWFCF is problematic for several reasons. First, the facility is contracted to operate from approximately October through the following June (H. Kubo personal communication May 2024) which does not cover the entire period of proposed reservoir releases. Second, stress associated with trap and haul efforts around migration barriers like those at the WWFCF have been shown to negatively impact survival of relocated individuals, particularly when water temperatures are elevated (Kock et al. 2021). Relocated fish can have an increased likelihood of perishing before they spawn, as has been observed in CHNSR in a Sacramento River tributary (100% mortality) (Mosser et al. 2013) and the Willamette River in Oregon (48% mortality) (Keefer et al. 2010). Finally, not all adult Chinook Salmon that stray into the Toe Drain and KLRC reach the WWFCF for rescue. Living and deceased adults are regularly observed in the KLRC and Toe Drain downstream of the facility and in the stilling basin at the base of the weir (Kubo and Kilgour 2022; Kubo and Diep 2023; Kubo et al. 2023).

Conclusions

Though increases in flows during August-October could potentially attract CHNSR into the Yolo Bypass, there has not been adequate monitoring and data collection to identify a clear connection between the two. However, there are several reasons for potential risk: 1) temporal and spatial overlap between CHNSR presence and proposed reservoir releases, 2) an increase in adult Chinook Salmon catches at the WWFCF in KLRC observed during and after the 2019 NDFS flow pulse, including 2 genetically verified CHNSR adults salvaged in October, 3) high water temperatures common in KLRC in the summer and early fall, and 4) the migration delay, stress and increased potential for mortality of strays that must volitionally backtrack downstream out of the Yolo Bypass or must be salvaged at the WWFCF and transported back to the Sacramento River.

4.1.6.2. Adult Upstream Passage out of the Yolo and Sutter Bypasses

Changes in the magnitude and frequency of flow over the weirs into the Yolo and Sutter Bypasses could block passage of migrating adult winter-run Chinook Salmon and spring-run Chinook Salmon.

The existing weir structures create the potential for stranding of upstream migrating adult Chinook Salmon behind the weirs when overtopping ceases. Under current conditions, fish rescue teams are deployed to manually relocate adults stranded below the weirs once overtopping stops back into the mainstem Sacramento River. While some CHNSR utilize the Sutter Bypass canals to access their natal spawning streams, CHNWR would need to re-enter the Sacramento River to reach their natal spawning habitat. In the Yolo Bypass, once the Fremont Weir Adult Fish Passage structure is no longer passable, CHNWR and CHNSR fish must retreat downstream and resume their migration on the mainstem Sacramento River.

The ITP Application (Sites Authority 2023) analyzed potential impacts of the Project on adult CHNWR and CHNSR upstream passage at weirs in the Yolo and Sutter bypasses by comparing the number of days from 2009–2018 that fish passage criteria are met for the NAA and the Alt3B scenarios based on flows estimated using the Daily Divertible Flow Tool. Results showed small changes in passage days in some years, ranging from 1 more day to 5 fewer days of passage for Alt3B compared to the NAA.

Project diversions will also result in fewer days of weir overtopping (see Section 4.1.7.1), which would reduce the number of fish migrating through the bypasses and therefore the number of fish that could be stranded behind weirs. CDFW expects that these two effects combined, as well as planned passage projects at Freemont and Tisdale weirs, would result in no substantial changes in adult upstream passage at weirs in the Yolo and Sutter bypasses.

A rehabilitation project that is designed to reduce adult Chinook Salmon stranding is scheduled to be completed on the Tisdale Weir before the Project would be operational. The rehabilitation project plans to install a "notch" which will remain open allowing water to flow from the Sacramento River into the Sutter Bypass after the Tisdale Weir stops overtopping. This will provide a point of egress for adult salmonids back into the Sacramento River after overtopping has stopped. As river levels continue to drop, flow through the notch will reverse, draining the area behind the weir back into the Sacramento River.

A 15 ft-wide adult fish passage structure was completed on the eastern side of the Yolo Bypass Fremont Weir in 2018 to facilitate upstream adult passage for a short period of time after water levels recede. However, some CHNWR and CHNSR stranding still occurs as it has in the past at the Fremont and Sacramento Weirs, once the areas behind the weirs become hydraulically disconnected. The completion of a notch on Fremont Weir's west side is slated to be completed before the Project is operational and is anticipated to reduce stranding in the future. Project operations are not anticipated to alter adult salmonid stranding at either of these weirs.

Conclusions

Project operations are not expected to result in substantial changes in adult stranding behind Freemont Weir or weirs in the Sutter Bypass. Project operations are likely to decrease weir overtopping and increase the rate of flow reductions following overtopping events, thus decreasing the number of CHNWR and CHNSR that may migrate up the bypasses and require upstream passage at the weirs.

4.1.7. Juvenile Rearing and Migration in the Sutter and Yolo Bypasses

Floodplains are a unique habitat that juvenile Chinook Salmon often utilize during rearing (Sommer et al. 2005). Floodplains are generally associated with faster growth rates (Jeffres et al. 2008) which may provide survival benefits. Nearly all of the natural floodplain habitat of the Sacramento River has been lost due to human development (Hanak et al. 2011). The flood bypasses of the Sacramento River system, such as the Yolo and Sutter Bypasses, serve as surrogate floodplain habitat for juvenile Chinook Salmon and have been shown to provide similar growth benefits to remaining natural floodplains (Jeffres et al. 2020). Access to floodplains also allows for diversity in life history strategies, as individuals within the population disperse into different habitat types. Therefore, access to floodplains allows for evolutionary bet hedging strategies for Chinook Salmon (Sommer et al. 2005).

4.1.7.1. Juvenile Entry to Bypass Floodplain Habitat

Changes in the magnitude and frequency of flow over the weirs into the Sutter and Yolo bypasses could reduce access to important floodplain rearing habitat for juvenile winter-run Chinook Salmon and spring-run Chinook Salmon.

While the ITP Application (Sites Authority 2023) presented estimates of juvenile CHNWR entrainment into Yolo Bypass over Fremont Weir, no such analysis was performed for the Sutter Bypass. All three of the major weirs that spill into Sutter Bypass are upstream of Fremont Weir, thus more fish are likely to reach these locations than Fremont Weir. Furthermore, the Colusa and Tisdale weirs overtop more frequently than the Fremont Weir, presenting greater opportunities for juvenile Chinook Salmon entrainment. For this reason, CDFW assessed weir overtopping for all weirs that spill into both Sutter and Yolo Bypasses.

The analysis of juvenile salmon entrainment into the bypasses provided in the ITP Application (Sites Authority 2023) assumed that the proportion of fish entering through a given weir matches the proportion of flow going over the weir. This assumption has been shown to approximate fish routing for some natural river bifurcations (Perry et al. 2009). However, bypass weirs represent a sharper, approximately 90° departure from the mainstem river. Therefore, this assumption may over-estimate the proportion of fish entering the bypass. Despite this, the proportion of flow entering the bypass via the weir is likely highly correlated with fish routing, if not directly proportional. Until routing estimates over the weirs as a function of flow can be made from telemetry studies, assuming equal proportion is reasonable.

The analysis in the ITP Application (Sites Authority 2023) also assumed that changes in Sacramento River flow caused by Project diversions occur instantaneously throughout the downstream reaches of the river. This assumption is unrealistic and may obscure Project impacts since reductions in flow are observed at some downstream locations days after the termination of diversions upstream. For example, according to CDFW's DRAT, impacts on river height and discharge at the Tisdale Weir are observed up to 72 hours after changes are made to diversions at the upstream Project diversion locations.

For these reasons, CDFW's analysis of impacts to juvenile salmon bypass entrainment opportunities were assessed using routed river flows that account for downstream travel time and attenuation of diversions upstream using DRAT. CDFW then focused on days which the daily average flow spilling over the Moulton, Colusa, or Tisdale Weirs was >0 cfs as a day in which overtopping occurred. CDFW compared the number of days in which the daily average flow over each weir was >0 cfs under NAA and Alt3B. Days with average flow >0 cfs over a weir were considered days in which juvenile salmonid entry into the Sutter Bypass was possible.

CDFW found that the Alt3B operational scenario would reduce access to the Sutter Bypass considerably at Colusa and Tisdale Weirs (Figure 4-85). Project diversions have the greatest proportional impact on entry access at Tisdale and Colusa weirs during drier years. For example, Project operations are expected to eliminate 100% of bypass entry access at Tisdale in critical years (Tables 4-20 through 4-22**)**. Moulton Weir is unaffected in drier years because this weir only overtops in the wettest years.

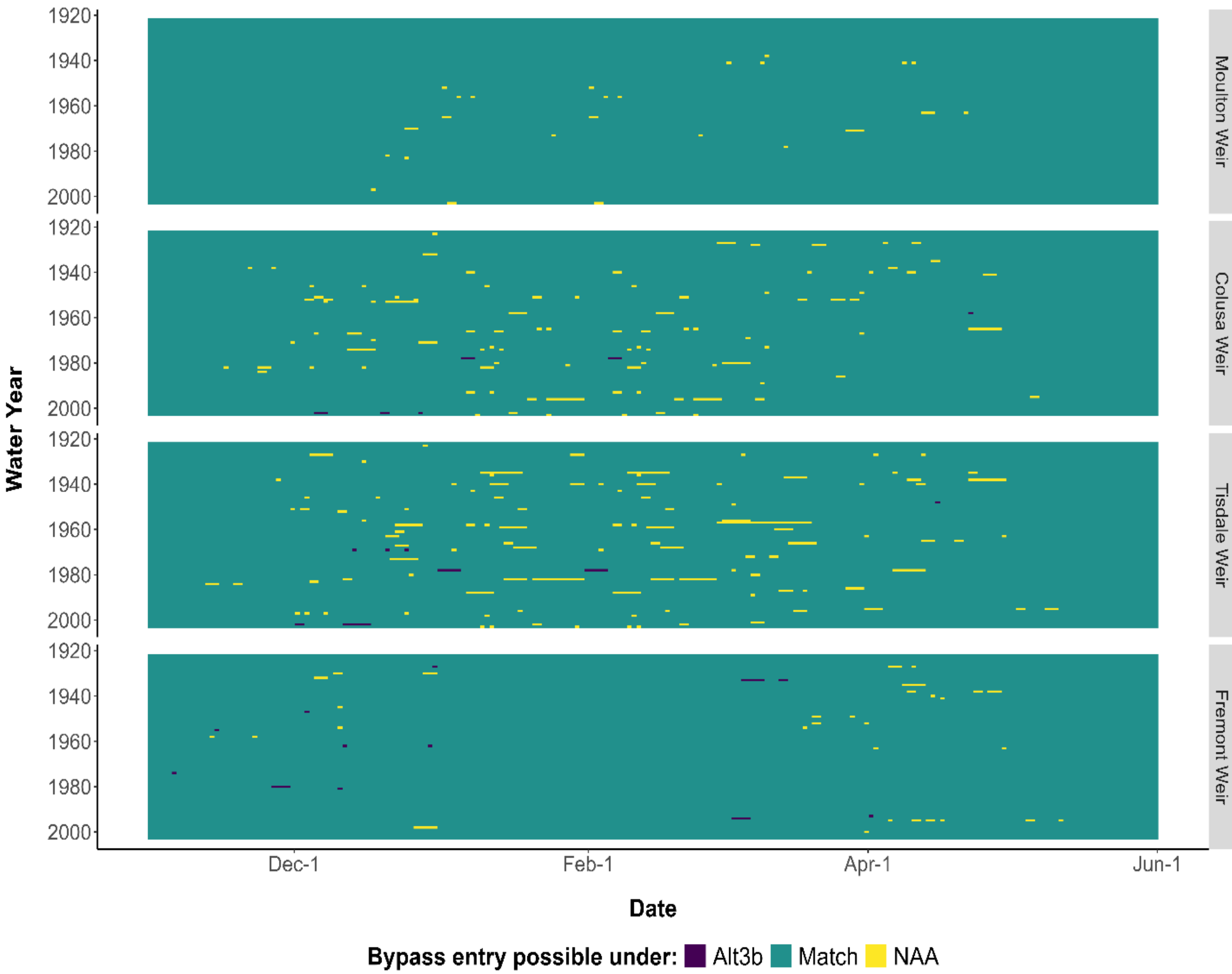


Figure 4-85. Differences in weir overtopping for the three major weirs that spill into the Sutter Bypass are highlighted using color. The green color are days in which the No Action Alternative (NAA) and Alt3B operational scenarios match overtopping conditions (i.e. both spilling or both not spilling). Yellow cells are days when spilling would only occur under NAA and purple are days when spilling would only occur under Alt3B. Water year is on the y-axis and date following a salmon brood year cycle is on the x-axis.

Table 4-20. The number of days with daily average flow >0 cfs at **Moulton Weir** from October to March by water year type over the study period (1921-2002) under the No Action Alternative (NAA) and the Alt3B operational scenario, the 'Difference' in days under Alt3B relative to NAA and the percentage change in days of average flow >0 cfs ('Difference (%)').

Water Year Type	NAA	Alt3B	Difference	Difference (%)
Wet	538	515	-23	-4.3
Above Normal	61	54	-7	-11.5
Below Normal	6	6	0	0.0
Dry	0	0	0	0.0
Critical	0	0	0	0.0

Table 4-21. The number of days with daily average flow >0 cfs at **Colusa Weir** from October to March by water year type over the study period (1921-2002) under the No Action Alternative (NAA) and the Alt3B operational scenario, the 'Difference' in days under Alt3B relative to NAA and the percentage change in days of average flow >0 cfs ('Difference (%)').

Water Year Type	NAA	Alt3B	Difference	Difference (%)
Wet	1416	1319	-97	-6.9
Above Normal	385	352	-33	-8.6
Below Normal	77	64	-13	-16.9
Dry	82	76	-6	-7.3
Critical	0	0	0	0.0

Table 4-22. The number of days with daily average flow >0 cfs at **Tisdale Weir** from October to March by water year type over the study period (1921-2002) under the No Action Alternative (NAA) and the Alt3B operational scenario, the 'Difference' in days under Alt3B relative to NAA and the percentage change in days of average flow >0 cfs ('Difference (%)').

Water Year Type	NAA	Alt3B	Difference	Difference (%)
Wet	1799	1708	-91	-5.1
Above Normal	523	475	-48	-9.2
Below Normal	167	99	-68	-40.7
Dry	151	139	-12	-7.9
Critical	12	0	-12	-100.0

Winter-run Chinook Salmon Juvenile Entry into Sutter Bypass

To quantify the number of juvenile CHNWR that may be excluded from Sutter Bypass entry as a result of Project operations, CDFW used the number of smolts at Red Bluff reported in the annual JPE reports published by NMFS as an estimate for the number of CHNWR smolts emigrating from Red Bluff each year. CDFW then imputed migratory survival rates between Red Bluff and each weir location from acoustic telemetry studies that tagged CHNWR with JSATS tags. CDFW used the nearest available receivers to impute survival to each weir in each year. This survival estimate was used to estimate the number of fish that would be expected to survive to reach each weir in each year. This approach is similar to the analysis of juvenile salmon entrainment into Yolo Bypass provided in the ITP Application (Sites Authority 2023), which imputed survival to each weir from telemetry-derived survival between Red Bluff and the Delta.

The departure date of the individuals estimated to survive to each weir was assigned such that the distribution of departure dates of simulation individuals matched the density distribution of CHNWR daily passage estimates at Red Bluff for that year (Figure 4-85; Columbia Basin Research 2024). To determine the arrival date at each weir, CDFW calculated the median travel time from Red Bluff to each weir from CHNWR JSATS data (Figure 4-87) and added the median travel time to the departure date for each individual. Fish departing Red Bluff late in the season may be less likely to stopover before reaching the downstream weirs than fish departing Red Bluff earlier in the same year. In the absence of such stopover behavior, late-season departing fish may travel faster than median travel times. Thus, the estimated weir arrival date for late-departing fish may be biased to later in the season than would be expected. Overtopping events this late in the season are extremely rare, and thus this effect may slightly underestimate Project impacts on bypass entrainment.

The proportion of fish entrained into the bypass was assumed to be equal to the proportion of Sacramento River flow spilling into the bypass for each arrival date at each respective weir. This process was repeated for the NAA and Alt3B scenarios and the number of fish entrained was compared. The Fremont Weir with simulated Big Notch flows was also included for comparison. The data necessary for this calculation are only available for 2013-2023.[7] Only one fish was estimated to be entrained into the bypass in 2013 and 0 fish in 2014 due to limited overtopping opportunities. Therefore, the below figures only present results from 2015-2023 for simplicity.

[7] JSATS data for this analysis are available from the National Oceanic and Atmospheric Administration's ERDDAP data server at: https://oceanview.pfeg.noaa.gov/erddap/tabledap/index.html

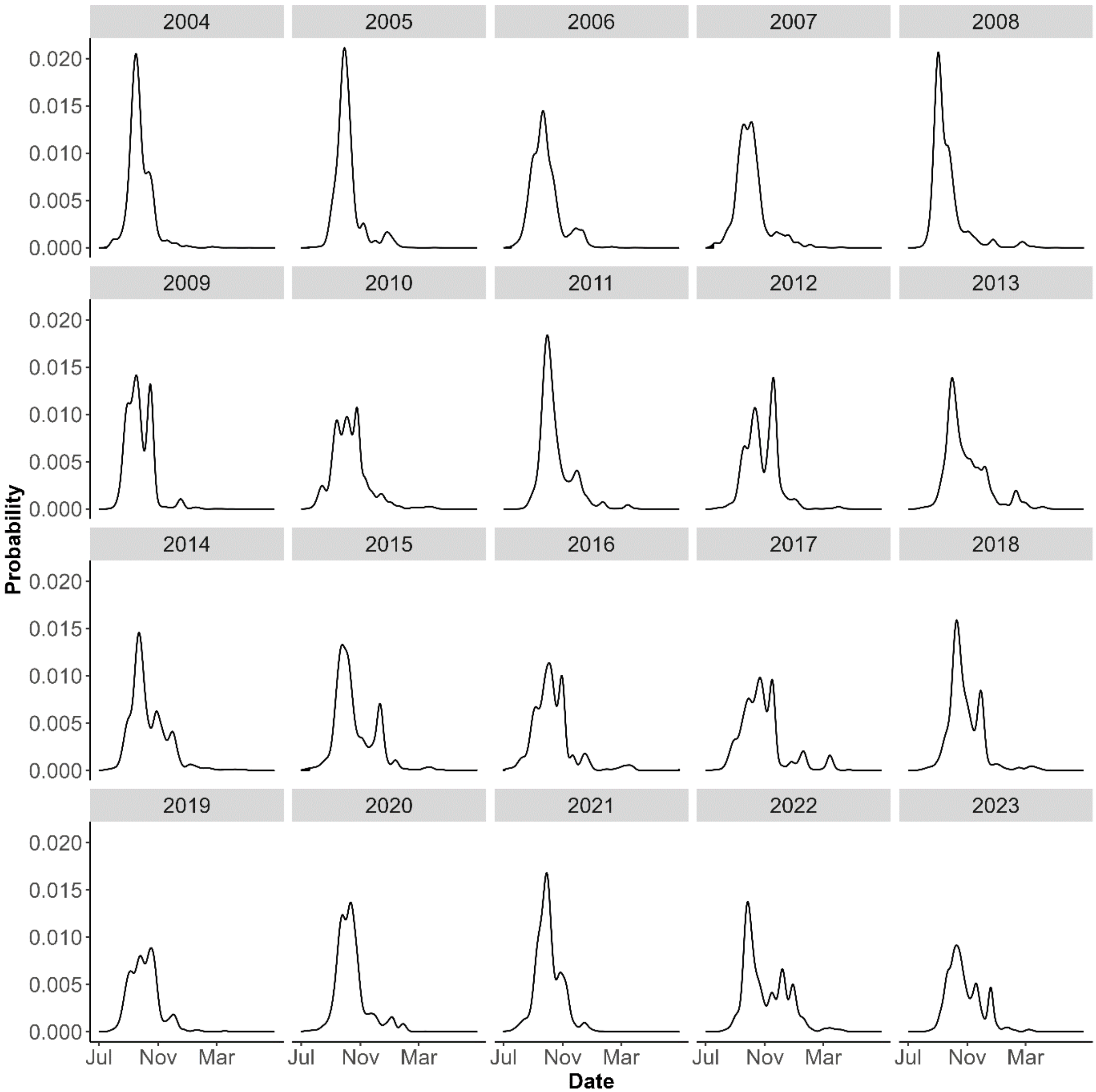


Figure 4-86. Catch distribution of juvenile winter-run Chinook Salmon at the Red Bluff Rotary Screw Trap by date. The entrainment analysis only used catch data for years 2015-2019.

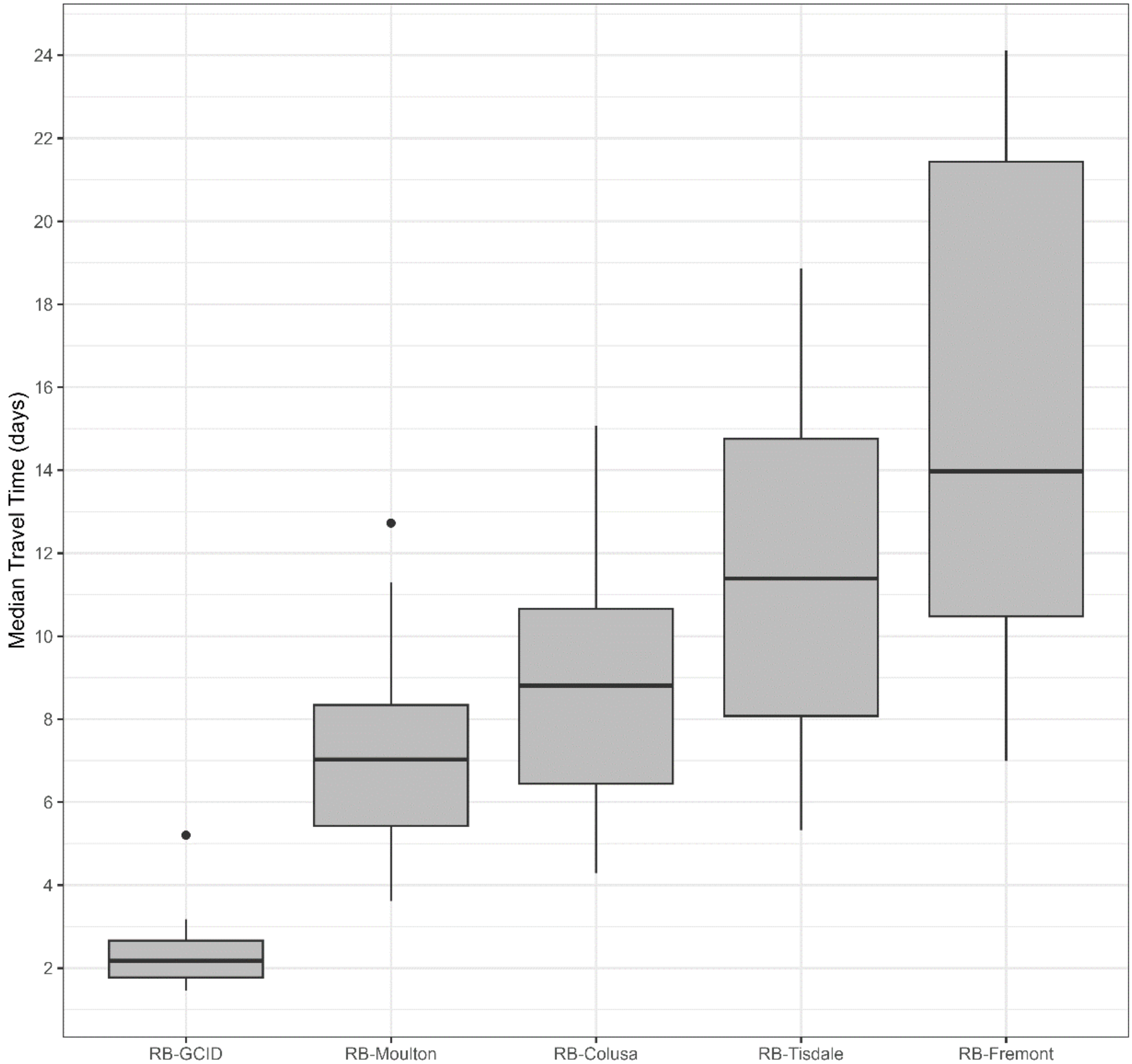


Figure 4-87. Median travel time in days across water years 2013-2023 from Red Bluff (RB) to each weir derived from Juvenile Salmon Acoustic Telemetry System tagged winter-run Chinook Salmon.

CDFW's analysis found the greatest reductions in entrainment at Tisdale and Colusa Weirs because these weirs overtop the most often and thus are most susceptible to impacts (Table 4-24). The greatest percentage reduction in entrainment due to Alt3B was 21% in the Sutter Bypass compared to 12% in Yolo Bypass. The greatest absolute reduction in entrainment caused by Alt3B was 6,010 fewer individuals entrained in the Sutter Bypass compared to 1,251 fewer individuals entrained in Yolo Bypass (Tables 4-27 and 4-28) Project operations are expected to reduce floodplain access for CHNWR in all years when weir overtopping occurs.

Table 4-23. Differences in yearly estimated bypass entrainment at **Moulton Weir**. 'Arriving' is the number of fish that survived to reach the weir. 'NAA' is the number of fish estimated to be entrained over the weir under the No Action Alternative (NAA) scenario. 'Alt3B' represents the difference in entrainment between the NAA and the Project scenario (Alt3B). Negative values represent reductions in entrainment relative to NAA; positive values represent increases in entrainment.

Water Year	Arriving	NAA	Alt3B
2015	1,255,137	0	0 (0%)
2016	180,071	0	0 (0%)
2017	149,117	22	-7 (-32%)
2018	175,531	0	0 (0%)
2019	302,976	2	-1 (-62%)
2020	503,262	0	0 (0%)
2021	560,265	0	0 (0%)
2022	126,416	0	0 (0%)
2023	56,439	1	-1 (-87%)

Table 4-24. Differences in yearly estimated bypass entrainment at **Colusa Weir**. 'Arriving' is the number of fish that survived to reach the weir. 'NAA' is the number of fish estimated to be entrained over the weir under the No Action Alternative (NAA) scenario. 'Alt 3B' represents the difference in entrainment between the NAA and the Project scenario (Alt3B). Negative values represent reductions in entrainment relative to NAA; positive values represent increases in entrainment.

Water Year	Arriving	NAA	Alt3B
2015	1,231,060	8,939	-1,948 (-22%)
2016	167,411	280	-76 (-27%)
2017	137,278	893	-99 (-11%)
2018	174,250	17	0 (0%)
2019	281,878	485	-94 (-19%)
2020	470,601	0	0 (0%)
2021	518,261	0	0 (0%)
2022	118,866	0	0 (0%)
2023	51,418	736	-95 (-13%)

Table 4-25. Differences in yearly estimated bypass entrainment at **Tisdale Weir**. 'Arriving' is the number of fish that survived to reach the weir. 'NAA' is the number of fish estimated to be entrained over the weir under the No Action Alternative (NAA) scenario. 'Alt3B' represents the difference in entrainment between the NAA and the Project scenario (Alt3B). Negative values represent reductions in entrainment relative to NAA; positive values represent increases in entrainment.

Water Year	Arriving	NAA	Alt3B
2015	1,264,332	21,934	-4,062 (-19%)
2016	137,357	593	-111 (-19%)
2017	112,455	1,340	-224 (-17%)
2018	167,515	111	-1 (-1%)
2019	237,924	871	-108 (-12%)
2020	401,568	0	0 (0%)
2021	433,197	0	0 (0%)
2022	104,882	71	0 (0%)
2023	45,068	1,483	-153 (-10%)

Table 4-26. Differences in yearly estimated bypass entrainment at **Fremont Weir**. 'Arriving' is the number of fish that survived to reach the weir. 'NAA' is the number of fish estimated to be entrained over the weir under the No Action Alternative (NAA) scenario. 'Alt3B' represents the difference in entrainment between the NAA and the Project scenario (Alt3B). Negative values represent reductions in entrainment relative to NAA; positive values represent increases in entrainment.

Water Year	Arriving	NAA	Alt3B
2015	1,283,096	13,090	-1,251 (-10%)
2016	108,026	293	-21 (-7%)
2017	87,213	1,227	-119 (-10%)
2018	159,615	110	0 (0%)
2019	193,132	440	-51 (-12%)
2020	317,113	243	0 (0%)
2021	310,025	4	0 (0%)
2022	89,312	52	-6 (-11%)
2023	10,729	245	-18 (-7%)

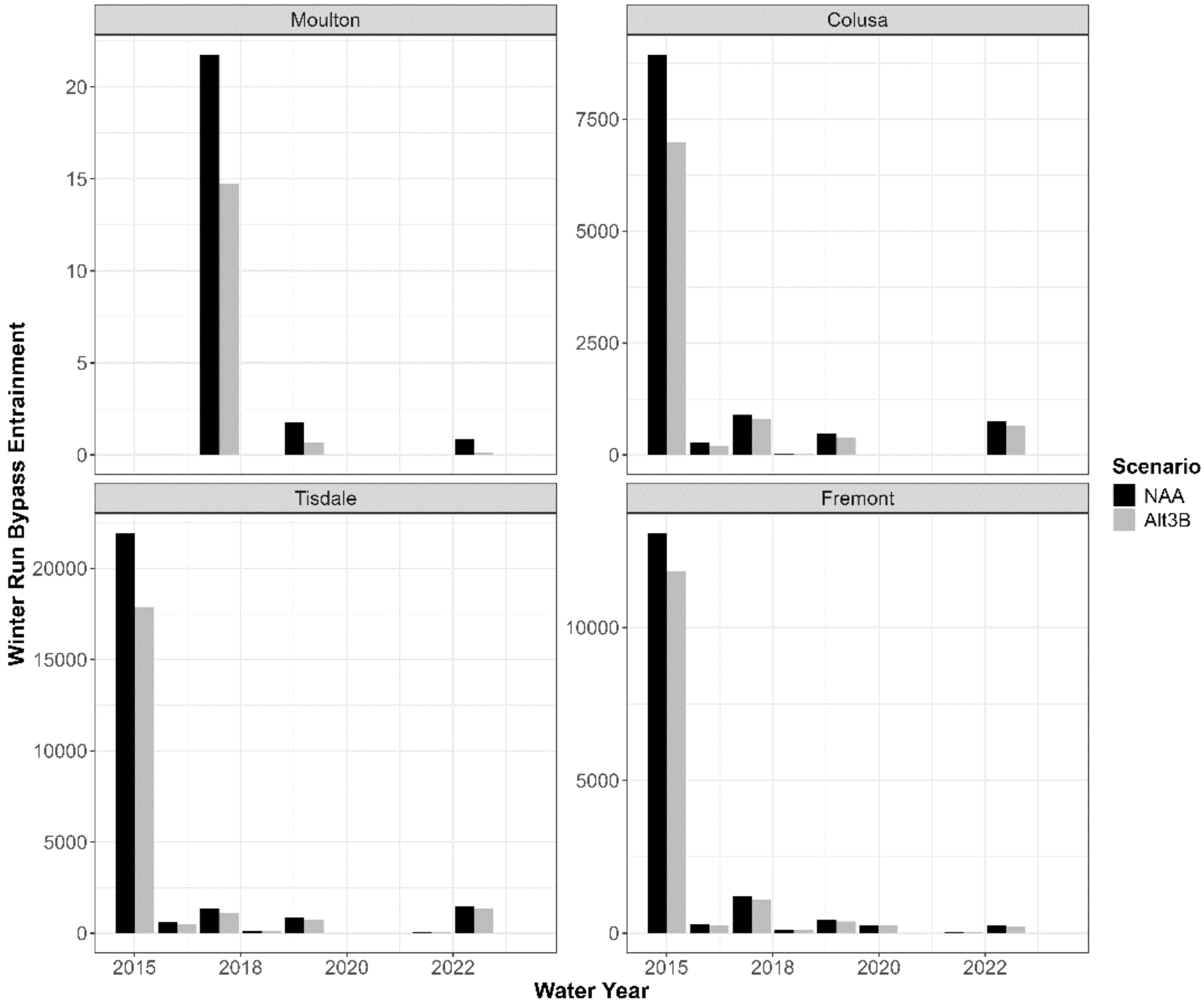


Figure 4-88. Estimated winter-run Chinook Salmon bypass entrainment at each weir under the No Action Alternative (NAA) and the Project scenario (Alt3B). Note: y-axis scales differ to allow more effective comparison between scenarios.

Table 4-27. The cumulative differences in the number of juvenile winter-run Chinook Salmon entrained into **Sutter Bypass**. ‘Arriving’ is the number of fish estimated to survive to a bypass weir in each year. ‘NAA’ is the number of fish estimated to be entrained each year under the No Action Alternative. ’Alt3B’ represents the difference in entrainment between the NAA and the Alt3B scenario. Negative values represent reductions in entrainment relative to NAA.

Water Year	Arriving	NAA	Alt3B
2015	3,750,529	30,873	-6,010 (-19%)
2016	484,839	872	-187 (-21%)
2017	398,850	2,255	-329 (-15%)
2018	517,297	127	-1 (0%)
2019	822,778	1,358	-203 (-15%)
2020	1,375,431	0	0 (0%)
2021	1,511,723	0	0 (0%)
2022	350,164	71	0 (0%)
2023	152,925	2,242	-271 (-12%)

Table 4-28. The cumulative differences in the number of juvenile winter-run Chinook Salmon entrained into **Yolo Bypass**. ‘Arriving’ is the number of fish estimated to survive to a bypass weir in each year. ‘NAA’ is the number of fish estimated to be entrained each year under the No Action Alternative. ’Alt3B’ represents the difference in entrainment between the NAA and the Alt3B scenario. Negative values represent reductions in entrainment relative to NAA.

Water Year	Arriving	NAA	Alt3B
2015	1,283,096	13,090	-1,251 (-10%)
2016	108,026	293	-21 (-7%)
2017	87,213	1,227	-119 (-10%)
2018	159,615	110	0 (0%)
2019	193,132	440	-51 (-12%)
2020	317,113	243	0 (0%)
2021	310,025	4	0 (0%)
2022	89,312	52	-6 (-11%)
2023	10,729	245	-18 (-7%)

Floodplain habitat area and duration of inundation are not expected to be limiting for CHNWR in most water years (Hendrix et al. 2019). At flows high enough to overtop weirs so that CHNWR juveniles can access floodplain habitat in the bypasses, floodplain area is sufficient to support rearing of those fish. Access to floodplain habitat, which can be measured in days of weir overtopping, is the limiting factor for juvenile salmonids in the Sacramento River system. While Sacramento River Chinook Salmon are extensively studied, data gaps remain that limit CDFW's ability to quantify population-level impacts of preventing juvenile salmonids from entering the flood bypasses. Studies that estimate routing proportions over the weirs as a function of flow at the weir and survival through the bypass compared to survival through the mainstem river are needed for each of the weirs that spill into the Sutter Bypass. Additionally, understanding how floodplain rearing affects marine survival and adult escapement will greatly improve our ability to assess the impact of reduced access to the flood bypasses.

Spring-run Chinook Salmon Juvenile Entry into Sutter Bypass

CHNSR generally experience the same environmental impact considerations as CHNWR except the seasonal timing of their rearing and migration and the locations in which they can be found are expected to differ between runs. Typically, juvenile CHNWR inhabit the upper Sacramento River (i.e. between Red Bluff and the Delta) for rearing and emigration from November through the end of February, whereas CHNSR are typically found in this reach from December through the end of April (Poytress 2024). Furthermore, while CHNWR are predominantly found in the mainstem Sacramento River and connected floodplains, CHNSR have a distinct population that utilize the Sutter Bypass canal to reach their natal spawning streams in Butte Creek.

Juvenile CHNSR from Butte Creek will naturally have access to Sutter Bypass through the creek's connectivity to the bypass canal. Project operations should not prohibit Butte Creek CHNSR entry into the Sutter Bypass but could influence floodplain habitat availability by reducing inflows into the bypass. Conversely, CHNSR spawned in the upper Sacramento River and tributaries (i.e. above Tisdale Weir) will experience nearly identical impacts from Project operations on their entry access into the Sutter Bypass as CHNWR, described above. Because JPEs of CHNSR populations are not readily available, it is not possible to quantify the reduction in bypass entrainment for CHNSR as was done for CHWR. However, a relative assessment of Project scenarios relative to the NAA is possible using a hypothetical starting population of CHNSR.

CDFW analyzed the relative difference in population entrainment under the Project scenarios using a fixed starting population across all years (i.e. 4 million smolts departing Red Bluff). The estimate of fish entrained at each weir location followed the same approach as described in the previous section, substituting CHNWR data for CHNSR or CHNSR surrogates, where appropriate. For example, the seasonal timing of CHNSR departing Red Bluff was determined from RST catch data of CHNSR at Red Bluff. JSATS data for tagged CHNSR were only available for the most recent two years, so JSATS tagged CHNFR released at similar time frames were used as surrogates when estimating CHNSR survival and travel time from Red Bluff to each weir. Even with the inclusion of CHNFR released from Red Bluff as surrogates, not all years had JSATS tagged fish that could be included in this analysis.

CDFW found a reduction of 14-50% in CHNSR entrainment at multiple weirs in several years under the Alt3B operational scenario relative to the NAA (Tables 4-29 through 4-34). In years with little to no weir overtopping (i.e. drier years), there is little to no difference in entrainment due to minimal overtopping entry opportunities. The largest percentage reduction in entrainment was estimated for Moulton Weir in 2023 (89%), but the this was due to a small number of individuals (i.e., 52) being entrained that year (Table 4-29 under 'NAA'). Therefore, this example likely represents a very brief period of overtopping where only a small number of individuals would have had the opportunity to be entrained under the NAA, and most of those individuals would have been excluded under the Alt3B scenario. However, this type of brief reduction in bypass entry opportunity would be less impactful than other years when a much larger number of individuals may be excluded from bypass entry. For example, in 2017, a small percentage of individuals that would have been entrained at Colusa and Tisdale weirs under the NAA are excluded from bypass entry under the Alt3B scenario. However, a much larger number of individuals would ultimately be prevented from entering since more individuals were expected to access the bypass in this year at these locations (Tables 4-30 and 4-31). Overall, juvenile salmonid access to the Sutter Bypass (Table 4-33) is expected to be impacted by Project operations more than access to the Yolo Bypass (Table 4-34). This result is due to the multiple entry points into the Sutter Bypass, which are farther upstream than the entry into Yolo Bypass. Additionally, the weirs spilling into Sutter Bypass overtop more often than the weir spilling into Yolo Bypass, providing greater access opportunities in the absence of the Project.

To better understand the importance of bypass floodplain access to Chinook Salmon populations, we need to better understand if and to what extent the growth benefits from juvenile floodplain rearing translate to improved fitness (e.g., improved ocean survival and subsequent reproduction). Quantifying the proportion of returning adults that reared in bypass floodplains relative to the proportion of the juvenile population that reared in the floodplain in the year of their rearing could indicate the role of floodplain rearing in longer-term population trajectories.

Table 4-29. The percentage difference in spring-run Chinook Salmon bypass entrainment at **Moulton Weir** under the Project scenario (Alt3B) relative to the NAA scenario. 'NAA' represents the number of entrained individuals simulated from a fixed starting population of 4,000,000 under the NAA scenario. Negative percentages indicate a reduction in entrainment under Alt3B relative to NAA.

Water Year	Arriving	NAA	Alt3B
2015	0	0	0 (0%)
2016	2	0	0 (0%)
2017	2,267,835	163	-42 (-26%)
2018	2,738,739	0	0 (0%)
2019	0	0	0 (0%)
2020	2,578,917	0	0 (0%)
2021	1,312,035	0	0 (0%)
2022	2,517,720	0	0 (0%)
2023	2,466,365	52	-46 (-89%)

Table 4-30. The percentage difference in spring-run Chinook Salmon bypass entrainment at **Colusa Weir** under the Project scenario (Alt3B) relative to the NAA scenario. 'NAA' represents the number of entrained individuals simulated from a fixed starting population of 4,000,000 under the NAA scenario. Negative percentages indicate a reduction in entrainment under Alt3Brelative to NAA.

Water Year	Arriving	NAA	Alt3B
2015	0	0	0 (0%)
2016	1	0	0 (0%)
2017	2,164,570	127,453	-64,293 (-50%)
2018	2,593,760	3,273	0 (0%)
2019	0	0	0 (0%)
2020	2,483,259	0	0 (0%)
2021	1,060,786	0	0 (0%)
2022	2,323,375	0	0 (0%)
2023	2,192,464	23,668	-3,567 (-15%)

Table 4-31. The percentage difference in spring-run Chinook Salmon bypass entrainment at **Tisdale Weir** under the Project scenario (Alt3B) relative to the NAA scenario. 'NAA' represents the number of entrained individuals simulated from a fixed starting population of 4,000,000 under the NAA scenario. Negative percentages indicate a reduction in entrainment under Alt3B relative to NAA.

Water Year	Arriving	NAA	Alt3B
2015	0	0	0 (0%)
2016	1	0	0 (0%)
2017	1,532,739	317,419	-60,483 (-19%)
2018	2,094,720	17,488	-98 (-1%)
2019	0	0	0 (0%)
2020	2,183,985	0	0 (0%)
2021	796,272	0	0 (0%)
2022	1,666,088	1	0 (0%)
2023	1,287,580	48,812	-15,528 (-32%)

Table 4-32. The percentage difference in spring-run Chinook Salmon bypass entrainment at **Fremont Weir** under the Project scenario (Alt3B) relative to the NAA scenario. 'NAA' represents the number of entrained individuals simulated from a fixed starting population of 4,000,000 under the NAA scenario. Negative percentages indicate a reduction in entrainment under Alt3B relative to NAA.

Water Year	Arriving	NAA	Alt3B
2015	0	0	0 (0%)
2016	0	0	0 (0%)
2017	815,669	106,040	-18,677 (-18%)
2018	1,653,334	342	0 (0%)
2019	0	0	0 (0%)
2020	1,944,169	2,848	0 (0%)
2021	665,988	30	0 (0%)
2022	1,274,661	4,419	-720 (-16%)
2023	664,318	9,897	-967 (-10%)

Table 4-33. The percentage difference in spring-run Chinook Salmon bypass entrained across all weirs into the **Sutter Bypass** for the Project scenario (Alt3B) relative to the NAA scenario. 'NAA' indicates the number of fish estimated to be entrained under NAA scenario, assuming a fixed starting population of 4,000,000 individuals. 'Alt3B' represents the percentage difference in entrainment relative to NAA. Negative values represent reductions in entrainment.

Water Year	Arriving	NAA	Alt3B
2015	0	0	0 (0%)
2016	4	0	0 (0%)
2017	5,965,144	445,035	-124,819 (-28%)
2018	7,427,219	20,762	-98 (0%)
2019	0	0	0 (0%)
2020	7,246,161	0	0 (0%)
2021	3,169,093	0	0 (0%)
2022	6,507,183	1	0 (0%)
2023	5,946,409	72,532	-19,142 (-26%)

Table 4-34. The percentage difference in spring-run Chinook Salmon bypass entrained across all weirs into the **Yolo Bypass** for the Project scenario (Alt3b) relative to the NAA scenario. 'NAA' indicates the number of fish estimated to be entrained under NAA scenario, assuming a fixed starting population of 4,000,000 individuals. 'Alt3B' represents the percentage difference in entrainment relative to NAA. Negative values represent reductions in entrainment.

Water Year	Arriving	NAA	Alt3B
2015	0	0	0 (0%)
2016	0	0	0 (0%)
2017	815,669	106,040	-18,677 (-18%)
2018	1,653,334	342	0 (0%)
2019	0	0	0 (0%)
2020	1,944,169	2,848	0 (0%)
2021	665,988	30	0 (0%)
2022	1,274,661	4,419	-720 (-16%)
2023	664,318	9,897	-967 (-10%)

Conclusions

CDFW's analysis shows that Project operations would result in negative impacts to juvenile CHNWR and CHNSR access to floodplain rearing habitat. The greatest impacts are expected to occur at Colusa and Tisdale weirs, reducing entry into Sutter Bypass. Project operations are also expected to reduce entrainment into Yolo Bypass at Fremont Weir under full weir overtopping and through "Big Notch." Additional studies are needed to validate the impact of reduced access to floodplains on population abundance of salmonids.

4.1.7.2. Days of Inundation of Bypass Floodplain Habitats

Changes in the magnitude and frequency of flow over weirs into the Sutter and Yolo bypasses could decrease the length of time that floodplains are activated, which reduces habitat and food availability for winter-run Chinook Salmon and spring-run Chinook Salmon juveniles.

The ITP Application (Sites Authority 2023) did not assess duration of inundation under existing (i.e., NAA) conditions compared to the Project for the Sutter Bypass. Instead, the ITP Application (Sites Authority 2023) only includes analyses for Yolo Bypass, where the minimum flow necessary to exceed the Toe Drain must be observed as the daily average flow in Yolo Bypass in order to count as a day of inundation (Sommer et al. 2001). This analysis found a reduction of 1-3 days of inundation in the Yolo Bypass per year on average. To CDFW's knowledge, a similar metric for a flow value that corresponds to toe drain overtopping onto the floodplain has not been published for the Sutter Bypass. The necessary data and hydraulic modeling to reasonably estimate the days of inundation in the Sutter Bypass under the Project and the NAA are not currently publicly available. Calculating the days of inundation would allow for the assessment of floodplain utility for juvenile salmonid rearing. The benefit of floodplain rearing comes from the highly productive zooplankton food web that is generated after approximately 14 days of floodplain inundation. Therefore, alterations to the system that would interrupt floodplain inundation such that prolonged periods of inundation become several shorter inundation periods with dry periods in between may greatly reduce the beneficial qualities of floodplain habitat to juvenile salmonids. More data and hydraulic modeling are needed to reasonably estimate these potential impacts.

The Sutter Bypass can become partially inundated via weir overtopping or backfilling. Backfilling occurs when discharge from the Feather River confluence causes the Sacramento River to back fill into the lower Sutter Bypass, which can be sufficient to inundate the entire lower Sutter Bypass. Similarly, Sutter Bypass inundation can be prolonged due to a limited capacity to drain for the same reason. Inundation caused by backfilling may be a significant source of juvenile Chinook Salmon entrainment into flooded bypass habitat according to preliminary examination of JSATS telemetry data (NMFS 2024). Additionally, CHNSR juveniles migrating from Butte Creek migrate through the Sutter Bypass and benefit from the inundated rearing habitat (Cordoleani et al. 2018).

Three main weirs provide flood water and fish entry access at increasing river stages: Tisdale, Colusa, and Moulton weirs. Tisdale Weir is the most downstream weir in the Sutter Bypass and has the lowest elevation, thus it overtops most frequently. Colusa and Moulton weirs provide access to additional floodplain habitat higher up in the system. All of the floodplain habitat in the Sutter Bypass is upstream of the Yolo Bypass, potentially allowing juvenile salmon access to floodplain rearing habitat after a shorter migration and earlier in the season than the Yolo Bypass. During periods of prolonged high flows, the Sutter Bypass can connect to the Yolo Bypass, creating extended periods of inundated floodplain access for juvenile salmonids.

Conclusions

Project operations are expected to reduce the duration of floodplain inundation in Sutter and Yolo Bypasses. The impact to duration of inundation was quantified for Yolo Bypass, but the necessary hydrologic data are lacking to quantify the extent of this impact for the Sutter Bypass. Reduced duration of inundation may reduce growth benefits to juvenile CHNWR and CHNSR rearing in these habitats. Additional studies are needed to verify the change in the duration of inundation and related impacts to CHNWR and CHNSR.

4.1.7.3. Inundated Area in the Yolo and Sutter Bypasses

Changes in the magnitude of flow over the weirs into the Sutter and Yolo bypasses could decrease the area of floodplains that are inundated, which would reduce habitat and food availability for winter-run Chinook Salmon and spring-run Chinook Salmon juveniles.

Project original analyses of inundated area in the Yolo and Sutter Bypasses provided in the ITP Application (Sites Authority 2023) relied on two important assumptions about suitable floodplain habitat. The ITP Application (Sites Authority 2023) assumed that suitable rearing habitat for salmon had to: 1) be <1 m deep, and 2) have flow velocities <1.5 fps. Any inundated area within the bypass that did not meet both of these criteria according to hydraulic modeling was considered unsuitable floodplain habitat for salmon. Therefore, Project operations that reduce water depths from >1 m deep to <1 m deep were considered to have created additional floodplain habitat for juvenile salmonids. When averaging across months and water year types, periods when the Project was presumed to increase available habitat by reducing water depths to <1 m mathematically cancelled out impacts when the Project reduced available inundated habitat, resulting in little to no net difference between NAA and Project scenarios.

The ITP Application (Sites Authority 2023) cites Whipple et al. (2019) to support the <1 m deep criterion, and cited Hampton (1997) to justify the <1.5 fps flow velocity criterion. These criteria are inappropriate in the context of bypass floodplain habitat for multiple reasons. First, these criteria were derived from habitat suitability index studies performed in the upper-most reaches of the salmon-accessible portions of the Sacramento and Trinity rivers, respectively. Additionally, these criteria were based on fry <60 mm FL. Most importantly, these criteria were derived for upper river in-channel habitat. It is inappropriate to apply such criteria to off-channel floodplain habitat in the lower river (Gard 2023) and for fish that may be >60 mm FL. Therefore, CDFW reassessed the modeled Project impacts on all inundated area in the Yolo and Sutter bypasses without using depth or velocity limits to define suitable floodplain habitat for salmonids.

Floodplain Inundation in the Yolo Bypass

The unfiltered inundated area by flow rating curve for Yolo Bypass showed that inundated area continued to increase as flow increased. However, the filtered area by flow rating curve showed that inundated area would begin to decrease after flows in the bypass exceed 9,200 cfs (Figure 4-89). Using the unfiltered rating curve, CDFW found that the Alt3B operational scenario resulted in a considerably reduced inundated habitat more frequently and to a greater degree (Figure 4-90, right) compared to the original findings reported in the ITP Application (Sites Authority 2023), which found that the Project had an approximately net-neutral impact on inundated habitat across water year types (Figure 4-90, left). Additionally, anomalous flow inputs that are suspected to be caused by a CalSim II modeling artifact[8] appear to be responsible for the periods of the largest modeled increases in inundated habitat.

[8] CalSim II uses a linear optimization procedure with a complex logic structure to allocate flows under different modeled scenarios. This complex logic structure can result in unexpected changes in flow at various locations at a specific time point, making it difficult to identify the cause(s) of flow differences across modeled scenarios.

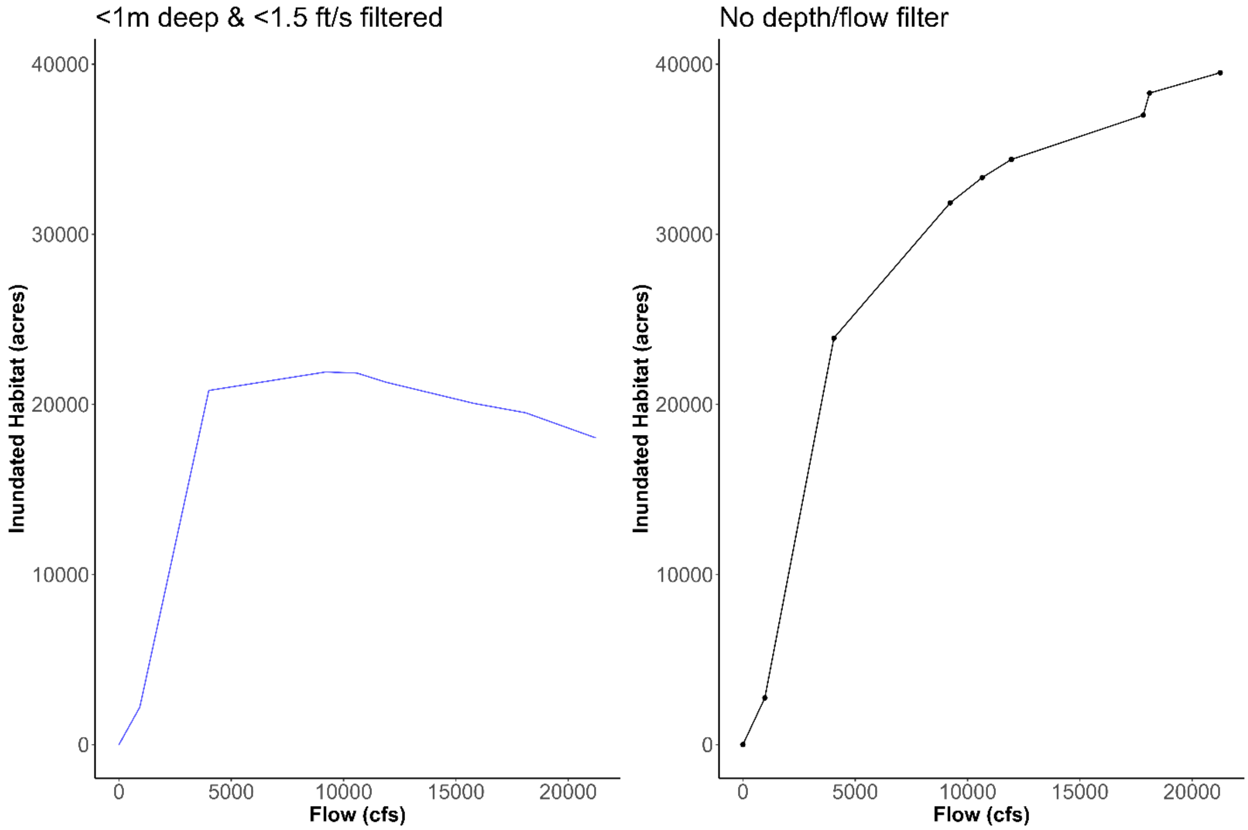


Figure 4-89. The original inundated area-flow rating curve that filtered inundated area >1 m deep or >1.5 fps (ft/s) surface velocity (left) and the unfiltered inundated area-flow rating curve (right) for the Yolo Bypass.

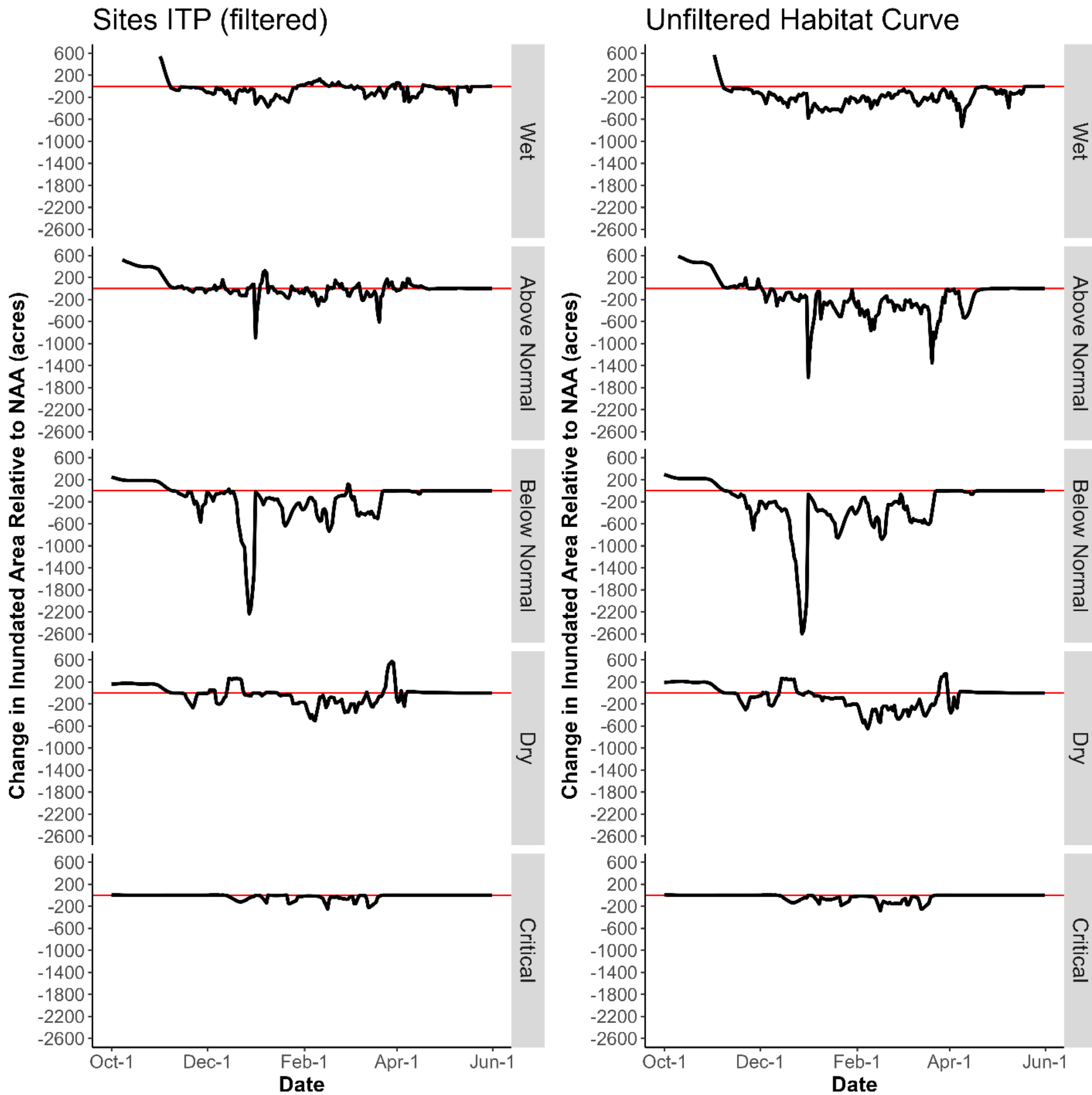


Figure 4-90. The change in inundated area in the Yolo Bypass under Alt3B relative to No Action Alternative (NAA) by day of water year averaged by water year type using the filtered area-flow rating curve (left) and the unfiltered rating curve (right). The horizontal red line represents no difference between Alt3B and NAA.

Floodplain Inundation in the Sutter Bypass

The unfiltered inundated area by flow rating curve for Sutter Bypass showed that inundated area continued to increase as flow increased. However, the filtered area by flow rating curve showed that inundated area would begin to decrease after flows in the bypass exceed 2,000 cfs (Figure 4-91). Using the unfiltered rating curve, CDFW found that the Alt3B operational scenario resulted in a considerably reduced inundated area in the Sutter Bypass across water year types (Figure 4-92, right). This result differs from the original findings reported in the ITP Application (Sites Authority 2023) which found that the Project increased inundated area relative to the NAA across water year types (Figure 4-92, left).

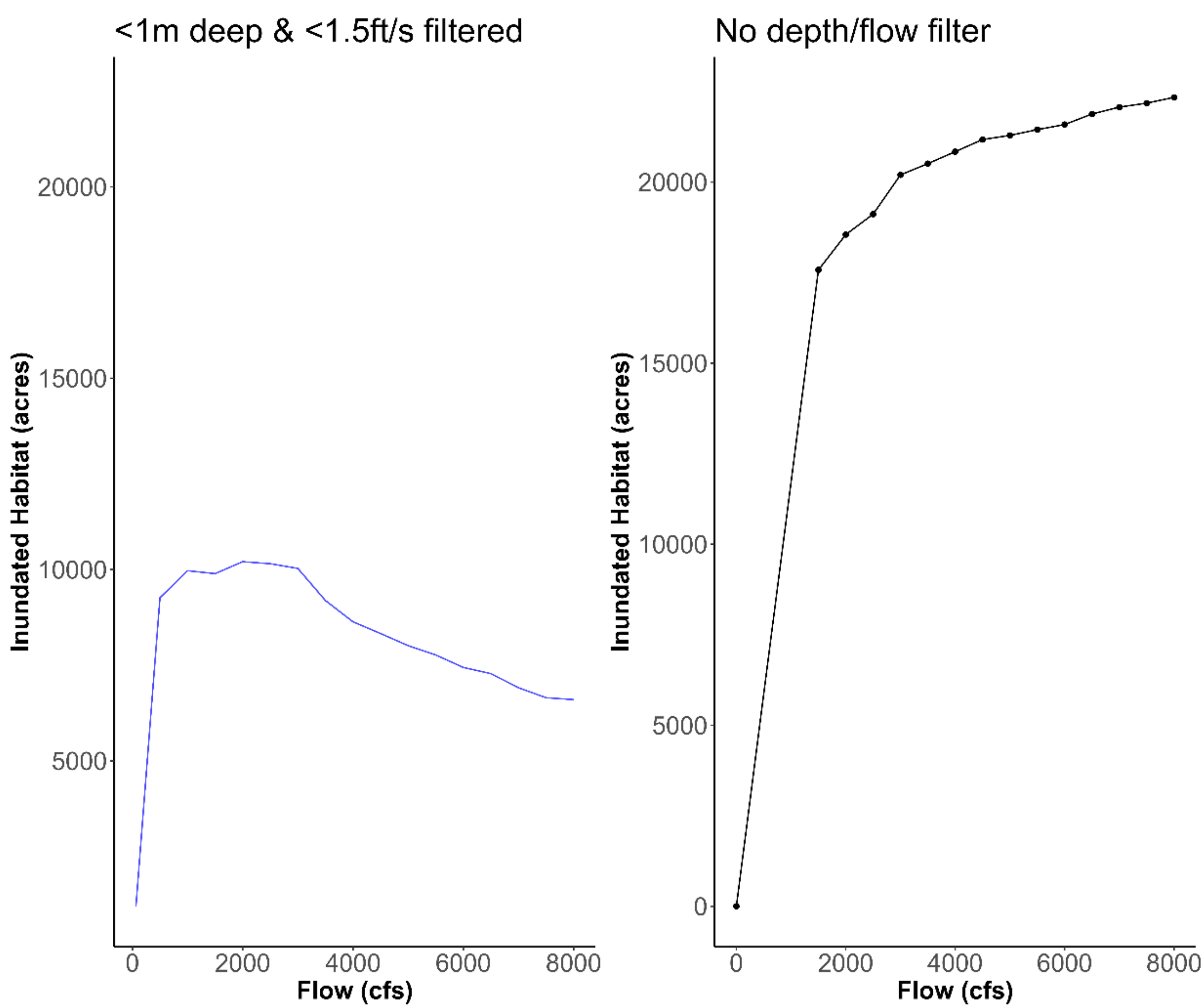


Figure 4-91. The original inundated area-flow rating curve that filtered inundated area >1 m deep or >1.5 fps (ft/s) surface velocity (left) and the unfiltered inundated area-flow rating curve (right) for the Sutter Bypass.

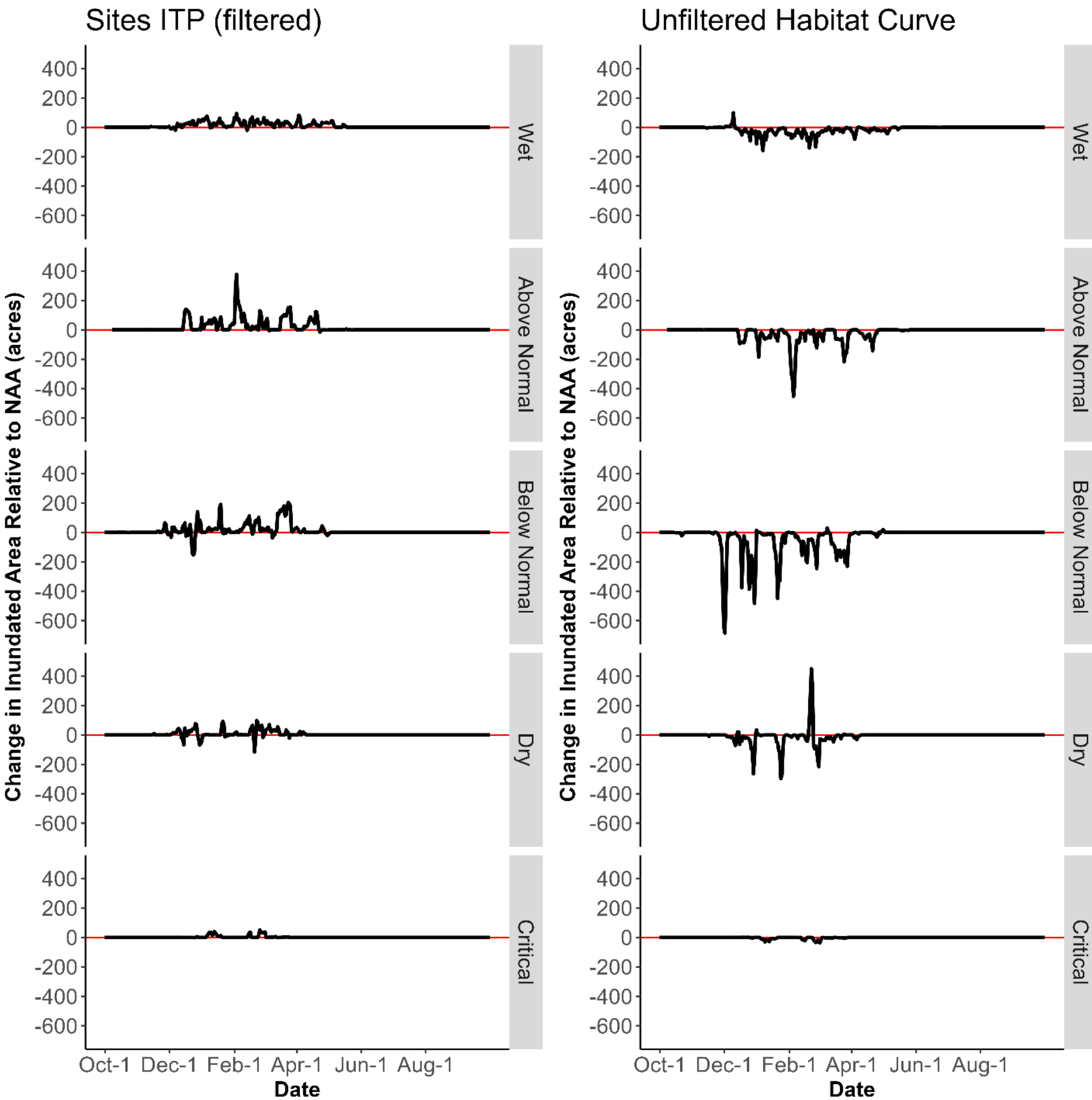


Figure 4-92. The change in inundated area in the Sutter Bypass under Alt3B relative to No Action Alternative (NAA) by day of water year averaged by water year type using the filtered area-flow rating curve (left) and the unfiltered rating curve (right). The horizontal red line represents no difference between Alt3B and NAA.

Conclusions

The Project is expected to reduce the quantity of inundated floodplain habitat in Yolo and Sutter Bypasses in all years where bypass inundation would occur. The estimate of impacts to inundated area provided in the Sites ITP Application (Sites Authority 2023) under-estimated impacts by limiting the consideration of suitable habitat to only include habitat <1 m deep. Eliminating this limitation and considering all impacted inundated habitat resulted larger and more frequent impacts to inundated floodplain habitat in Yolo and Sutter Bypass.

4.1.8. Spawning and Juvenile Rearing in the Feather River

Exchanges with Oroville Reservoir as a result of Project operations would affect flows in the Feather River below the Oroville Dam complex, which may have impacts to spring-run Chinook Salmon spawning, redd viability, and juvenile rearing.

CHNSR are present in the Feather River downstream of Oroville Dam year-round. Adults typically enter Feather River from March–June and hold until they spawn the following Fall. Spawning is known to occur in the Low Flow Channel (LFC) between the Fish Barrier Dam and the Thermalito Afterbay Outlet (RM 67-59), and the High Flow Channel (HFC) from the Thermalito Afterbay Outlet to Honcut Creek (RM 59-44) (Sommer et al. 2001) (Figure 4-93). Young emerge from gravel nests (redds) in the fall and migrate downstream from approximately November–June (Sommer et al. 2001; Bilski and Kindopp 2009).

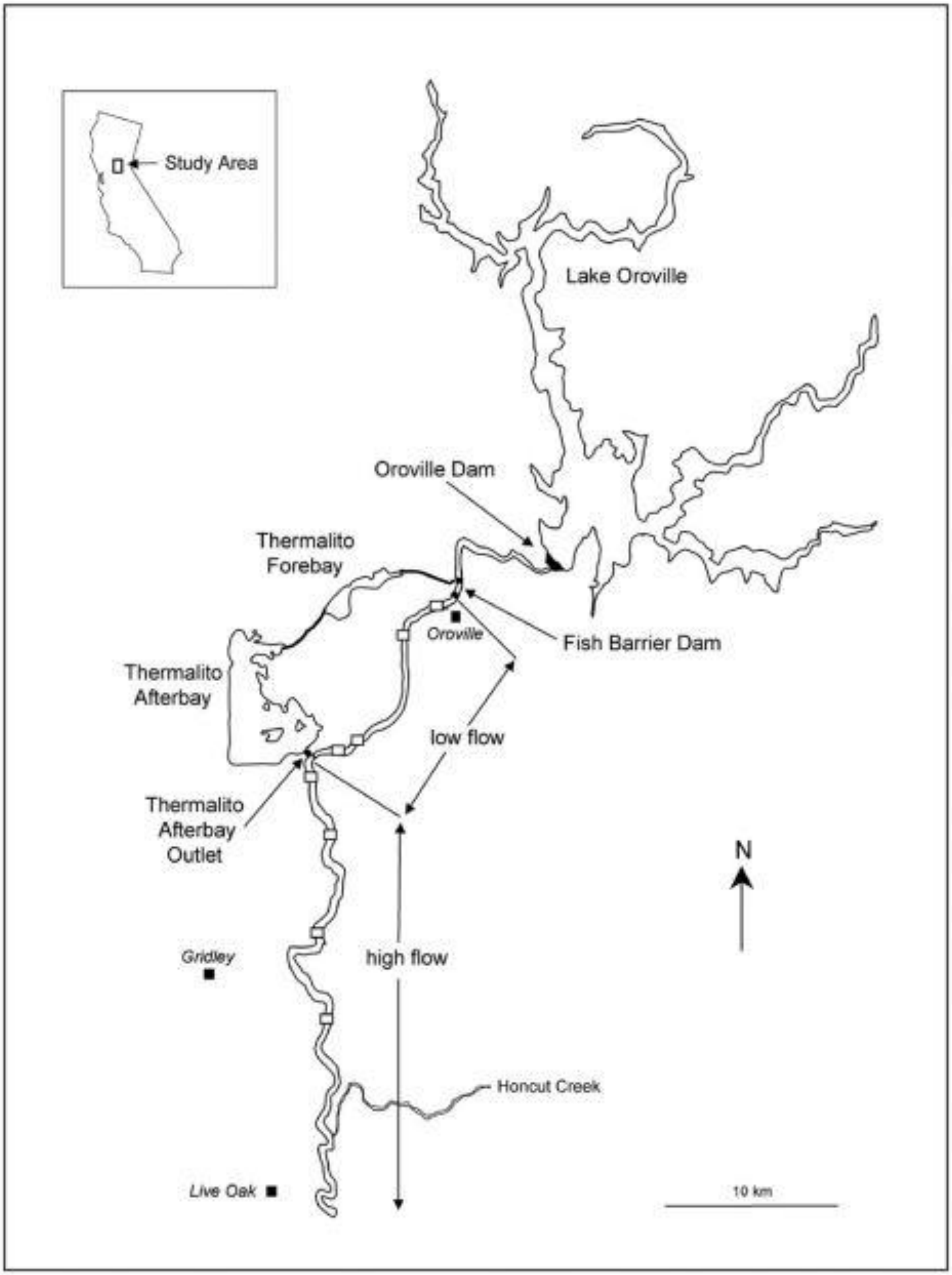


Figure 4-93. Map of the Oroville Dam complex from Marchetti et al. 2011.

The hydrology of the portion of the Feather River utilized by CHNSR is highly altered, primarily influenced by operations at the Oroville Dam Complex (Oroville Dam, Thermalito Diversion Dam, and Thermalito Afterbay Outlet) (Marchetti et al. 2011; Seesholtz et al. 2004). As a consequence, environmental conditions that impact CHNSR, like flow and temperature, are heavily dependent on dam operations.

The ITP Application (Sites Authority 2023) proposes water exchanges with Oroville Reservoir where water would be released from the Project to meet SWP needs during June and July. Water held in Oroville Reservoir could then be released by DWR in late summer and fall. Volumes involved could be up to 136 TAF in dryer water years, however, the specific frequency, volumes, flow, and timing of exchanges and associated discharges are not specified in ITP Application (Sites Authority 2023). Because Oroville operations can strongly affect CHNSR use of the Feather River downstream of Oroville Dam, these details are essential for proper evaluation of potential impacts to the species.

4.1.8.1. Water Temperature in the Feather River

The ITP Application (Sites Authority 2023) temperature analysis compared modeled monthly average temperatures on the Feather River for the NAA and the Alt3B operational scenario. Results showed that monthly average temperature could exceed targets 11-13% more frequently in some months under the Alt3B operational scenario than under the NAA, but that and that the average monthly temperature change would be within 0.5 °F. As temperature modeling in the ITP Application (Sites Authority 2023) relies on monthly averages, it does not capture sub-monthly changes in temperature that could cause mortality or sub-lethal impacts on CHNSR.

4.1.8.2. Redd Dewatering in the Feather River

The ITP Application (Sites Authority 2023) evaluated redd dewatering impacts in the Feather River based on redd depth distribution data and monthly average CalSim II model flows. Results showed a potential increase in dewatering of 2% in some months (Sites Authority 2023). This approach likely underestimates redd dewatering potential, as it does not capture sub-monthly flow variability. Because salmon spawn in relatively shallow water, with optimum depths less than 1 meter (Gard 2023), relatively small changes in flow that occur at daily or shorter timesteps could result in dewatering. Such impacts are not quantified when using a monthly timestep.

4.1.8.3. Habitat Capacity

The ITP Application (Sites Authority 2023) estimated changes in the availability of spawning habitat due to Project operations using a WUA approach similar to what is described in Section 4.1.4.1 for the Sacramento River. Results showed a range from a decrease of 3.7% to an increase of 7.6% in the HFC, depending on water year type. Similar to redd dewatering, the model relied on monthly average flows from September-November, which does not incorporate variability that may occur at a sub-monthly time step. Sites did not evaluate spawning habitat WUA effects in the LFC, where the majority of CHNSR spawning occurs (Sommer et al. 2001), nor did they evaluate rearing habitat use area in the Feather River.

Conclusions

Analyses in the ITP Application (Sites Authority 2023) evaluating impacts to CHNSR in the Feather River are limited by an absence of specific information on exchanges with Oroville Reservoir that may impact the conditions on the Feather River (e.g., exchange frequency, timing, volume). Since environmental conditions important for salmonids are strongly tied to operations at the Oroville Dam complex, these details are essential for properly evaluating the applicability and validity of the methods used in the ITP Application (Sites Authority 2023) to examine effects of Project operations. Thus, given that 1) critical details on the frequency, volume, flow and timing of exchanges with Oroville Reservoir are not clear, 2) water operations at the Oroville Dam complex drive environmental conditions important for salmon in the Feather River, 3) the use of monthly averaged flows and temperatures leave much uncertainty about the variability that could impact CHNSR at shorter timesteps and, 4) impacts to rearing habitat area in the HFC were not evaluated, there is the potential for the impacts to CHNSR.

Impacts of transfers between Oroville Reservoir and Sites on redd dewatering would be minimized through DWR's implementation of their Water Transfer Monitoring Plan (required by ITP No. 2081-2019-066-00; CDFW 2020a). CDFW does not expect operations of the Project to appreciably change the area or availability of spawning habitat for CHNSR, as spawning primarily occurs in the LFC.

4.1.9. Juvenile Rearing and Survival in the Delta

4.1.9.1. Juvenile Through-Delta Survival

Changes in timing and magnitude of flow through the Delta as a result of Project operations could result in changes in survival of juveniles migrating through the Delta.

Through-Delta Survival was estimated using a spreadsheet version of the Survival, Travel Time, and Routing Analysis (STARS) model, based on Pope et al. (2018). STARS is a stochastic, individual-based simulation model designed to predict survival of a cohort of fish that experience variable daily river flows as they migrate through the Delta from the Sacramento River. Detailed methods and results for the STARS model are presented in Perry et al. (2019). Modeling results herein are based on information CDFW obtained from ITP Application (Sites Authority 2023).

Although the STARS model considers variability in survival, travel time, and routing, the spreadsheet model provides only one estimate of survival and does not account for the variability of coefficient estimates (Perry et al. 2018). The spreadsheet model estimates monthly survival using CalSim II inputs of Sacramento River flow at Freeport and the Delta Cross Channel (DCC) gate position. It does not differentiate between CHNWR, CHNSR, or other Chinook Salmon; however, analysis of juvenile Chinook Salmon entry into the Delta was conducted for each month from September through June to capture the period when CHNWR and CHNSR are likely to be present in the Delta.

Changes in mean through-Delta survival between the NAA and Project ranged from a decrease of about 1% to an increase of about 5% in any month or water year type (Table 4-35). Small decreases in survival between NAA and the Alt3B operational scenario appear in January through April of above normal and below normal water years (approximately 1% decrease; Table 4-35), months that CHNWR and CHNSR are expected to be present in the Delta. Increased through-Delta survival is predicted in September through November in all but wet year types (approximately 1–5% increase; Table 4-35), when CHNWR YOY or CHNSR yearlings may be present in the Delta.

Table 4-35. Probability of juvenile Chinook Salmon Through-Delta Survival for the No Action Alternative (NAA) and the Alt3B operational scenario, averaged by month and water year type (Sites Authority 2023).

Month	Water Year Type	NAA	Alt3B
Sep	Wet	0.37	0.37 (1%)
Sep	Above Normal	0.37	0.38 (2%)
Sep	Below Normal	0.29	0.30 (3%)
Sep	Dry	0.27	0.28 (3%)
Sep	Critically Dry	0.29	0.30 (5%)
Oct	Wet	0.35	0.35 (0%)
Oct	Above Normal	0.33	0.33 (2%)
Oct	Below Normal	0.31	0.32 (4%)
Oct	Dry	0.30	0.31 (4%)
Oct	Critically Dry	0.25	0.25 (2%)
Nov	Wet	0.40	0.40 (0%)
Nov	Above Normal	0.37	0.37 (1%)

Month	Water Year Type	NAA	Alt3B
Nov	Below Normal	0.38	0.39 (3%)
Nov	Dry	0.34	0.34 (2%)
Nov	Critically Dry	0.29	0.30 (0%)
Dec	Wet	0.49	0.48 (0%)
Dec	Above Normal	0.46	0.46 (0%)
Dec	Below Normal	0.48	0.48 (0%)
Dec	Dry	0.45	0.45 (0%)
Dec	Critically Dry	0.40	0.40 (0%)
Jan	Wet	0.61	0.61 (0%)
Jan	Above Normal	0.57	0.57 (-1%)
Jan	Below Normal	0.50	0.50 (-1%)
Jan	Dry	0.46	0.46 (0%)
Jan	Critically Dry	0.43	0.43 (0%)
Feb	Wet	0.64	0.64 (0%)
Feb	Above Normal	0.61	0.61 (0%)
Feb	Below Normal	0.56	0.55 (-1%)
Feb	Dry	0.51	0.51 (0%)
Feb	Critically Dry	0.46	0.46 (0%)
Mar	Wet	0.61	0.61 (0%)
Mar	Above Normal	0.62	0.61 (0%)
Mar	Below Normal	0.52	0.51 (-1%)
Mar	Dry	0.48	0.48 (0%)
Mar	Critically Dry	0.43	0.43 (0%)
Apr	Wet	0.56	0.56 (0%)
Apr	Above Normal	0.54	0.53 (-1%)
Apr	Below Normal	0.47	0.47 (0%)

Month	Water Year Type	NAA	Alt3B
Apr	Dry	0.43	0.43 (0%)
Apr	Critically Dry	0.40	0.40 (0%)
May	Wet	0.49	0.49 (0%)
May	Above Normal	0.45	0.45 (1%)
May	Below Normal	0.43	0.43 (0%)
May	Dry	0.41	0.41 (0%)
May	Critically Dry	0.38	0.38 (0%)
Jun	Wet	0.35	0.34 (-1%)
Jun	Above Normal	0.32	0.32 (0%)
Jun	Below Normal	0.32	0.32 (0%)
Jun	Dry	0.34	0.34 (0%)
Jun	Critically Dry	0.30	0.30 (0%)

Inherent limitations of the STARS model introduce some level of uncertainty in the results and could be responsible for muting potential impacts of the Project and contribute to a lack of differences in survival between the Alt3B operational scenario and the NAA. Perry et al. (2018) relies predominantly on data from acoustic-tagging studies of large (>140 mm FL) hatchery CHNLFR smolts; therefore, conclusions should be applied cautiously to pre-smolt migrants. Juvenile salmon less than 80 mm FL are more likely to rear in the Delta for extended periods of time rather than emigrate quickly from the Delta (Moyle 2002) and will not be represented well by the STARS model. Survival data are lacking for small (fry-sized) juvenile emigrants due to the difficulty of tagging small individuals; therefore, through-Delta survival estimates should primarily be used to inform smolt survival estimates and not be relied upon to represent rearing survival (Simenstad et al. 2017). Perry et al. (2018) also does not account for water temperature impacts on survival that may occur beginning in April when water temperatures start to increase in the Delta. Hance et al. (2022) found that juvenile CHNWR survival decreases with reduced flow and increased water temperatures and found the strongest correlation with daily water temperature and survival after March 1 in the upper Delta between Knights Landing and Sacramento. Singer et al. (2020) documented similar results between Sacramento and Hood, with reduced survival of CHNFR and CHNSR smolts as water temperatures in April increased. Furthermore, Perry et al. (2018) is currently limited in that it cannot account for impacts associated with south Delta export operations or entrainment because it only includes Freeport inflow and DCC gate operations as covariates of through-Delta survival and interior Delta routing probability. Because the STARS model does not account for south Delta operations of the SWP and CVP, any positive or negative impacts to survival from changes in exports would not be reflected in STARS survival estimates.

For CHNWR and CHNSR smolts rapidly transiting the Delta, survival estimates generated by STARS and Ecological Particle Tracking Model (ECO-PTM) are not intended to predict future outcomes or current conditions. Instead, STARS and ECO-PTM provide simulation tools that compare the effects of different water management options to smolt migration survival, with accompanying estimates of uncertainty. There is an assumption of stationarity of basic relationships within these two models to enable comparison of scenarios for the current analysis. As with all other methods found in the ITP Application (Sites Authority 2023), it is possible that underlying relationships (e.g., flow-survival) used to inform STARS and ECO-PTM could change in the future. It may be necessary to re-examine the relationships as new information becomes available.

Conclusions

Modeling results show changes in survival ranging from -1% to +5%. Given these results, and acknowledging the uncertainty in these estimates, CDFW expects operations of the Project to have minimal impacts on survival of migrating CHNWR and CHNSR smolts in the Delta.

4.1.9.2. Juvenile Rearing Habitat in the Delta

Changes in timing and magnitude of flow through the Delta due to Project operations could decrease the availability of juvenile rearing habitat.

While Delta waterways function as migratory corridors for CHNWR and CHNSR smolts, these waterways also provide holding and rearing habitat. Juvenile salmonids use the region for rearing for several months during the winter and spring before migrating to the marine environment. Natural juvenile CHNWR can spend from three days to three months rearing and migrating through the Delta to the mouth of San Francisco Bay (Brandes and McLain 2001; MacFarlane and Norton 2002). CHNWR are present in the Delta for an extended period of time, with apparent residence times ranging from 41 to 117 days and longer apparent residence times for juveniles arriving earlier at Knights Landing (del Rosario et al. 2013). Sizeable fractions of the adult CHNFR escapement are made up of fish that left freshwater and entered the estuarine environment as fry or parr life stages in addition to the expected number that entered the estuary as smolts (Miller et al. 2010; Sturrock et al. 2015). Among the CHNFR parr and fry life stages leaving the freshwater environment, a large fraction (25% of parr and 55% of fry migrants) spent time rearing in the brackish waters of the Bay-Delta region (Miller et al. 2010). Similar life history diversity strategies likely exist for CHNWR and CHNSR (Flitcroft et al. 2019).

The ITP Application (Sites Authority 2023) quantifies the effects of the Project on inundation of restored riparian benches in the north Delta, which were designed to improve channel margin habitat and restore habitat function (Hellmair et al. 2018) that has been historically reduced due to construction of levees and bank armoring (Williams 2006). This was accomplished using Habitat Suitability Indices from USFWS (2005) to estimate “bench inundation indices” that weigh the quality of juvenile Chinook Salmon rearing habitat based on water depth, as simulated in the WSE using DSM2-HYDRO. Three seasonal periods were evaluated: fall (October-November), winter (December-February), and spring (March-June) (Sites Authority 2023, Appendix 4I).

Sites evaluated 37 riparian benches and 17 wetland benches (Figure 4-94) with a total length of 6.0 miles and 3.0 miles, respectively, estimating water depth at each 15-minute timestep from DSM2-HYDRO. Habitat Suitability Indices from the USFWS (2005) for juvenile CHNWR were applied to each depth and then multiplied by the length of the site. An overall “bench inundation index” was calculated for each bench type in each of the five geographic group locations for all three seasons and ranges from zero (no water of suitable depth available at any time) to one (optimal water depth available always) (Reclamation and Sites Authority 2023).

CDFW notes the same caution about the application of the USFWS (2005) habitat suitability index curves to Delta rearing habitat, that was discussed in Section 4.1.7.3 for floodplain rearing. These curves were developed for fry rearing in the far upstream areas of the Sacramento River and Battle Creek and may not accurately represent rearing habitat characteristics in the Delta. Unlike Project analysis for floodplain habitat, which considered water depth as a binary yes-or-no factor, the Delta rearing habitat analysis in the ITP Application (Sites Authority 2023) considered habitat suitability as a curve of various habitat qualities. This approach reduces bias from applying habitat suitability index curves from further upstream; however, reanalyzing habitat changes should be completed if habitat curves specific to Delta rearing habitat are available in the future.

Conclusions

Modeled riparian and wetland bench habitat inundation was reduced between 0% and 10% under the Project, relative to the NAA, depending on season and location. Proportional differences were greater for riparian benches than wetland benches, and the overall reduction in inundated bench habitat was approximately 2,000 ft (4%) (Sites Authority 2023 Appendix 4I, Table 4I-3). Sites Authority proposed mitigation for this reduction in rearing habitat loss in the Delta in the ITP Application (Sites Authority 2023), which is discussed in Section 6.3.

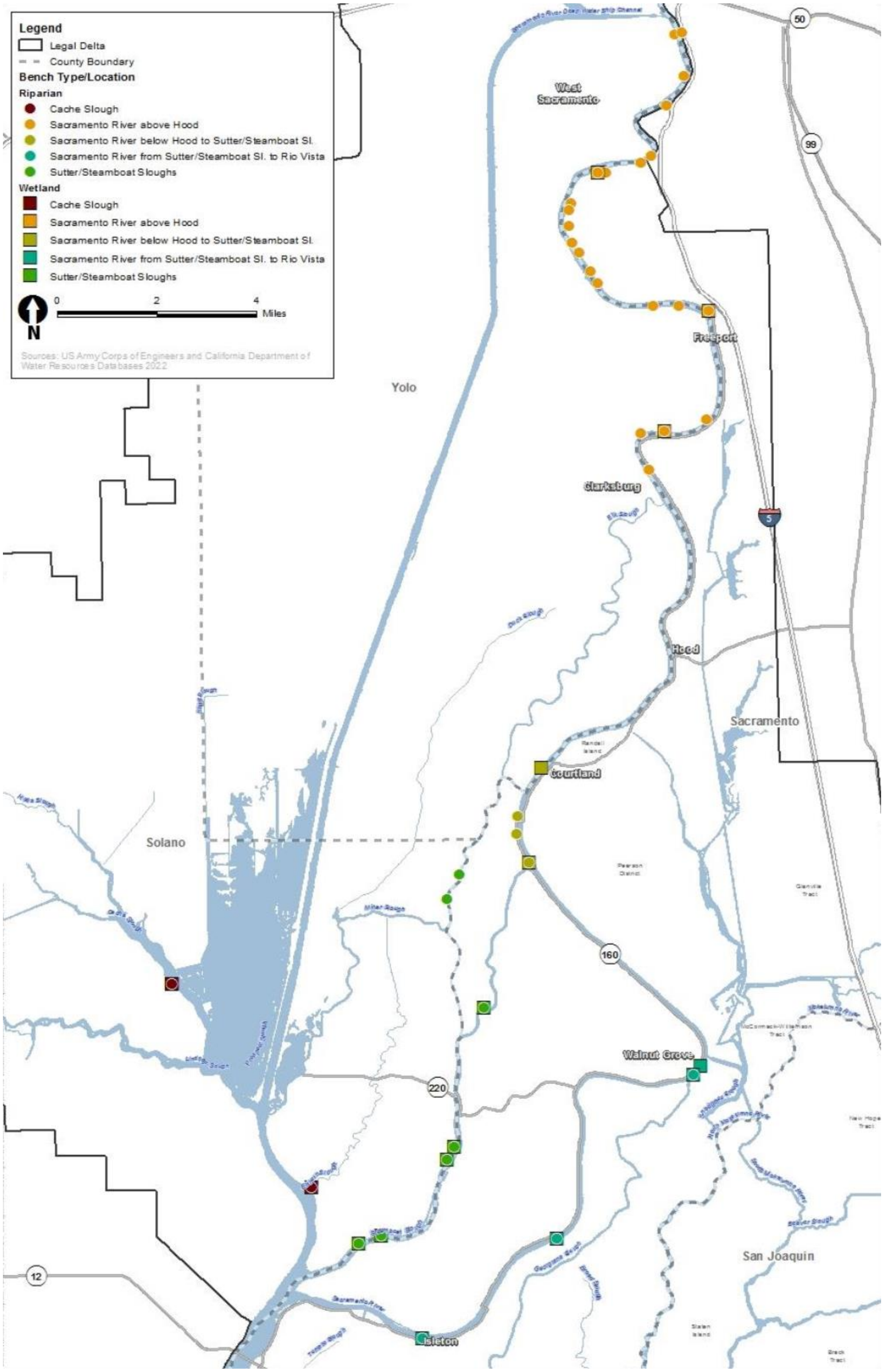


Figure 4-94. Benches analyzed for inundation effects of the Project (from Sites Authority 2023).

4.1.9.3. Entrainment - Salvage Density Method

Changes in timing and magnitude of exports could result in changes to entrainment of winter-run Chinook Salmon and spring-run Chinook Salmon at the south Delta exports facilities.

The ITP Application (Sites Authority 2023) used the Salvage-Density Method to estimate entrainment loss for both hatchery-origin and natural-origin CHNWR and CHNSR. The Salvage-Density Method evaluates the differences in entrainment loss at the CVP and SWP export facilities between NAA and the Alt3B operational scenario. These outputs are not predictions of future entrainment, but rather depict expected differences in south Delta exports between scenarios weighted by historical salvage or loss density of fish. The Salvage-Density Method relies on CalSim II modeled differences in SWP exports, including changes to spring export curtailments for Delta outflow under the Alt3B operational scenario and assumes that changes in salvage and loss occur in proportion to the change in amount of water pumped between scenarios.

The majority of historical entrainment for CHNWR occurs from January through April, and the majority of historical loss for CHNSR occurs between April and May. The greatest differences in estimated entrainment between the NAA and the Alt3B operational scenarios is an increase of 11% in April in below normal water years. Based on CalSim II modeling results, Site's operations would result in increased exports during some years during these months (Figure 4-10).

Conclusions

Modeling results suggest the Project may increase CHNSR entrainment and salvage due to increased South Delta exports to move Project water to south of Delta participants. During the months of January through May, exports at the CVP and SWP export facilities are limited by OMR flow requirements, which minimize entrainment and loss of CHNWR and CHNSR juveniles (ITP No. 2081-2019-066-00; CDFW 2020a). Further limitations on exports during the spring may have unintended consequences for flow in the Sacramento River, which could affect survival, flow, and water temperature for CHNWR and CHNSR (e.g., see Section 4.1.2.1).

4.1.10. Winter-run Chinook Salmon Life Cycle Modeling

Project operations could result in changes in winter-run Chinook Salmon production, survival, and escapement. Life cycle models improve our understanding of cumulative and population-level effects of the Project.

Multiple life cycle models were used to assess potential Project impacts on CHNWR. Since each of the included models have slightly different inputs, assumptions, and structure, estimated outputs from each model may provide a slightly different perspective on life history dynamics. While these life cycle models may be highly complex and flexible, none of them were designed for the primary purpose of assessing the impacts of Project diversions on CHNWR. Therefore, their utility in this purpose is limited to the components of the model that can be influenced by Project operations.

For each model, two of the primary inputs that can be altered by the Project are water temperature and depth in the upper river (i.e. above Project diversion locations) as a result of water exchanges with Shasta Reservoir. These changes in water temperature in the upper river can alter temperature- and flow-driven mortality of early life stages (i.e. eggs and fry). The remaining life cycle model input that can be altered by Project operations is flow in lower portions of the river (i.e. below diversion locations), which may influence flow-based migration survival. Migration survival can be influenced by flow directly or by altering routing, which changes migration survival probability.

The Interactive Object-oriented Simulation (IOS) model estimated a flow-survival relationship for Red Bluff to Verona from seven years of tagged CHNWR telemetry data. Migration survival through the Delta is modeled using the Delta Passage Model (DPM), in which survival is a function of flow. Oncorhynchus Bayesian Analysis (OBAN) assumes that only individuals that take specific routes through the Delta experience flow-mediated survival probabilities, while the others experience a fixed survival rate. Finally, the WRLCM assumes that migratory survival is affected by monthly average river flow at Bend Bridge, which is altered by monthly average diversions. Monthly average flows and diversions are insufficient to capture Project operation impacts on migratory survival because diversions vary widely within a monthly period. The life cycle models as implemented in the provided analyses are generally not set up well to account for variance in migration survival as a function of river flow, despite flow being widely recognized as highly relevant to migration survival (Michel et al. 2015; Michel et al. 2021; Notch et al. 2020a).

Another major shortcoming of all of the life cycle models used is the inability to account for possible influences of the floodplain bypasses on population dynamics. The Sutter Bypass is unaccounted for in the WRLCM, and the Yolo Bypass only plays a very minor role in the model. Routing into the bypasses under different flow conditions, survival through the bypasses based on date and location of entry, and the potential influence of growth benefits from floodplain rearing on ocean survival are all potentially important factors that are not well understood. These dynamics are left out of the life cycle models because there are not studies available that quantify these aspects of Chinook Salmon life history in the Sacramento River. It is imperative to fill some of these knowledge gaps to better understand Project impacts on salmon population dynamics.

4.1.10.1. Winter-run Chinook Salmon Interactive Object-Oriented Simulation (IOS) model

The ITP Application (Sites Authority 2023) examined IOS model estimates of temperature-driven egg and fry survival, upper river migration survival influenced by flow, Delta migration survival influenced by flow in certain reaches, and female escapement influenced by ocean productivity. Female escapement is only indirectly affected by Project operations that alter the number of juveniles that survive to enter the ocean.

The IOS model found no differences in egg and fry survival between the NAA and Alt3B operational scenarios in the vast majority of years in the simulated 82-year time series. This result is unsurprising because egg and fry survival are only directly influenced by temperature during periods when the temperature exceeds the observed range from the underlying study used to develop the recruitment model in IOS. Therefore, since the temperature rarely exceeded the observed range used to fit the recruitment model, temperature differences between scenarios rarely resulted in differences in predicted egg survival in this model. In the years when temperature-mediated mortality is included in the model, the Alt3B operational scenario greatly reduced the predicted egg mortality relative to the NAA. A similar pattern is observed with respect to temperature-mediated fry survival with less dramatic reductions in fry mortality in the Alt3B operational scenario compared to NAA than seen in estimated egg mortality.

River migration survival in both the upper portions of the river and through the Delta are influenced by flow in this model. The model predicted only minor reductions in river survival in most years under the Alt3B operational scenario relative to the NAA. A similar result was observed in the Delta migration survival component of model outputs. The Alt3B operational scenario resulted in only very minor reductions in survival in most years. This is particularly unsurprising for the Delta passage component because flow is only a predictor of survival in a subset of routes through the Delta.

CDFW combined the survival proportion from the IOS results for multiple life stages to estimate cumulative survival within a given year and scenario. Cumulative egg to ocean entry survival was estimated as:

Equation 9.

$$\text{Egg to Ocean Survival} = S_{\text{egg}} * S_{\text{fry}} * S_{\text{river}} * S_{\text{delta}}$$

Migration survival was estimated as:

Equation 10.

$$\text{Migration survival} = S_{\text{river}} * S_{\text{delta}}$$

where: S_{egg} is egg to fry survival, S_{fry} is fry to smolt survival, S_{river} is smolt migratory survival from Red Bluff to the Delta, and S_{delta} is smolt migratory survival through the Delta.

Cumulative survival from egg to ocean was nearly identical across the time series for the Alt3B operational scenario and the NAA. This is likely because the temperature benefits to early life stages were cancelled out by flow reductions that impact migrating smolts (Figure 4-95). The cumulative migration survival was nearly identical for each operational scenario across years as well (Figure 4-96).

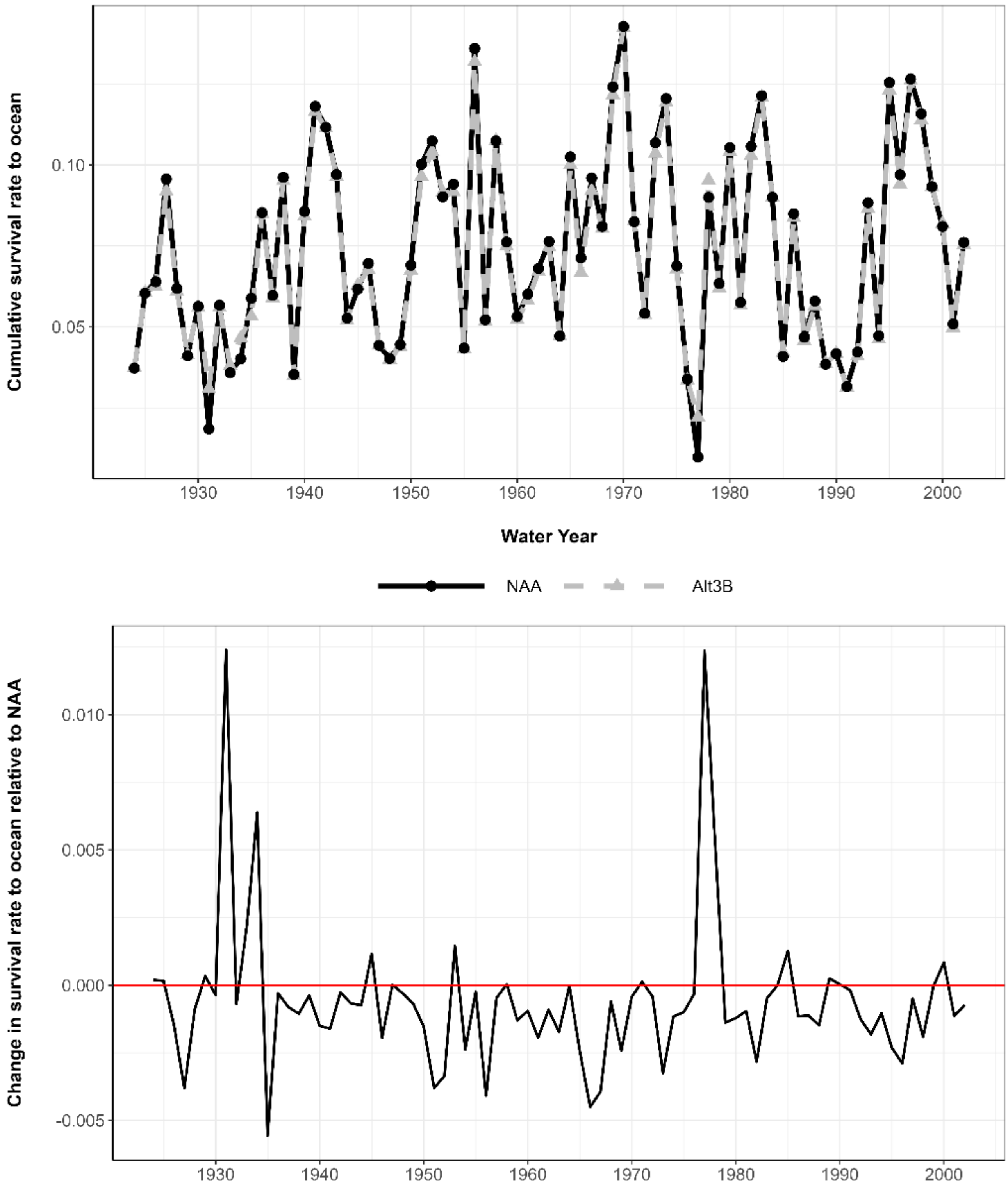


Figure 4-95. Top: Cumulative survival proportion from egg to ocean entry by water year and operational scenario. Black lines and circles are NAA scenario. Grey dashed lines and triangles are Alt3B. Bottom: The change in cumulative survival proportion from egg to ocean entry under Alt3B relative to NAA by water year. The horizontal red line indicates no difference between NAA and Alt3B.

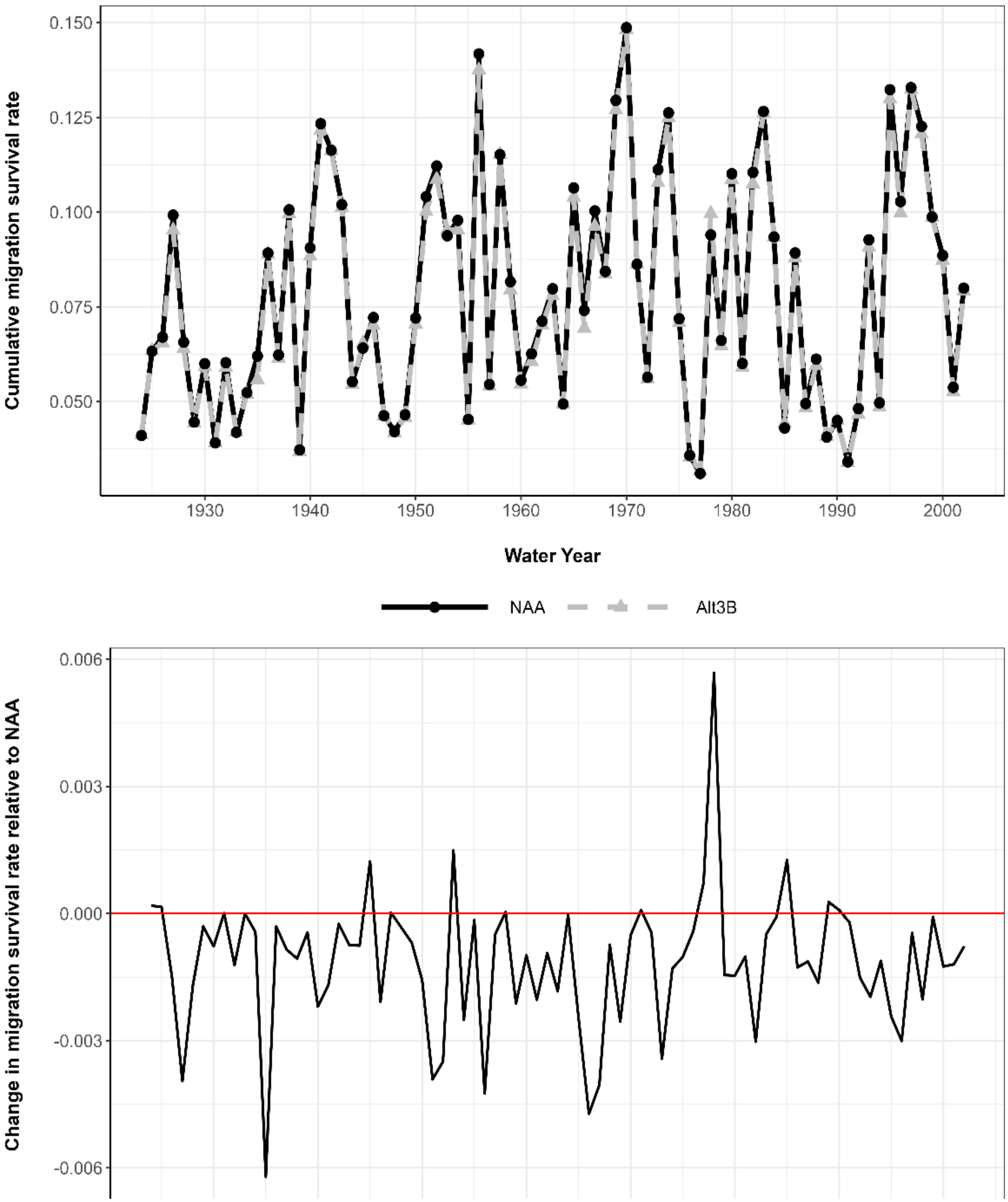


Figure 4-96. Top: Cumulative migration survival proportion (i.e. river and delta) by water year and operational scenario. Scenario NAA is represented by solid black lines and circles. Scenario Alt3B is represented by grey triangles and dashed line. Bottom: The change in cumulative migration survival rate under Alt3B relative to NAA. The horizontal red line indicates no difference between NAA and Alt3B.

Project operations do not influence ocean survival directly. However, adult escapement (i.e. the number of adults returning to spawn) is indirectly influenced by the number of fish that survive to reach the ocean, which is a function of early-life stage survival. Adult escapement is the only output of the IOS model that is not presented as a proportion. Thus, it is perhaps the best indicator of long-term population trends from the IOS model. CDFW did not observe any noticeable long-term trends (e.g., population abundance declining over time) and there are no major differences between the operational scenarios.

The IOS model was also used to evaluate the effects of NoSha and NoShaOro operational scenarios. IOS model outputs showed that egg survival only differed between the scenarios in three years of the 82-year time series (Figure 4-97). The greatest benefit of scenario Alt3B to Chinook Salmon is the potential ability to reduce temperature-dependent mortality of eggs by increasing the amount of cold water released from Shasta Reservoir during egg incubation. However, this benefit only appears to occur in a select few years when temperatures are hot enough to cause considerable temperature-dependent egg mortality, and yet cold water is still available. The scenarios without exchanges significantly reduced the benefit of the Project relative to the NAA. NoSha and NoShaOro operational scenarios predicted egg mortality closer to the NAA scenario than to the Alt3B scenario (Figure 4-98). The no exchanges scenarios still show some improvement in egg survival relative to NAA, but to a much lesser extent than Alt3B. A very similar pattern is observed for fry survival as well (Figure 4-99).

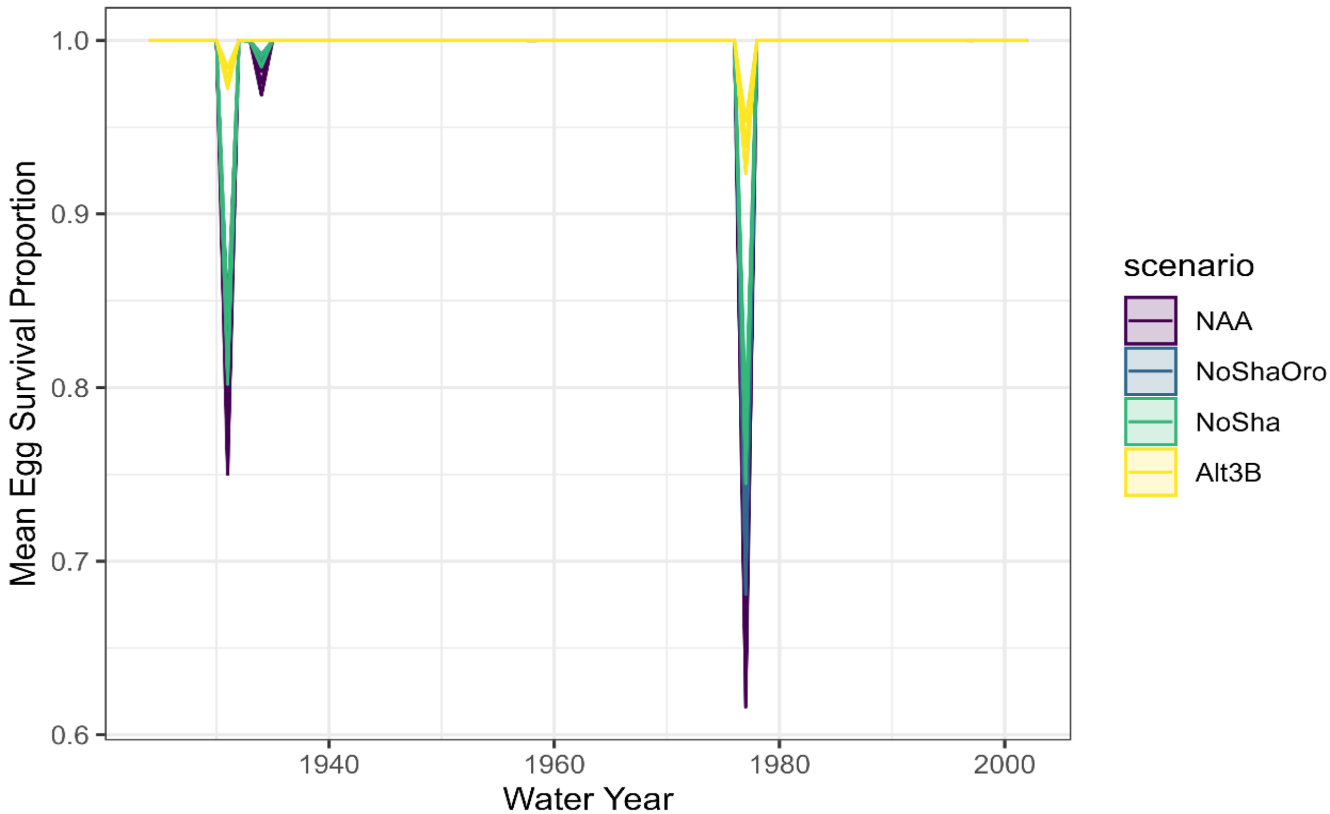


Figure 4-97. Interactive Object-Oriented Simulation model estimated egg survival over the 82-year time series under No Action Alternative (NAA) and operational scenarios (Alt3B, NoSha, and NoShaOro).

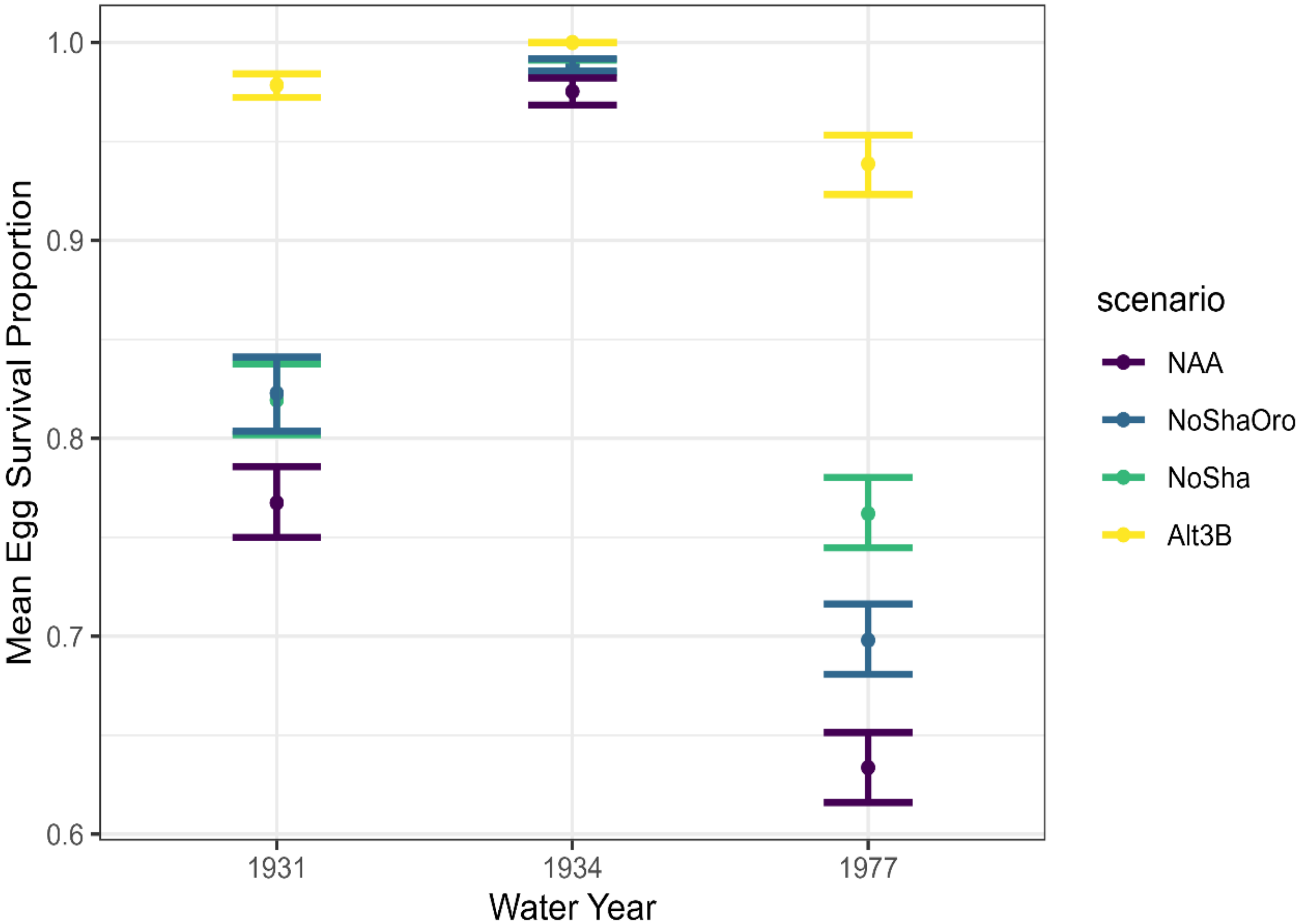


Figure 4-98. Interactive Object-Oriented Simulation model outputs of egg survival for the three years of the time series that had any difference in survival between the operational scenarios.

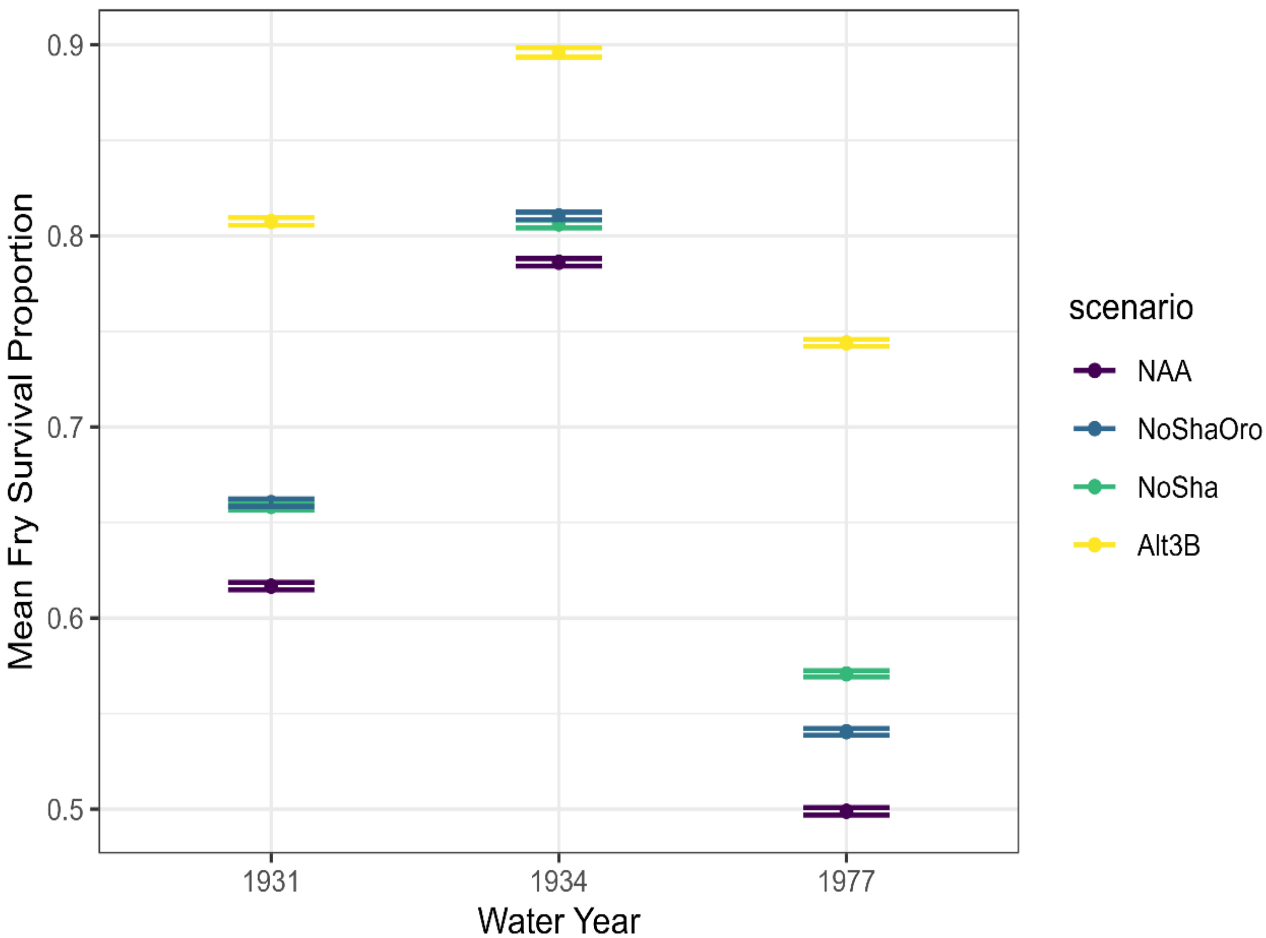


Figure 4-99. Interactive Object-Oriented Simulation model outputs of fry survival for the three years of the time series that had any difference in survival between the operational scenarios.

The cumulative survival to the ocean for the three years when egg and fry survival differed across scenarios was highest under the Alt3B operational scenario (Figure 4-100). However, the survival benefit of Alt3B relative to NAA is reduced when examining cumulative YOY survival compared to egg or fry survival. This suggests that there may be a tradeoff between improvements to egg and/or fry survival from increased cold-water flows during early life stages and reduced flows during outmigration reducing river and Delta survival in those same years. As with egg and fry survival, the cumulative YOY survival under the no exchanges scenarios was more similar to the NAA scenario than to Alt3B.

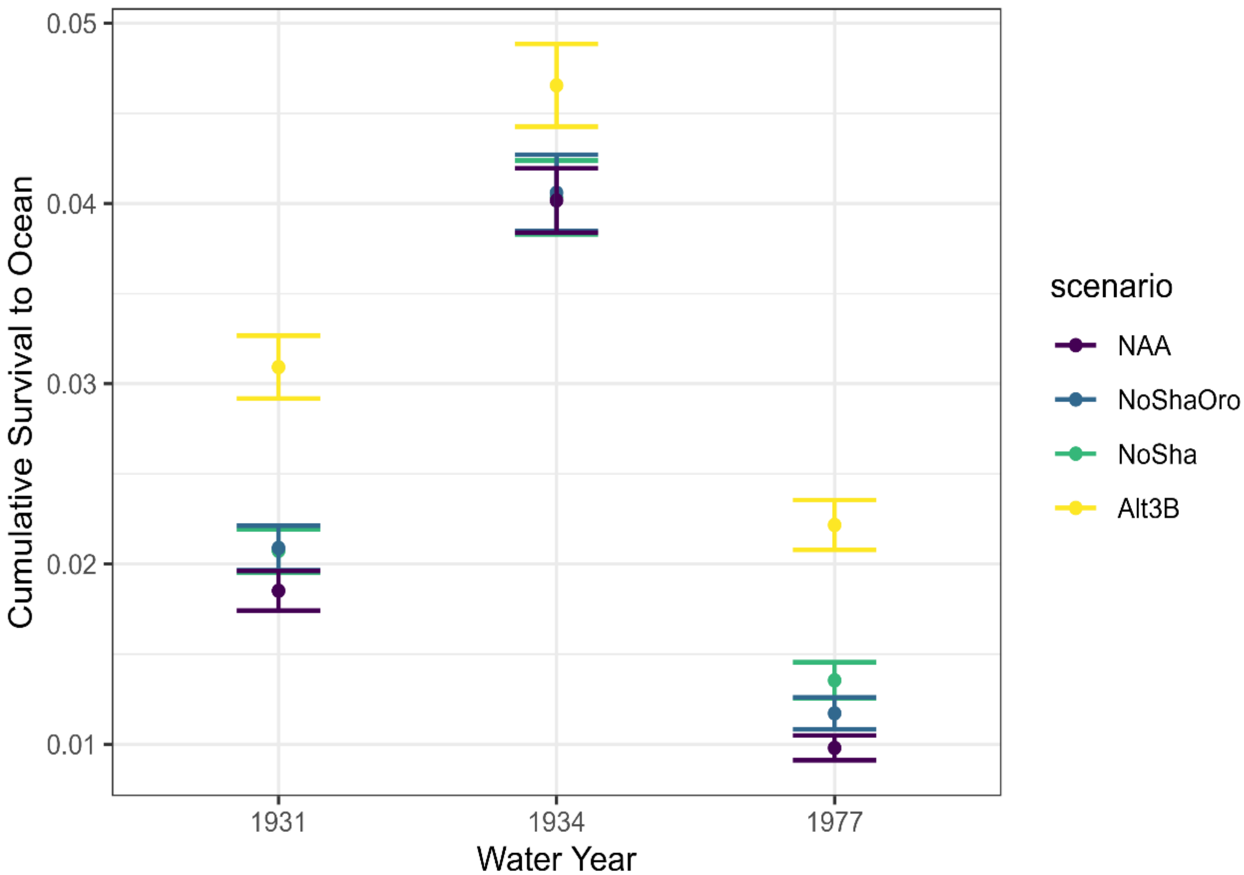


Figure 4-100. Interactive Object-Oriented Simulation model cumulative survival from egg to ocean for the three years of interest when egg and fry survival differed across operational scenarios.

4.1.10.2. Winter-run salmon Oncorhynchus Bayesian Analysis (OBAN) model

The OBAN model estimates temperature influenced egg survival, temperature and flow influenced fry survival, flow influenced juvenile out migration survival, and ocean productivity influenced adult returns. Functionally, egg and fry survival are the only components of this life cycle model that can be directly affected by Project operations. While estimates of smolt migration do rely on flow as an input, which is modified by Project operations, it is modeled in a way that cannot effectively capture impacts of Project operations on migrating individuals. The OBAN model uses the Michel et al. (2021) flow-survival threshold model with monthly average flows to determine the migration survival rate of simulated individuals. However, monthly average flows may not accurately reflect the flows experienced by individuals during their migration through the upper Sacramento River because the Michel et al. (2021) model was fit using flows during the period of time fish were present in the reach, not monthly average flows, and this migration often takes less than one week to complete (Michel et al. 2021). The time series analyzed by OBAN estimated very minor differences between NAA and the Alt3B operational scenario for nearly all life stages. Egg and fry survival is increased in rare years under the Alt3B operational scenario relative to NAA. This finding is consistent with findings from other life cycle models. In the warmest years, additional cold water supplied from Shasta Reservoir could reduce early life stage mortality in the upper Sacramento River. The model predicted one year when survival from Red Bluff to Chipps Island under the Alt 3B operational scenario was greater than the NAA, and no years when survival was worse out of the 82-year time series (Figure 4-101). This difference is a direct result of how survival was configured in this model. This result is observed in the only year when monthly average flow at Wilkins Slough was modeled to be greater than 10,700 cfs under the Alt3B operational scenario less than <10,700 cfs under the NAA (January 1953; Sites Authority 2023, Appendix 4K).

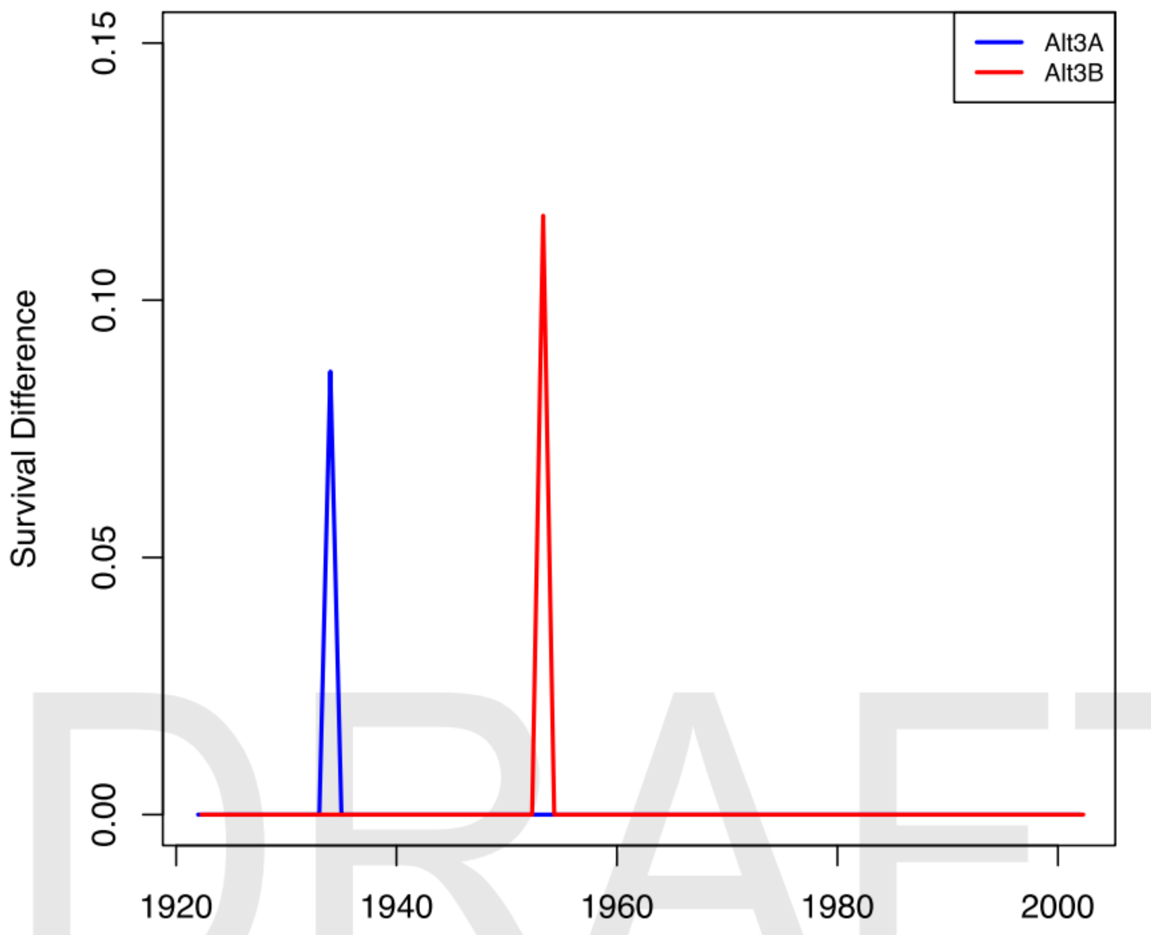


Figure 4-101. Taken from Figure 2 of Appendix K of the ITP Application (Sites Authority 2023). Difference in river migration survival from Red Bluff to Chipps Island for project scenarios relative to NAA, based on monthly average flows at Wilkins Slough.

It is unclear exactly how the monthly flows differed in this year, but since Project diversions which reduce river flows only occur when flows at Wilkins Slough are above 10,700 cfs in the proposed modeling, it is likely that additional releases due to CVP operational flexibility or exchanges with Shasta Reservoir increased flows during a period of low flows. However, it is also possible that these releases from exchanges did not actually cause the river to change from less than 10,700 cfs to greater than 10,700 cfs, which would be expected to improve salmon migration survival. If flows below 10,700 cfs were increased to a value still below 10,700 cfs, this could result in the monthly average tipping from less than 10,700 to greater than 10,700 cfs. Such a scenario would not be expected to provide any real survival benefit for salmonids according to the Michel et al. (2021) model because this model was fit using flow data at Wilkins Slough during the period of time that fish were in the reach, and survival only increases when flow experienced is greater than 10,700. Yet, the OBAN model would estimate increased salmonid survival from this scenario because OBAN uses monthly averaged flows, not necessarily the flow during the sub-monthly period of an individual fish's migration. The reciprocal case where the OBAN model would fail to detect impacts to salmon survival due to periods of Project operations reducing flow at Wilkins Slough to <10,700 cfs that are not detected in monthly averages is also a concern.

The OBAN model found no appreciable differences in spawner abundance between NAA and the Alt3B operational scenario in most years. The two noticeable peaks in spawner abundance occur three years after the peaks in egg and fry survival when additional cold water from Shasta Reservoir was expected to prevent mortality of early life stages. This reduced mortality in early life stages resulted in a larger returning cohort of adults three years later.

This model found that Project operations may aid salmon populations in the hottest and driest years by reducing early life stage mortality via exchanges with Shasta Reservoir. Otherwise, OBAN estimated minimal impacts to salmon in the Sacramento River. However, smolt outmigration survival is an important source of mortality in the salmon life cycle and this model does not adequately account for Project impacts on smolt outmigration survival. The analysis described the trends (or lack thereof) in figures, but it made no attempt to explain causal mechanisms driving any observed differences between the NAA and the Alt3B operational scenario. Therefore, what few differences were observed were not attributed to any particular action or consequence of Project operations.

4.1.10.3. Winter-run Salmon Sacramento River Winter Run Life Cycle Model (WRLCM)

The WRLCM (Hendrix et al. 2019) differs from IOS and OBAN in its flexibility and its complexity (parameter count). It is specifically designed to account for water infrastructure management actions to a greater degree than the other life cycle models. The WRLCM also differs from the other models by because it accounts for spatial variation in each life stage. The WRLCM allows most life stages to disperse into five different habitats during the freshwater portions of the life cycle: upper river, lower river, floodplain, Delta, and the Bay. The life stages included are very similar to the life stages used by the other life cycle models (i.e. eggs, fry, smolts, ocean sub-adults, and mature adults/spawners).

Water depth, flow, and temperature can be affected by Project operations and have direct impacts on: 1) egg-to-fry survival; 2) fry-to-smolt survival; 3) fry and smolt dispersal into different habitats; 4) upper and lower river smolt outmigration survival; and 5) fecundity and the timing of spawning. Changes in water depth will change density, which alters dispersal probabilities into other habitats. As in IOS and OBAN, temperature plays a critical role in egg and fry mortality. Smolt migration survival for fish rearing in the upper river is affected by flow at Bend Bridge, which is modified by Project diversions. Migration survival from other locations is fixed for each reach and independent of rearing habitat selection, but routing may be influenced by changes in flow. The enhanced Particle Tracking Model (PTM) that estimates migration survival was fit using CHNLFR, which are typically much larger than CHNWR during migration.

The ITP Application (Sites Authority 2023) ran the WRLCM with simulated flows (CalSim II, DSM2, HEC-RAS) and upper river temperatures (USBR temperature model) under the Alt3B, NoSha and NoShaOro operational scenarios for comparison to the NAA. Adult escapement (number of returning spawners), which is the only metric not returned by the WRLCM as a proportion and is thus the primary indicator of the long-term, modeled population trend, was substantially lower under both no-exchange scenarios than under Alt3B, as compared to the NAA (Figure 4-102). The WRLCM estimated a 55% probability that the Alt3B operational scenario would result in an increase (0.3%) in mean CHNWR adult escapement over the 82-year time series, relative to NAA; under the NoSha and NoShaOro operational scenarios, the probabilities of increased escapement were 0.0% (-5.2% change in mean escapement) and 0.02% (-3.6% change in mean escapement) (Figure 4-102). Changes in escapement relative to the NAA were largely driven by changes in egg-to-fry survival and flow-dependent survival during upper and lower river outmigration under all three operational scenarios for the Project.

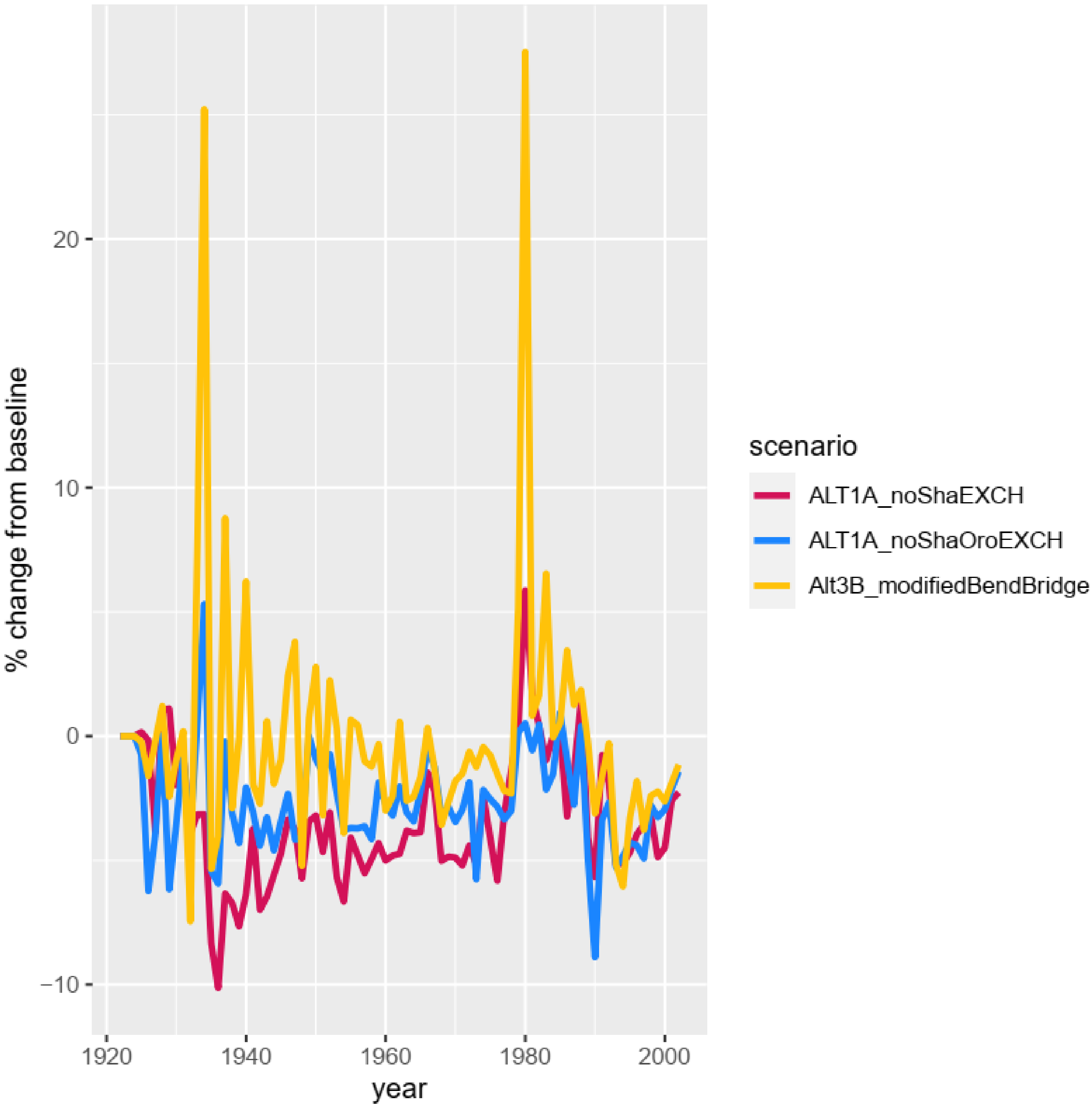


Figure 4-102. The percent change in annual escapement under the Project scenarios relative to the No Action Alternative (NAA; 'baseline'). Original Project scenario Alt3B ('Alt3B_modifiedBendBridge'), no exchanges with Shasta but maintaining exchanges with Oroville ('ALT1A_noShaEXCH'), and no exchanges with Shasta and no exchanges with Oroville ('ALT1A_noShaOroEXCH') are shown relative to NAA. Figure by QEDA Consulting, LLC, Institute of Marine Sciences (UC Santa Cruz) and NOAA Fisheries.

Egg-to-fry survival results under Alt3B resembled those in IOS and OBAN. For all three operational scenarios (i.e., Alt3B, NoSha, and NoShaOro), there were no differences relative to the NAA in most years, while Alt3B dampened large egg mortality events in the hottest and driest years, especially 1936 and 1977 (Figure 4-103). The reductions in egg mortality (shown as increases in survival in Figure 4-103) in 1936 and 1977 under Alt3B were far more substantial than under the NoSha and NoShaOro scenarios.

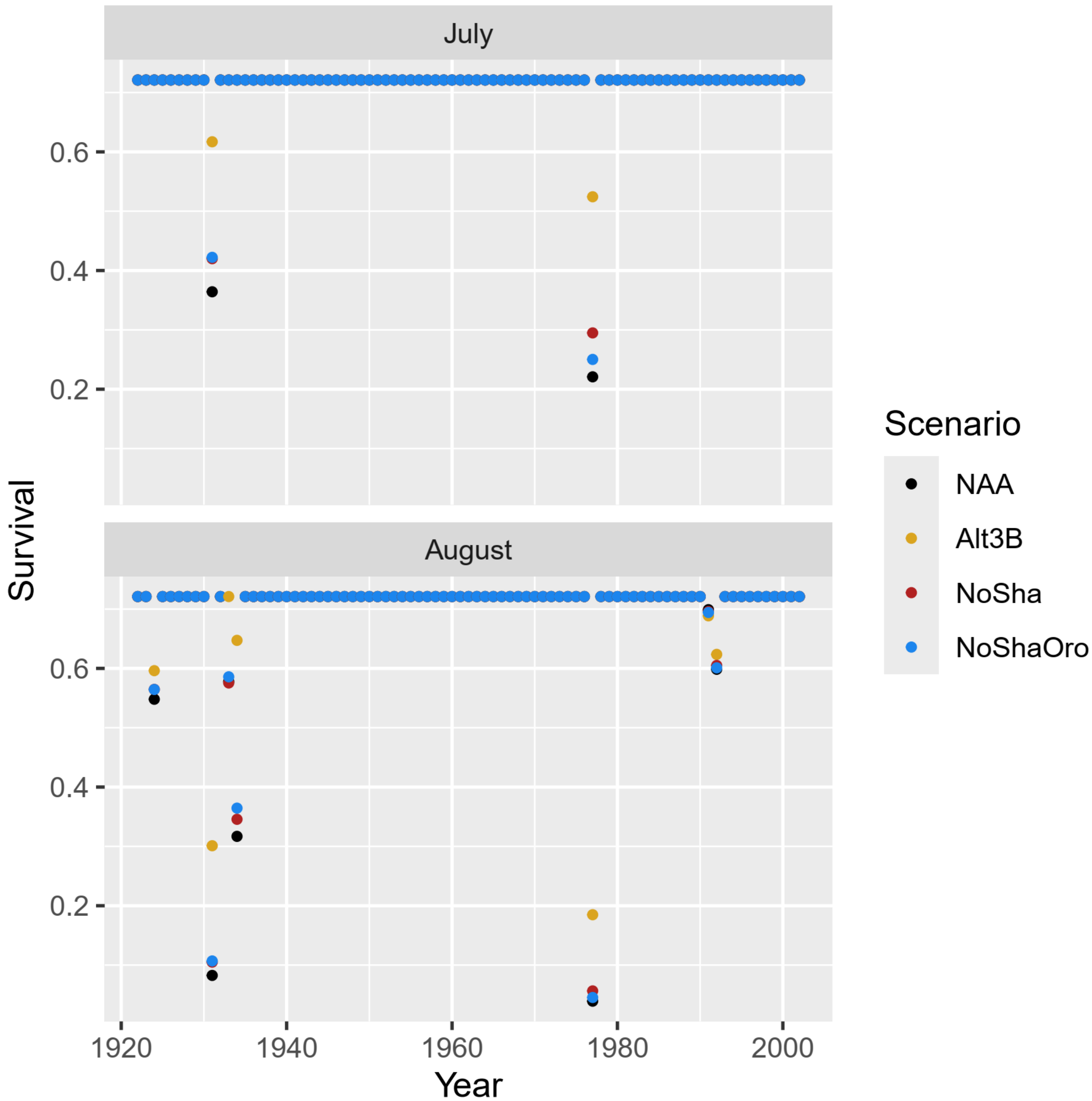


Figure 4-103. Annual egg – fry survival rate in July (top) and August (bottom) under the NAA (No-Action Alternative), the original Alt3B (Project Alternative 3B), NoSha (no exchanges with Shasta but maintaining exchanges with Oroville), and NoShaOro (no exchanges with Shasta and no exchanges with Oroville). Data provided by QEDA Consulting, LLC, Institute of Marine Sciences (UC Santa Cruz) and NOAA Fisheries.

The benefit of reduced egg mortality from the two years with the worst conditions (1936 and 1977) is seen in later life stage estimates like freshwater productivity in the birth year (Figure 4-106) and adult escapement three years later (Figure 4-102). The reduced egg mortality in these two years of the 82-year time series is likely responsible for the small increase in mean adult escapement under Alt3B; however, the comparatively small benefits to escapement in those two years were not sufficient to eliminate negative impacts to escapement under the NoSha and NoShaOro scenarios.

Egg-to-fry survival is temperature-dependent, and the WRLCM considers the interaction between temperature and egg-to-fry survival. The benefits to egg-to-fry survival observed under Alt3B in the WRLCM during the hottest and driest years resulted from potential additional cold water releases from Shasta Reservoir during late summer. These releases were smaller or absent under NoSha and NoShaOro operational scenarios, tempering benefits to egg-to-fry survival and subsequent escapement. If exchanges facilitated by the Project, with an associated increase in egg-to-fry survival, do not occur, then the overall net-neutral to slightly positive effects of the Project observed under Alt3B in the WRLCM may be replaced by significant negative impacts to CHNWR.

Survival of outmigrating CHNWR fry and smolts from the upper and lower Sacramento River to the reach near the city of Sacramento is modeled in the WRLCM as a function of flow at Bend Bridge, which is modified by subtracting Project diversions at Red Bluff and Hamilton City under Alt3B, NoSha and NoShaOro (Sites Authority 2023, Appendix 4K). The predicted flow-dependent survival in November–April was frequently as much as 5% lower in the upper river and as much as 2% lower in the lower river under all three Project alternatives, relative to the NAA (Figure 4-104).

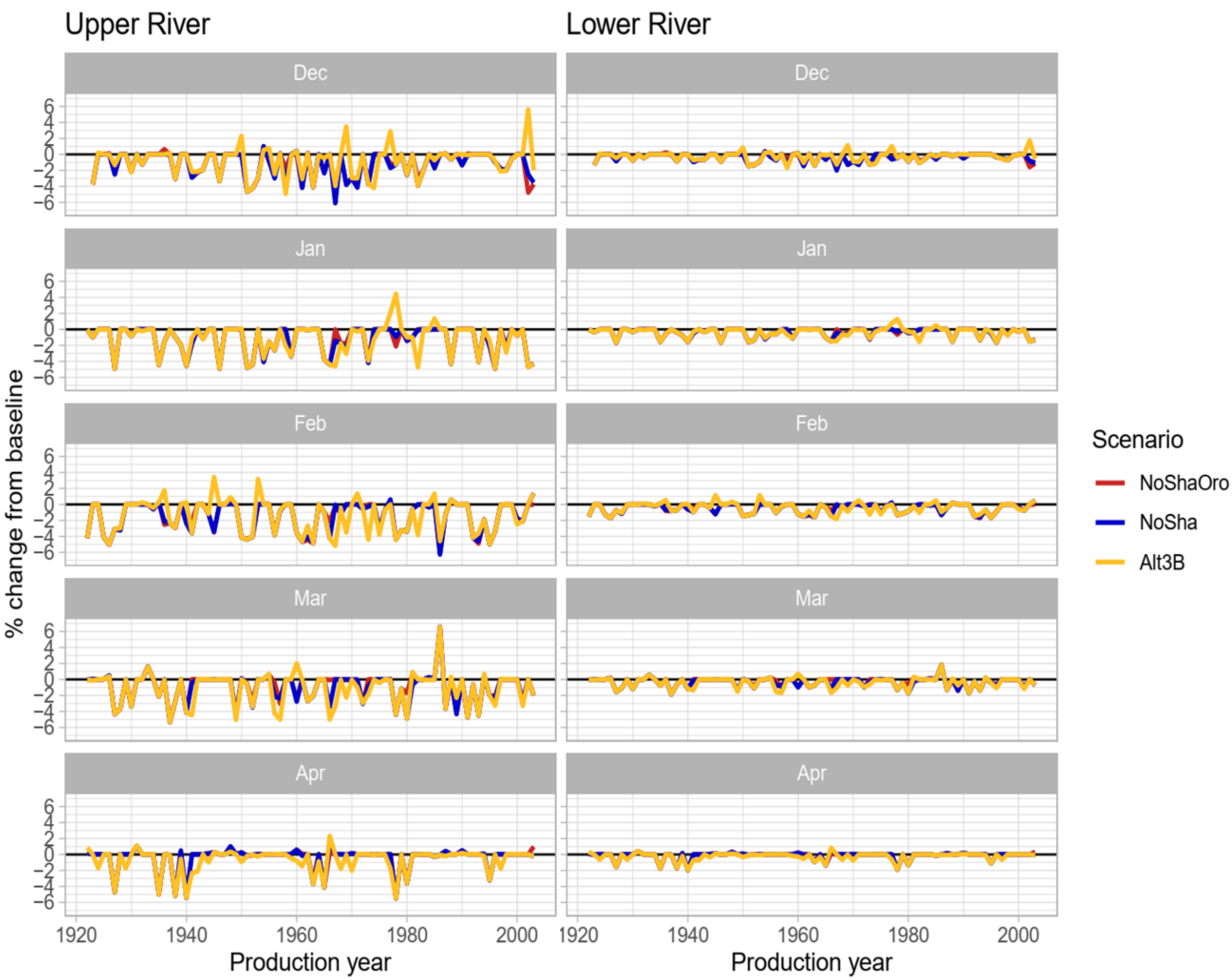


Figure 4-104. Predicted percent change in outmigration survival of smolts in the upper river (left) and lower river (right) in November – May (top to bottom) under Alt3B (gold), NoSha (dark blue) and NoShaOro (dark red), relative to the NAA. Data from QEDA Consulting, LLC, Institute of Marine Sciences (UC Santa Cruz) and NOAA Fisheries (Sites Authority 2023).

Mean annual probability of a decrease in survival in the upper river ranged from 0.22 (NoShaOro, April) to 0.59 (NoShaOro, February) (Figure 4-105); annual probabilities of decreased lower river survival were identical to those in the upper river, as survival rates in the upper and lower river were modeled similarly, but with different intercepts (Sites Authority, Appendix 4K). Mean [95% CI] percent change in survival rate over the 82-year simulation period ranged from -1.49 [-4.98,0.57] (NoSha, February) to -0.40 [-5.15, 0.98] (NoShaOro, April); Mean percent change in the lower river ranged from -0.47 [-1.60, 0.19] (NoSha, February) to -0.14 [-1.75, 0.31] (NoShaOro, April) (Figure 4-105). While 95% confidence intervals overlapped zero in all months and under all three Project scenarios, the mean percent change was negative (a survival decrease) in all months and under all Project scenarios, indicating that Project operations are more likely to decrease than increase upper and lower river survival (Figure 4-105).

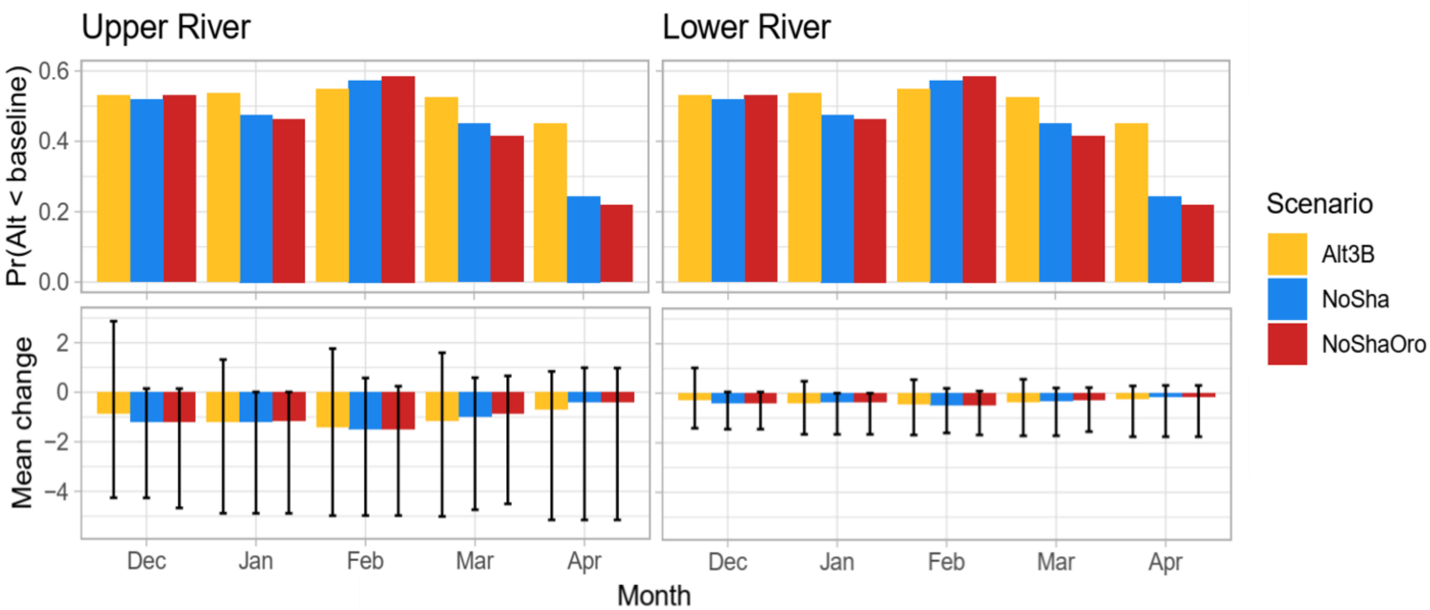


Figure 4-105. (top) Probability that CHNWR smolt survival in the Upper Sacramento River (left) and Lower Sacramento River (right) is lower under Project alternatives than under the NAA in December – April (left – right in each panel). (bottom) Mean (±95% CI) percent change in survival rate between Project alternatives and the NAA. Locations and months are as in top row. Survival data from QEDA Consulting, LLC, Institute of Marine Sciences (UC Santa Cruz) and NOAA Fisheries (Sites Authority 2023).

Survival in the upper and lower river depend on flow in the WRLCM, where Project diversions are subtracted from flow at Bend Bridge under the three Project scenarios. Relative to the NAA, decrements to upper and lower river survival due to Project diversions are far more common than increments under the modeled Alt3B, NoSha and NoShaOro (Figure 4-105). Decreased flow in the Sacramento River due to Project operations will very likely reduce average CHNWR outmigration survival in the long term (see also Zeug et al. 2014; Henderson et al. 2019; Notch et al. 2020a; Michel et al. 2021).

Combined, reduced egg survival in some years under NoSha and NoShaOro scenarios, and a fairly consistent reduction in upper and lower river outmigration survival under all three Project operational scenarios relative to the NAA result in many of the observed reductions in freshwater productivity (Figure 4-106) and adult escapement (Figure 4-102) predicted by the WRLCM. Taken together, these results suggest that Project operations may further impact the endangered CHNWR population.

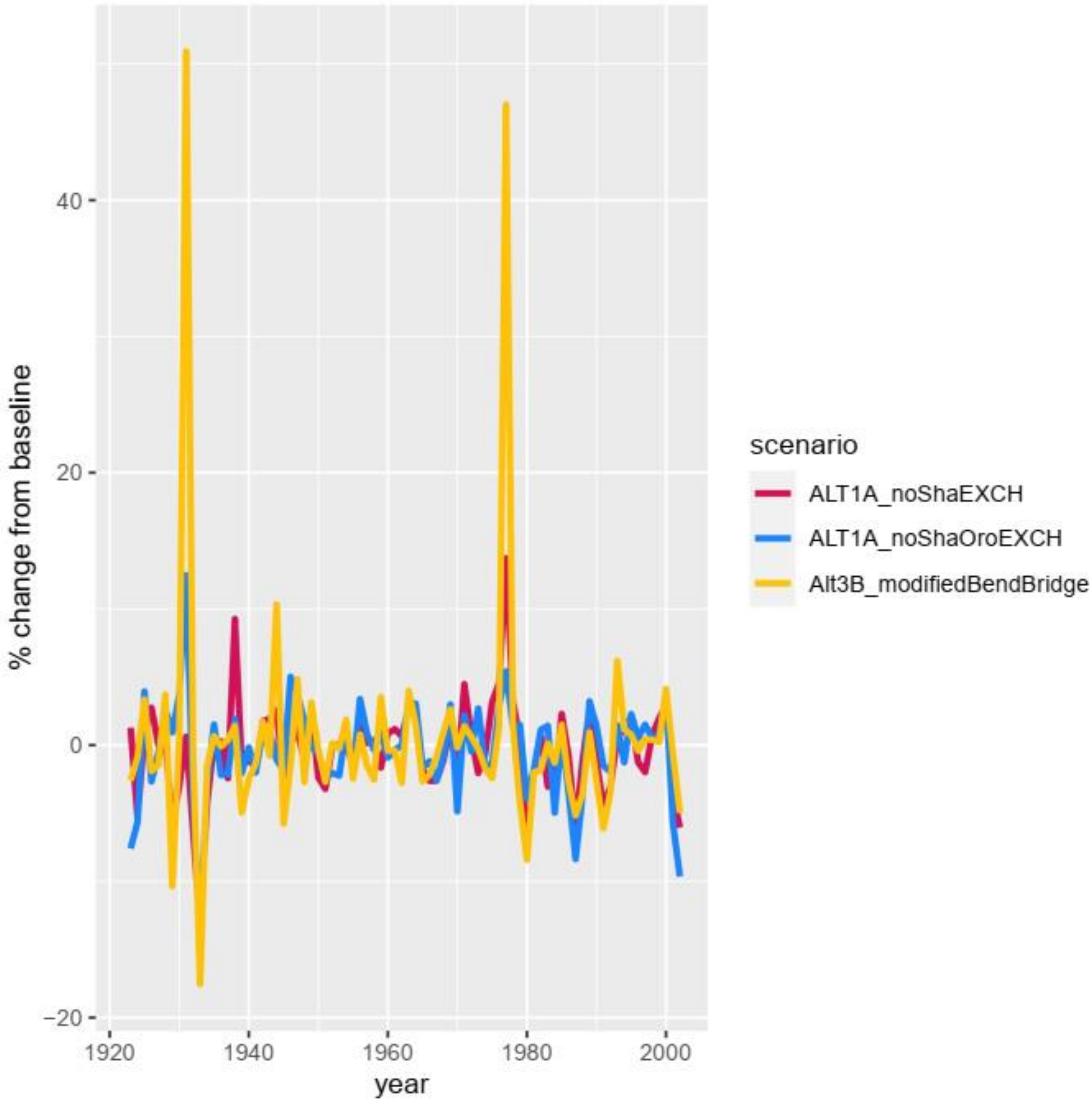


Figure 4-106. The percent change in annual freshwater productivity under the Project scenarios relative to the No Action Alternative (NAA; 'baseline'). Original Project scenario Alt3B ('Alt3B_modifiedBendBridge'), no exchanges with Shasta but maintaining exchanges with Oroville ('ALT1A_noShaEXCH'), and no exchanges with Shasta and no exchanges with Oroville ('ALT1A_noShaOroEXCH') are shown relative to NAA. Figure by QEDA Consulting, LLC, Institute of Marine Sciences (UC Santa Cruz) and NOAA Fisheries (Sites Authority 2023).

Life cycle models such as the WRLCM are able to integrate and capture some of the project effects, but it does not consider several Project effects that CDFW found significant earlier in this Effects Analysis:

- Although the WRLCM estimates egg-to-fry survival as a function of water temperature, the model does not include parameters linking water temperature to survival of rearing fry, migrating juveniles, and migrating, holding, and spawning adults. Temperature is frequently in the stressful or lethal ranges during times and places where CHNWR are present, and Project operations could affect flow and water temperatures in some of those locations and times (Section 4.1.2).
- The WRLCM does not differentiate between good- and poor-quality juvenile rearing. The model looks only at the quantity of rearing habitat available based on flow and assumes equal growth survival in all habitats, which is unrealistic. The lack of distinction between good- and poor-quality rearing habitat in the WRLCM may lead to unreasonable freshwater survival and productivity estimates for modeled scenarios that reduce streamflow. Such scenarios result in shallower depths and slower velocity in the mainstem river, which provide poor quality rearing habitat that the model weights equally to high quality side-channel or floodplain habitat.
- The WRLCM does not include rearing habitat that is available in Sutter Bypass during flood years. The Sutter Bypass provides floodplain habitat via weir overtopping when flows are over approximately 25,000 cfs at Tisdale Weir, which happens in approximately 93 percent of years. The lower Sutter Bypass can also provide floodplain habitat in the absence of overtopping via backfilling, which happens as a result of the complex hydrology that occurs at the confluence of the Feather River and can be influenced by inputs from the Feather and American Rivers. Backfilling of the lower Sutter Bypass can provide approximately 2,000 acres of floodplain habitat and occurs more frequently than weir overtopping.

Even with these gaps, the WRLCM is currently best available science and illuminates interactions and trade-offs between the modeled operational scenarios' effects on CHNWR.

4.1.11. Spring-run Chinook Salmon Life Cycle Models

The ITP Application (Sites Authority 2023) analyzed CHNSR near-field and far-field effects in much the same way as was done for CHNWR, but it was not possible to simulate CHNSR population dynamics using a life cycle model. Insufficient data, or data of insufficient quality, prevent adequate parameterization of a spring-run life cycle model (SRLCM) (Cordoleani et al. 2020). There is an ongoing, multi-agency effort to construct a CHNSR juvenile production estimate (JPE) (Nelson et al. 2022), the components of which would be of great utility in the development of a SRLCM. The establishment of a CHNSR JPE would contribute substantially to predicting the effects of the Project and others on CHNSR production; however, additional science will be required to achieve this goal (Cordoleani et al. 2020; Nelson et al. 2022). A CHNSR JPE will be developed per DWR's ITP No. 2081-2019-066-00 (CDFW 2020a).

Central Valley CHNSR currently spawn in the mainstem Sacramento River (above Red Bluff) and several of its tributaries, however the only independent, naturally-spawning populations of CHNSR originate in Battle, Mill, Deer and Butte creeks. Only the Butte Creek population has until recently been considered at a low risk of extinction (Nelson et al. 2022), however preliminary snorkel survey data indicate that 2023 adult escapement in Butte Creek was critically low (CDFW 2024b). CHNSR express a wide range of migratory life-histories (phenotypes) across their range, which can complicate management of Central Valley populations (Waples et al. 2004; Waples et al. 2022). The Central Valley CHNSR population typically expresses three outmigration phenotypes, early (fall-winter) fry/parr migrants, intermediate (winter-spring) parr/smolt migrants and late yearling migrants, which exit natal streams between the summer and spring of the brood year following that of their hatching. However, there is considerable variation in the ratios of these phenotypes among Sacramento tributary sub-populations and across time (Cordoleani et al. 2024).

Temporal and geographic overlap of CHNSR and CHNFR spawning and outmigration also complicate rapid run identification of spawners and captured juveniles. Lack of trap efficiency estimates in Mill Creek, Deer Creek and Butte Creek prevent the expansion of decades of RST catch data to passage estimates. Estimation of spawner abundance has been complicated by inconsistent methodology and the difficulty in distinguishing CHNSR from CHNFR spawners. Cordoleani et al. (2020) and Nelson et al. (2022) have outlined many solutions to these challenges, including increased genetic identification of juveniles and adults, increased funding for trap efficiency trials and more acoustic telemetry studies to estimate outmigration survival and routing of juvenile CHNSR migrants.

Because Project diversions and Shasta Reservoir releases occur on the upper Sacramento River, the ITP Application (Sites Authority 2023) focused analyses of impacts on CHNSR originating in the upper Sacramento, Battle Creek and Clear Creek, as passage estimates of these combined populations can be obtained from Red Bluff RST data (Sites Authority 2023). These analyses of Project impacts to spawning habitat (i.e., WUA, redd scour and dewatering), rearing habitat (i.e., WUA and juvenile stranding), and egg-to-fry survival necessarily apply only to the mainstem Sacramento River (Sites Authority 2023). Project operations at Hamilton City may also impact CHNSR from Mill Creek and Deer Creek, including near-field effects and changes in flow that affect habitat and survival. Project releases at KLOG have the potential to affect CHNSR adults and juveniles from all Sacramento River basin populations as they migrate through the area. Analyses of reductions in Sutter Bypass access, inundation and rearing habitat implicate Mill

Creek and Deer Creek CHNSR populations in addition to mainstem Sacramento River, Clear Creek and Battle Creek populations, and reductions in Yolo Bypass access, inundation and rearing habitat include all Sacramento tributary CHNSR juveniles except those originating in the Feather River. Mill Creek and Deer Creek CHNSR are at record low abundances (Nelson et al. 2022), and the preliminary estimate of 2023 adult escapement in Butte Creek was the lowest recorded since 1987. Project impacts to these three populations are highly uncertain.

4.2. Take and Impacts of Taking on Longfin Smelt

LFS have been observed as far upstream as Colusa on the Sacramento River (RM 144) (Merz et al. 2013). As this is more than 60 miles downstream of Project diversions, direct take of LFS through entrainment at the Project diversions is not expected to occur. However, since Project operations may decrease Delta Outflow and Q_{west} (estimate of flow past Jersey Point in the lower San Joaquin River) and may occasionally result in higher X2 (distance in kilometers from the Golden Gate Bridge to the 2 parts per thousand (ppt) bottom isohaline (Jassby et al. 1995)), the Project may affect the abundance and distribution of LFS and their habitat. LFS may also be at risk of entrainment into the south Delta and the SWP and CVP pumping facilities due to increased exports expected under Project operations.

4.2.1. Longfin Smelt Abundance (Delta Outflow)

Water diversions due to Project operations will decrease Delta outflow, which may reduce Longfin Smelt abundance and habitat.

LFS recruitment in the SFE is positively associated with Delta Outflow (Q_{out}) (Nobriga and Rosenfield 2016; Colombano et al. 2022) and negatively associated with X2 (Kimmerer 2002b; Kimmerer et al. 2009). Diversions from the Sacramento River by Sites would occur from September through June; thus, project operations could decrease Q_{out} and increase X2 during the critical LFS spawning and rearing period (December–June), reducing habitat availability and zooplankton production (Kimmerer 2002a; Hennessy and Burris 2017). While modeling in the ITP Application (Sites Authority 2023) predicted that the effects of Project operations on LFS recruitment will be minimal, the uncertainty associated with these predictions is extremely high.

To date, Sites Authority (2023) and other entities attempting to quantify the effects of changes in Q_{out} on LFS recruitment have relied on a population dynamic model created by Nobriga and Rosenfield (2016) and on refinements thereof (see Reclamation and Sites Authority 2023; Sites Authority 2023). The Nobriga and Rosenfield (2016) model was not intended for predicting LFS recruitment over time, but rather for comparing several population dynamic model concepts with Q_{out} as a covariate. Consequently, the model, and refined versions of it, cannot consistently predict LFS recruitment (represented by the Fall Midwater Trawl (FMWT) Index or the San Francisco Bay Study (SFBS) Index to within three orders of magnitude (Figure 4-107). Such high uncertainty renders model-based comparisons of predicted LFS recruitment between Project operational scenarios and the NAA minimally informative.

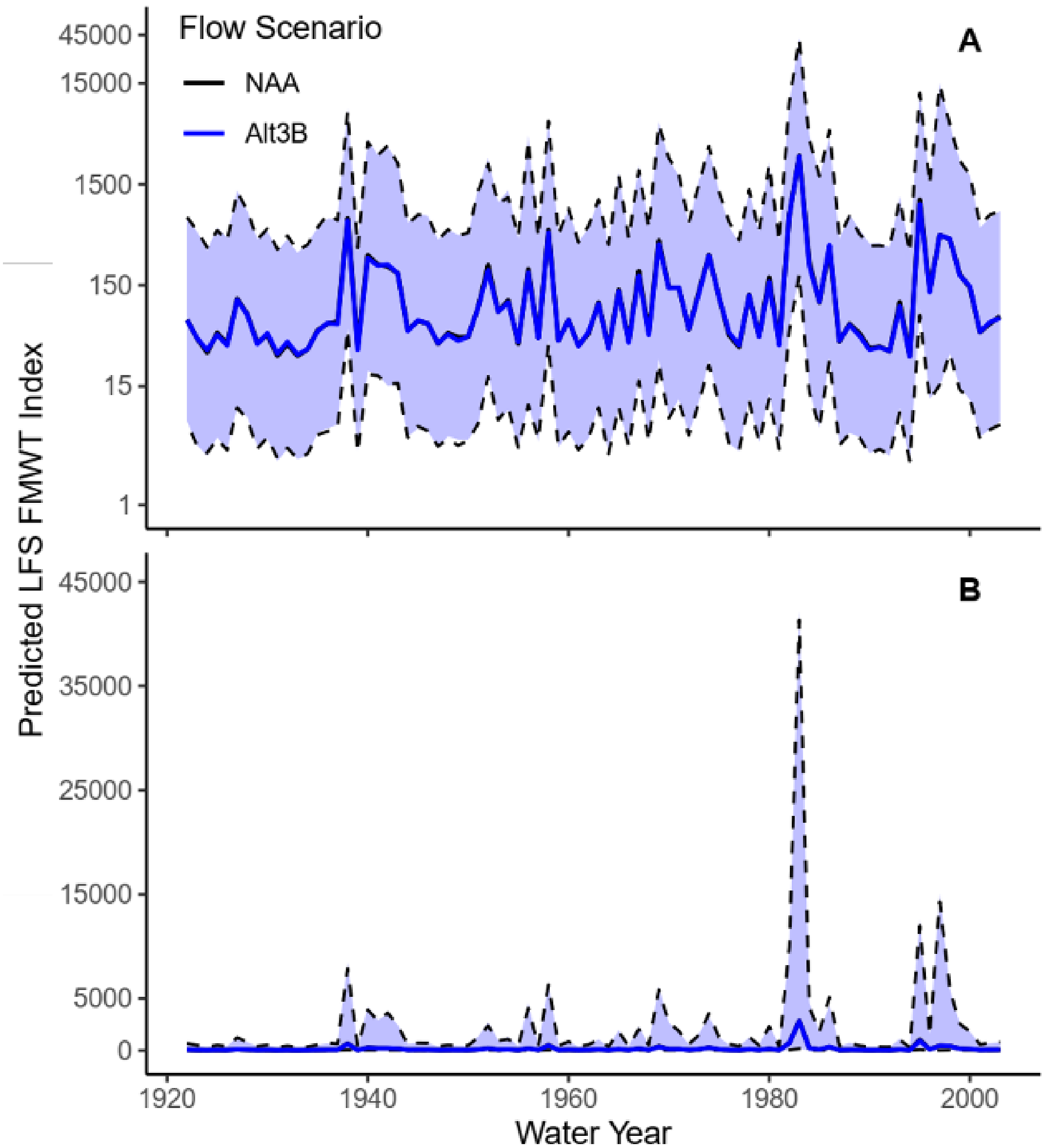


Figure 4-107. Predicted Longfin Smelt (LFS) Fall Midwater Trawl (FMWT) Index with 95% prediction intervals, plotted on (A) log10 and (B) linear scales. Shaded region indicates the 95% prediction band for Project Alternative 3B (Alt3B); dashed curves show the 95% prediction band for the No Action Alternative (NAA). Model predictions, provided by Sites Authority (2023), are from a modified version of the Nobriga and Rosenfield (2016) model.

Nobriga and Rosenfield (2016) and its descendent models have used the SFBS annual LFS spawner index and outflow aggregated over several months (December through May in Nobriga and Rosenfield 2016) to predict the FMWT annual LFS recruit (age-0) index. The SFBS and FMWT annual indices are calculated by first averaging CPUE by region within the SFE, then summing regional estimates for each survey month, then averaging those sums across several months (May–October for SFBS age-0 LFS, September – December FMWT age-0 LFS). While useful for calculating a total annual abundance index, aggregating CPUE data by year obscures the vast seasonal and spatial variation in LFS catch and reduces the total number of observations from thousands to tens (Table 4-36). Furthermore, aggregating Q_{out} data over six months may obscure the effects of shorter, biologically meaningful periods during the LFS spawning and rearing seasons when Q_{out} is especially important to recruitment.

Table 4-36. Annual index observations (number of index years) and total observations (accounting for location and survey month) of the San Francisco Bay Study and Fall Midwater Trawl surveys in the San Francisco Estuary and Sacramento-San Joaquin Delta.

Survey	Index Observations (years)	Total Observations
San Francisco Bay Study	44	>15,000
Fall Midwater Trawl	56	>9,000

A new model for predicting LFS recruitment and linking recruitment, and LFS population dynamics, to Q_{out} and/or X2 and other mechanistic drivers is needed, one that makes full use of the spatial and temporal complexity of the available data. Paired with hydrological tools like CalSim and DSM2, such a model could be used to evaluate the potential impacts of diversions by Sites on LFS. A multi-agency (DWR, CDFW, State Water Contractors, USFWS) effort is currently underway to construct a Longfin Smelt lifecycle model (LFSLCM; DWR et al. 2020). Model development began in 2023, with expected completion in 2028. Delta outflow, X2 and other Delta flow and salinity data that can be simulated by CalSim III and DSM2 are likely covariates in the LFSLCM. Effects of Project diversions on Delta flows and salinities, and thus on LFS vital rates and ultimately population dynamics, may be modeled by substituting simulated hydrological data into the LFSLCM in the future, as is currently done with the WRLCM to evaluate Project impacts on CHNWR (see Section 4.1.10).

Conclusions

While current modeling is limited in its ability to evaluate whether Project operations will significantly affect LFS population dynamics, the relationship between Delta outflow (and X2) and LFS recruitment is well established (Kimmerer 2002b; Kimmerer et al. 2009; Nobriga and Rosenfield 2016; Colombano et al. 2022). The ITP Application (Sites Authority 2023) DSM2 modeling indicated minimal changes in outflow-related LFS recruitment due to Project operations; however, the uncertainty in those predictions is extremely high. The ITP Application (Sites Authority 2023) DSM2 modeling also indicated that the Project would rarely increase X2 by more than 1 km or decrease Delta outflow by more than 2,000 cfs, except in very rare cases, (see Section 4.0 "Effects on Delta Hydrology") and is therefore unlikely to have large effects on LFS habitat area or food availability. In a small number of cases, however, DSM2 indicated that the Project could increase X2 by more than 4 km and as much as 7.3 km under Alt3B, and up to 10.8 km under the NoSha and NoShaOro operational scenarios (Figure 4-10). These occurrences and the potential impacts should be further evaluated using the LFSLCM when it is available.

4.2.2. South Delta Entrainment

Diversions from the Sacramento River for the Project may reduce Delta outflow, and therefore result in the location of X2 being upstream and change local hydrodynamics in the Delta that affect south Delta entrainment risk for Longfin Smelt.

The location of X2 changes with Delta outflow and influences how far upstream adult LFS will migrate and spawn. When X2 is higher, LFS will spawn farther upstream in the Delta, where those adults and the resulting larval and juvenile LFS are at higher risk of entrainment into the south Delta export facilities (CDFG 2009b; Kimmerer and Gross 2022; Sommer et al. 1997). Changes in Delta outflow influence the position of X2 and affect the dynamics of local flows in the Delta like downstream flow in the Lower San Joaquin River (Q_{west}), which also influences the risk of entrainment of LFS into the south Delta. When positive, Q_{west} helps transport larval LFS downstream into better quality habitat and away from areas of high entrainment risk and lower quality habitat in the south Delta.

LFS hatch from December through April or May (Baxter 1999; CDFG 2009a; USFWS 2022) and larvae and juveniles are susceptible to south Delta entrainment during spring and early summer. Hatching locations are directly related to adult LFS spawning migration efforts and site selection and, to some degree, determined by X2 location immediately prior to adult spawning. South and central Delta hydrodynamics associated with positive Qwest values can decrease entrainment of larval LFS into the south Delta export facilities. Therefore, DSM2 modeling provided in the ITP

Application (Sites Authority 2023) was used by CDFW to evaluate changes in X2 and Qwest as a result of Project operations that may increase entrainment of LFS at the south Delta export facilities.

DSM2 modeling in the ITP Application (Sites Authority 2023) indicated that Project operations may at times cause X2 to move farther upstream, especially in fall and winter (See "Effects of the Project on Conditions in the Delta"). When X2 is greater than 81 km, the LSZ is located upstream of the confluence of the Sacramento and San Joaquin rivers, where relatively small changes in flow can cause relatively large changes in X2 (Figure 4-11) bringing LFS closer to the zone of entrainment in the south Delta. The DSM2 modeling in the ITP Application (Sites Authority 2023) indicates that Project operations would, at times, result in changes in X2 from below 81 km to above 81 km (indicated by the red dots on Figures 4-15 through 4-17), but that these differences would be infrequent and usually less than 2 km. CDFW expects these changes in X2 to have small effects on bringing the distribution of LFS farther upstream closer to the zone of entrainment in the south Delta. In a small number of years, however, DSM2 results indicate that Project operations could increase X2 by more than 4 km and as much as 7.3 km under Alt3B, and up to 10.8 km under the NoSha and NoShaOro operational scenarios (see "Effects of the Project on Conditions in the Delta"). These occurrences and the potential impacts should be further evaluated using the LFSLCM when it is available.

The ITP Application (Sites Authority 2023) DSM2 modeling also indicated occasionally lower Q_{west} under Alt3B, NoSha, and NoShaOro operational scenarios compared to the NAA, which could increase larval LFS entrainment into poor quality habitat in the south Delta and into the South Delta export facilities. Most of these differences are less than 1,000 cfs (Figures 4-15 through 4-21); however, larger differences and more negative Q_{west} are shown in November and December of Above Normal water years and February and March of Below Normal water years. For the Alt3B operational scenario, modeling results indicate a reduction in Qwest as compared to the NAA from October through February in Dry and Critical water years (Figure 4-15), but similar reductions aren't seen for the NoSha (Figure 4-16) and NoShaOro operational scenarios (Figure 4-17).

Conclusions

The ITP Application's (Sites2023) DSM2 modeling indicated that Project operations would result in some small changes to X2 position and Q_{west}. CDFW concludes that the Project will cause small negative impacts to LFS by increasing south Delta entrainment risk to LFS adults, larvae, and juveniles.

4.2.3. Food Abundance in the Delta

Longfin Smelt are food-limited and abundance of their food is negatively correlated with X2 (Jassby et al. 1995). If diversions by the Project decrease Delta outflow and results in changes in X2, this could cause changes in food abundance and food availability for Longfin Smelt.

Food sources for LFS include the calanoid copepod *Eurytemora affinis* and the mysid shrimp *Neomysis mercedis,* which are important food sources in low salinity habitats (Barros et al. 2022; Rosenfield and Baxter 2007). Larval LFS under 25 mm TL feed primarily on copepods, while larvae greater than 25 mm TL almost exclusively target mysids. *E. affinis* abundance is positively correlated with spring outflow (Hennessy and Burris 2017; Kimmerer 2002a). Similarly, there is strong evidence that low outflow (as represented by X2) significantly reduces calanoid copepod biomass in spring and mysid biomass in summer within the LSZ (Mac Nally et al. 2010, Hennessy and Burris 2017). The introduced calanoid copepod *P. forbesi* and introduced mysids (primarily *H. longirostrus*) also provide important LFS diet components from late spring through fall (Barros et al. 2022; Baxter et al. 2010). The abundance of *P. forbesi* in the LSZ during summer and fall is subsidized from upstream and influenced by freshwater outflow (Durand 2010; Hennessy and Burris 2017; Kimmerer et al. 2018) and decreases as outflow decreases (reported as X2 advancing upstream). Decreased outflow also shifts the *P. forbesi* population further east, where it is at greater risk of entrainment and loss to south Delta and in-Delta water exports (Kimmerer et al. 2018).

The ITP Application's (Sites Authority 2023) CalSim II and DSM2 modeling indicates that the Project will result in small changes to Delta outflow and X2 position (see "Effects of the Project on Conditions in the Delta") and further statistical modeling (Reclamation and Sites Authority 2023) predicted small changes in food densities for LFS in the spring. CalSim II and DSM2 showed slightly lower Delta outflow and slightly greater X2 in March, with smaller differences in April, May, and June (Table 4-35 of Sites Authority 2023; Table 4L3-5-2c of Sites Authority 2023, Appendix 4L3). The ITP Application (Sites Authority 2023) also modeled the effect of changes in X2 position as a result of Project operations on the density of *E. affinis* in spring using the relationship developed by Greenwood (2018). This analysis found minimal changes in densities with Alt3B as compared to NAA (Table 4-36 of Sites Authority 2023). The ITP Application (Sites Authority 2023) also modeled the effect of changes in Delta outflow due to Project operations on the density of *E. affinis* from March through June using the relationship developed by Hennessy and Burris (2017) (Reclamation and Sites Authority 2023). The model predicted small changes in densities between Alt3B and the NAA (Table 4-37 of Sites Authority 2023). Lastly, the ITP Application (Sites Authority 2023) modeled the effects of changes in Delta outflow due to Project operations on the density of *N. mercedis* during spring using the relationship developed by Hennessy and Burris (2017). This analysis found slight decreases in *N. mercedis* densities under Alt3B, relative to the NAA (Table 4-49 of Sites Authority 2023). Due to the inherent variability of zooplankton data, modeled relationships between zooplankton abundance and Delta outflow or X2 position have high uncertainty (Hennessy and Burris 2017; Sites Authority 2023, Tables 4M-1 – 4M-3), as do predicted abundances.

Conclusions

Given that the Project is expected to result in small changes to Delta outflow, X2 position, and food densities for LFS in spring, CDFW concludes that the Project will cause small negative impacts to LFS by reducing food abundance. The ITP Application (Sites Authority 2023) analysis showed small changes in zooplankton abundance due to changes in X2 or outflow between the Alt3B operational scenario and the NAA, although the modeled relationships have high uncertainty (Sites Authority 2023, Tables 4M-1 – 4M-3). The ITP Application (Sites Authority 2023) compared changes in zooplankton abundance between Alt3B and NAA; however, because the change in in X2 under the Alt3B, NoSha, and NoShaOro operational scenarios will be similar and small, in most cases less than 2 km, CDFW concludes that effects to food densities would be small under all three of the operational scenarios for the Project.

4.3. Take and Impacts of Taking on Delta Smelt

DS have been observed as far upstream on the Sacramento River as Knights Landing (RM 90) (Vincik and Julienne 2012). As this is more than 100 RM downstream of Sites' diversion locations, direct take of DS through entrainment at the Project diversions is not expected to occur. However, Project releases to the Yolo bypass have the potential to result in take if water quality is poor. Changes in habitat quality and quantity could also occur.

Although several important aspects of the quality, quantity, and location of DS habitat are related to X2 (for example food abundance), DS abundance indices do not exhibit a linear relationship with Delta outflow or X2 (IEP 2015; Jassby et al. 1995, Kimmerer 2002b, Tamburello et al. 2019); therefore, unlike LFS abundance, DS abundance is not expected to decrease systematically with changes in X2 as a result of Project operations.

4.3.1. Yolo Bypass Water Quality

Project operations could diminish water quality in the Yolo Bypass if releases from Sites 1) have poor water quality or 2) move existing water with elevated contaminants and low dissolved oxygen from the Colusa Basin Drain and the Toe Drain into the Yolo Bypass.

The Project would release water to the Yolo Bypass via the CBD, KLRC, and Toe Drain, which will increase flows over existing conditions by approximately 9 cfs to approximately 464 cfs during the months of August through October. DS are known to utilize habitats along this corridor, including the Yolo Bypass, Liberty Island, and the Cache Slough Complex, during these months as well as during other seasons (Sommer and Meja 2013; Merz et al. 2011). Even as the population has plummeted in recent years, DS are still found utilizing the region in August through October (Figure 4-108).

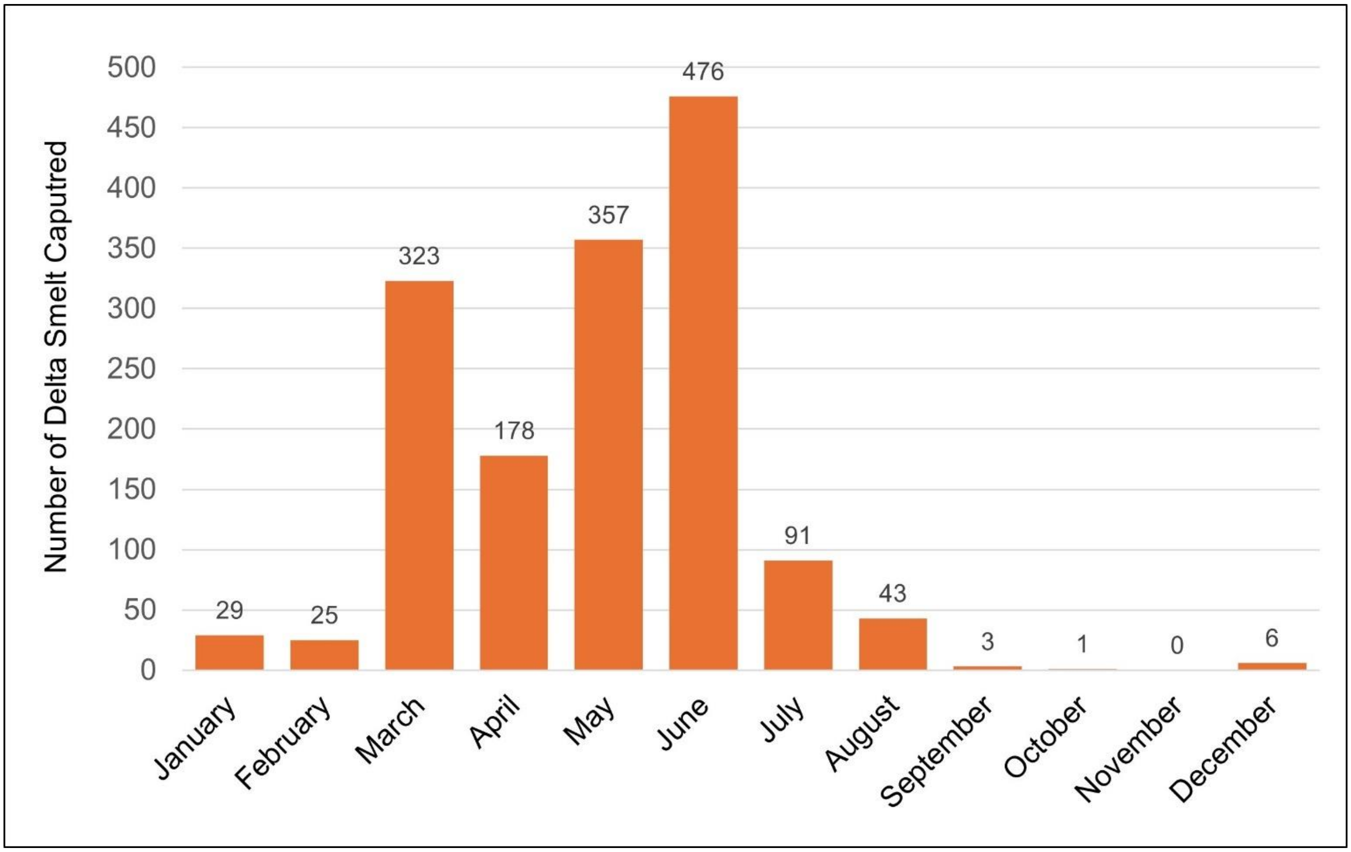


Figure 4-108. Number of Delta Smelt captured by month in the Yolo Bypass, Liberty Island and Cache Slough Complex. Data are from the Interagency Ecological Program's Smelt Larva Survey, 20-mm Survey, Summer Townet Survey, Spring Kodiak Trawl, and Enhanced Delta Smelt Monitoring since 2009.

4.3.1.1. Contaminants

Land use in the Yolo Bypass and pollutants from contributing watersheds can result in substantial contaminant transport to points downstream where DS are found. Nearly 80% of the land in the Yolo Bypass is used for agriculture (USACE 2023) where over 800,000 kg of pesticides are applied to crops annually. Pesticides move from fields into the aquatic ecosystem during elevated flows in dissolved form or bound to sediments that become resuspended in the water column (Smalling et al. 2007). The types and concentrations of herbicides, insecticides, and fungicides that make their way into the Yolo Bypass ecosystem depend on flow and timing of pesticide use in the surrounding watershed (Orlando et al. 2020).

In addition to pesticides, mercury is a contaminant of particular concern for the Delta and Yolo Bypass. The Delta is on the Clean Water Act 303(d) list for waters impaired by mercury, and the DMCP directs DWR to reduce methylmercury outputs from noncompliance areas including the Yolo Bypass (OWW and OWMTMW 2020). The DMCP also requires that inputs to the Yolo Bypass be reduced (CRWQCB 2010). Currently, the methylmercury load to the Yolo Bypass is estimated to be 100 g/year, and target load allocation is 22 g/year (OWW and OWMTMW 2020). Elevated methylmercury concentrations are common in newly flooded reservoirs for up to 10 years after filling. Analyses in the FEIR (Reclamation and Sites Authority 2023) anticipate mercury levels in the proposed reservoir to be double the long-term average for up to the first decade. Any additional mercury or methylmercury inputs from releases conducted by Sites would further impair the Yolo Bypass and have the potential to impact fish and wildlife resources, particularly since the Yolo Bypass is utilized for agriculture, fishing, winter waterbird habitat, and waterfowl hunting (Sommer et al. 2011).

Contaminants including pesticides are believed to be a major driver for the population decline of DS (Moyle et al. 2016; Fong et al. 2016). While it is common to report lethal levels of contaminants, they are most often found at lower levels where chronic exposure impairs normal biological function, affecting survival (Connon et al. 2019). A litany of sublethal pesticide effects have been found for DS, including impacts to the immune, nervous, muscular, and endocrine systems, as well as to osmoregulation and behavior (Fong et al. 2016).

An important secondary impact of pesticides is contamination of zooplankton, the main food source for DS. Pesticides can be transferred to fish through consumption and can depress densities of zooplankton prey (Davis et al. 2021). At a population level, lack of sufficient food is identified as a major cause for the overall decline in abundance of DS (Miller et al. 2012; Hamilton and Murphy 2018; Hamilton and Murphy 2022). On an individual basis, studies have found evidence of physiological food limitation stress in DS (Hammock et al. 2015, Dhayalan et al. 2024), and much research points to pesticides as a factor impacting zooplankton populations. Pesticides have been found to alter reproductive output (Hanazato 2001), and population abundance (Gustaffsson et al. 2010). Pesticides also impact the phytoplankton prey that many zooplankton rely on as food sources (Orlando et al. 2020). DS consume a variety of zooplankton, (FLOAT-MAST 2020), and preferred prey includes Calanoid and Cyclopoid copepods, particularly *E. affinis*, *P. forbesi,* and *S. doerrii (*FLOAT-MAST 2020, Mahardja et al. 2019, IEP-MAST 2015, Slater and Baxter 2014).

The NDFS pulse flows in the Yolo Bypass led by DWR serve as a model for pesticide impacts anticipated from Project discharges to the Yolo Bypass and points downstream, due to similarities in geography, volume and timing. The NDFS pulse flows ranged between 239 to 750 additional daily cfs routed through the CBD, KLRC, Toe Drain, Liberty Island, and the Cache Slough Complex between July and October. Water was routed into the Yolo Bypass from CBD agricultural drainage and/or from the Sacramento River (Davis et al. 2021).

Though pesticide concentrations in the region are generally high regardless of flow inputs, particularly in the northern portions of the Yolo Bypass, the highest pesticide concentrations in water and zooplankton were found during the NDFS pulse flows. The NDFS pulse flows also moved upstream masses of water downstream to habitats of the Cache Slough Complex, demonstrating that contaminants could also be transported (Davis et al. 2021). Several pesticides exceeded the USEPA's benchmarks for acute and chronic toxicity for fish and invertebrates, and some have been found to impact DS and their prey at even lower concentrations. For example, lower levels of Bifenthrin and Fluridone have been found to affect DS behavior, neurotransmitter concentrations and reproductive hormone concentrations (Segarra et al. 2021; Mundy et al. 2020; Jin et al. 2018). Azoxystrobin decreases abundance of calanoid copepods, including the DS primary prey item *E. affinis,* at concentrations much lower than USEPA benchmarks (van Wijngaarden et al. 2014; Gustafsson et al. 2010).

Much of the evaluation in the FEIR (Reclamation and Sites Authority 2023) is based on pesticide impacts caused by additional pesticide inputs from reservoir releases. It is unclear whether these discharges will increase pesticide inputs; however, the NDFS studies demonstrate that discharges may move pesticides from a region of high contamination southward, increasing concentrations in the lower Yolo Bypass and Cache Slough Complex where DS and their zooplankton prey reside. The Project's discharges may also constitute an additional Mercury input to an already impaired system. Impacts to DS will depend on the volume and duration of inputs and will also depend on the content and characteristics of water discharged from the reservoir. Monitoring concentrations of contaminants will be important to evaluate realized impacts during Project operations.

Conclusions

Given that 1) pesticide concentrations are highest at the upstream stations immediately above and within the Yolo Bypass; 2) multiple pesticides are found at levels above USEPA toxicity benchmarks for fish and invertebrate toxicity; and 3) the NDFS flows moved water and constituents downstream, particularly with higher flows (Davis et al. 2021), discharges from the CBD to the Yolo Bypass due to Project operations may impact DS and their prey.

4.3.1.2. Dissolved Oxygen

The FEIR (Reclamation and Sites Authority 2023) notes that decreases in reservoir DO levels are expected during initial filling due to decomposition of organic matter, and that decreases will recur regularly from the late spring through fall due to stratification and algae die-off. The exact level of DO expected to be discharged from the reservoir is unclear.

DO thresholds have not been scientifically evaluated for DS; therefore, the FEIR (Reclamation and Sites Authority) uses a DO threshold of 7 mg/L for reduced growth and a 2.3 mg/L threshold for mortality, put forward in Jabusch et al. (2008). However, the Jabusch et al. (2008) framework was developed specifically for dredging operations where plume impacts were brief (e.g., minutes or less) and localized. This framework is not comparable to a prolonged pulse flow that may last for multiple days or weeks over a larger spatial extent. Additionally, a target DO thresholds should be set well above levels that would cause mortality. The Central Valley Region Water Quality Control Plan stipulates that DO should not drop below 5.0 mg/L in the Delta (CRWQCB 2020), as these are considered the lowest concentrations needed for non-salmonid freshwater fishes.

Findings from the pulse-flows evaluated during the NDFS studies serve as a model for DO impacts that could arise from Project discharges to the Yolo Bypass and points downstream due to similarities in geography, volume and timing. The NDFS pulse flows ranged between 239 to 750 additional daily cfs routed through the CBD, KLRC, Toe Drain, Liberty Island and the Cache Slough Complex between July and October (Davis et al. 2021; Figure 4-59). Water was sourced from a mix of agricultural drainage and/or from Sacramento River. DWR found that DO generally decreased during the pulses at upstream locations immediately above and within the Yolo Bypass. DO did not appear to be affected in downstream locations of Liberty Island and Cache Slough Complex[9]. Results suggested that this was a result of flow pulses moving water from low DO areas upstream to downstream regions. Larger pulse-flows in 2018 and 2019 (548 cfs and 750 cfs, respectively) resulted in sudden DO declines at the LIS and STTD sites in the lower Yolo Bypass, dropping levels below the 5 and 7 mg/L thresholds (Figures 4-109 through 4-111).

[9] Upstream monitoring stations referenced in the NDFS study were Colusa Basin Drain at Rominger Bridge (RMB, 38.812214°, -121.774258°), Ridge Cut Slough (RCS, 38.793556°, -121.725349°), Yolo Bypass Toe Drain at Road 22 (RD22, 38.676367°, -121.643972°), Yolo Bypass Toe Drain at Lisbon Weir (LIS, 38.474781° -121.588226°), Yolo Bypass Toe Drain at the Rotary Screw Trap (STTD, 38.353383°, -121.643181°), and Yolo Bypass Toe Drain at Liberty Island Near Courtland, CA (TOE, 38.349167°, -121.644722°). Downstream monitoring stations referenced in the NDFS study included Liberty Cut at Little Holland Tract near Courtland (LIBCUT, 38.32885°, -121.6675306°), Cache Slough at Liberty Island Near Rio Vista (LIB, 38.242100°, -121.684900°), Cache Slough at Ryer Island (RYI, 38.212800°, -121.669200°), and Sacramento River at Rio Vista Bridge (RVB, 38.159737°, -121.686355°).

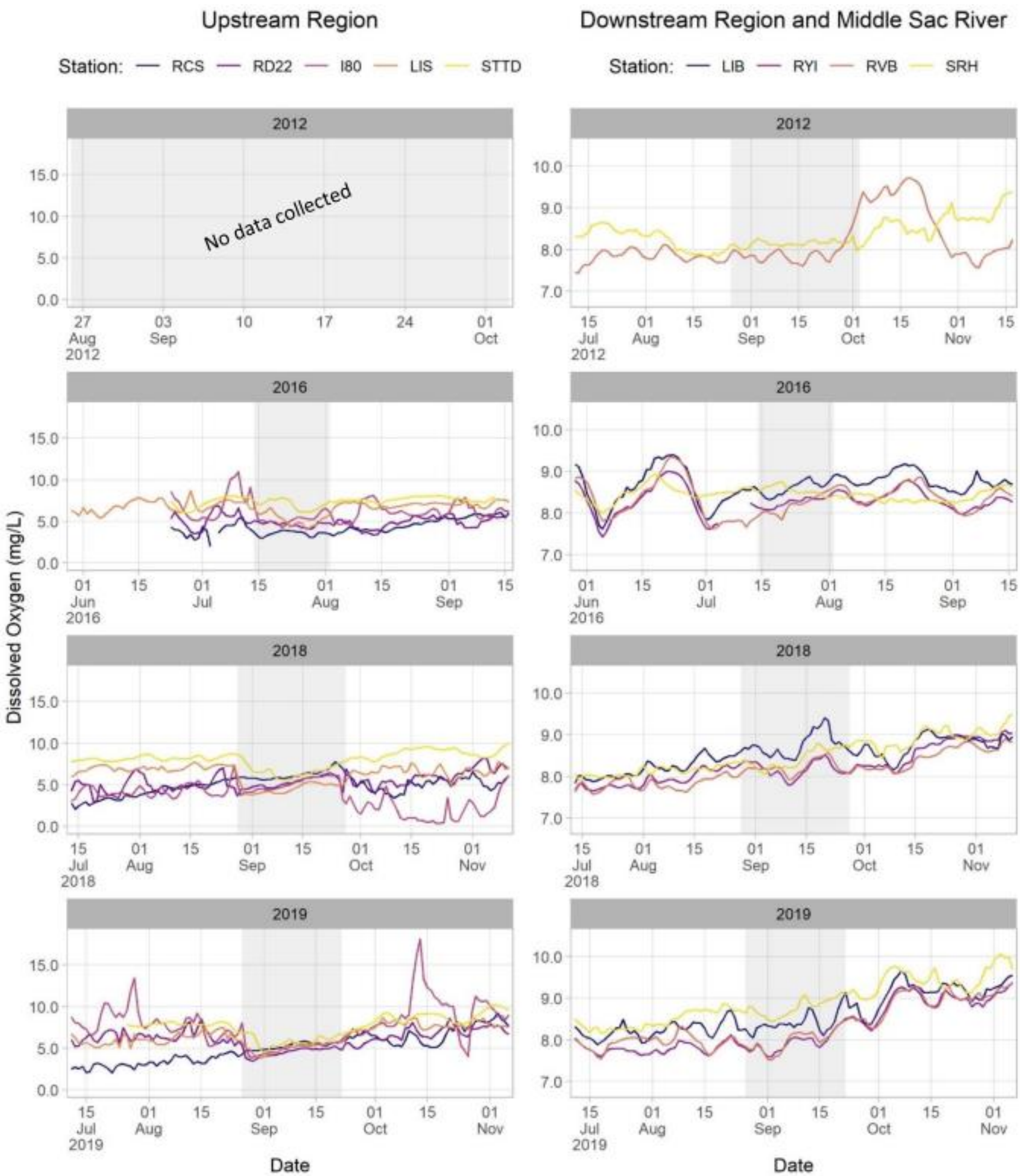


Figure 4-109. Daily average dissolved oxygen in North Delta Food Subsidy years with high flow, high magnitude and short duration flow pulses (2012, 2016, 2018, 2019). Grey shaded box represents flow pulse period. From Davis et al. 2021.

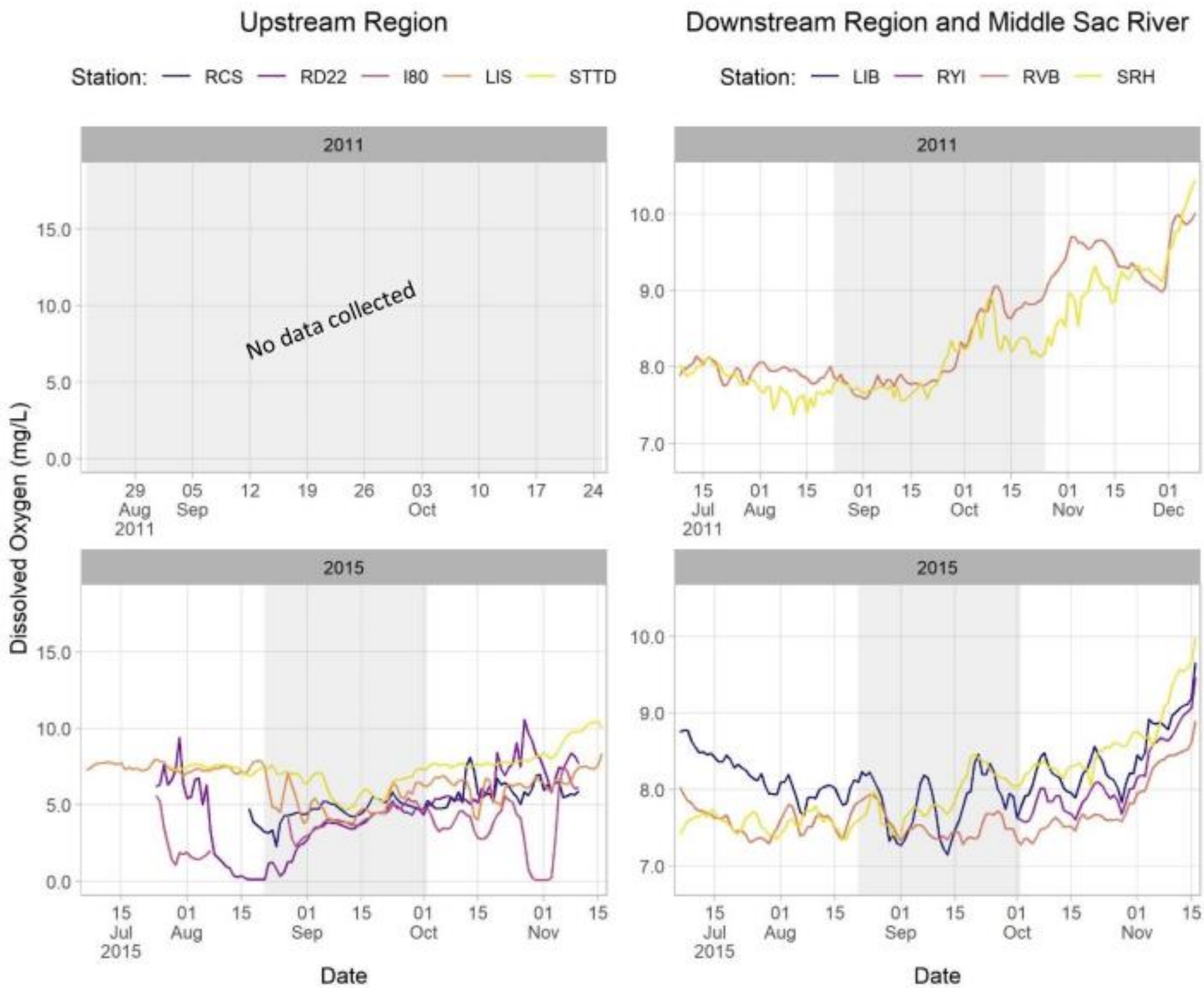


Figure 4-110. Daily average dissolved oxygen in North Delta Food Subsidy years with high flow, low magnitude and long duration flow pulses (2011 and 2015). Grey shaded box represents flow pulse period. From Davis et al. 2021.

Figure 4-111. Daily average dissolved oxygen values from low North Delta Food Subsidy flow-pulses (2013, 2014, 2017). Gray box represents the flow pulse period, from Davis et al. 2021.

The ITP Application (Sites Authority 2023) suggests that fish could move downstream if reservoir releases result in locally inhospitable DO levels. However, DS are not strong swimmers (Swanson et al. 1998) and utilize selective tidal movements to maintain position or migrate (Bennett and

Burau 2015). They may not be able to escape unfavorable changes in DO, especially if a drop occurs suddenly. For example, in 2001, larger, more mobile, and generally less sensitive fish species (i.e., adult Chinook Salmon, Striped Bass, Carp, sunfishes, and mosquitofish) experienced high rates of mortality after a sudden DO reduction in Putah Creek, a tributary to the Yolo Bypass (Rabidoux et al. 2022).

Conclusions

Based on results of the NDFS pulse flows, particularly those that occurred in 2018 and 2019, discharges from the Project to the Yolo Bypass have the potential to reduce DO to harmful levels in areas that impact DS. DS have been captured at the DWR RST site (STTD) in the downstream Yolo Bypass area (DWR's RST Site, "STTD" in Figures 4-109 through 4-111) in substantial numbers between January and June (Mahardja et al. 2019). The trap is not operated during Sites' proposed Yolo Bypass discharge period of August-October, so it is unclear if they are present in that area at that time. However, they have been found in downstream locations in the Liberty Island area during August-October (Sommer and Meja 2013; Merz et al. 2011) suggesting they may utilize the lower Yolo Bypass during this time as well. Sudden drops in DO similar to those during the 2018 and 2019 NDFS pulses, are of particular concern.

If discharges from the Project cause DO to decrease below 5 mg/L in downstream locations in the Yolo Bypass, they have the potential to impact DS, particularly if DO drops suddenly. It will therefore be important to monitor DO at the proposed reservoir discharge point, and at multiple points in the CBD, Yolo Bypass, and Cache Slough area as these operations occur.

4.3.1.3. Temperature

DS are highly sensitive to water temperature (FLOAT-MAST 2020). The amount of suitable thermal habitat for the species in the Delta has shrunk significantly since 1985 (Halverson et al. 2022), a trend that is expected to continue. Critical thermal maxima (CTmax) for DS range from 24.1–28.6 °C in the scientific literature, depending on acclimation temperature, origin (hatchery or wild), and life stage (Komoroske et al. 2014; Hung et al. 2022). However, CTmax is a high threshold near death, where individuals are no longer able to escape unfavorable conditions. Lower, sub-lethal temperature thresholds that negatively influence physiological function or behavior are more relevant for avoiding impacts to the species. Such thresholds in the scientific literature include:

- 20 °C: Genes indicative of stress become more active (Jeffries et al. 2016)
- 21 °C: Behavior is impacted, increasing predation vulnerability (Davis et al. 2019). Metabolic rate increases to attempt to maintain homeostasis under thermal stress (Pasparakis et al. 2023)
- 2–4 °C below CTmax: Genetic indicators for protein, DNA and cellular damage are upregulated (Komoroske et al. 2015).

Due to uncertainties surrounding temperature modelling of discharges from Sites Reservoir provided in the ITP Application (Sites Authority 2023 Appendix 4B; see Section 4.1.2.2), findings from the pulse flows implemented during the NDFS study serve as a model for temperature impacts anticipated from discharges to the Yolo Bypass and points downstream. After analyzing water temperature monitoring data, DWR could not distinguish temperature effects of the NDFS pulses from seasonal trends. Thus, if temperatures released from Sites Reservoir are similar to those of agricultural discharge in the CBD, thermal impacts to the system may not be evident. However, if Project discharges increase temperatures in the CBD above ambient levels, additional flows may push warm water to the south, impacting thermal habitat for DS downstream. The anticipated temperature of Project water at the point of discharge is unclear, and because water temperatures in this region currently often approach and exceed DS sublethal and CTmax thresholds in the August through October timeframe (Figure 4-112), prevention of further increases from Project operations will help protect DS.

Conclusions

Based on the results of temperature modeling during the NDFS studies, CDFW concludes that the temperature effects on DS will be minimal. However, there is significant uncertainty around expected water temperatures of Sites' releases. If releases cause temperatures to increase above 20 °C in the lower Yolo Bypass, Liberty Island or Cache Slough area, there is the potential for impacts to DS.

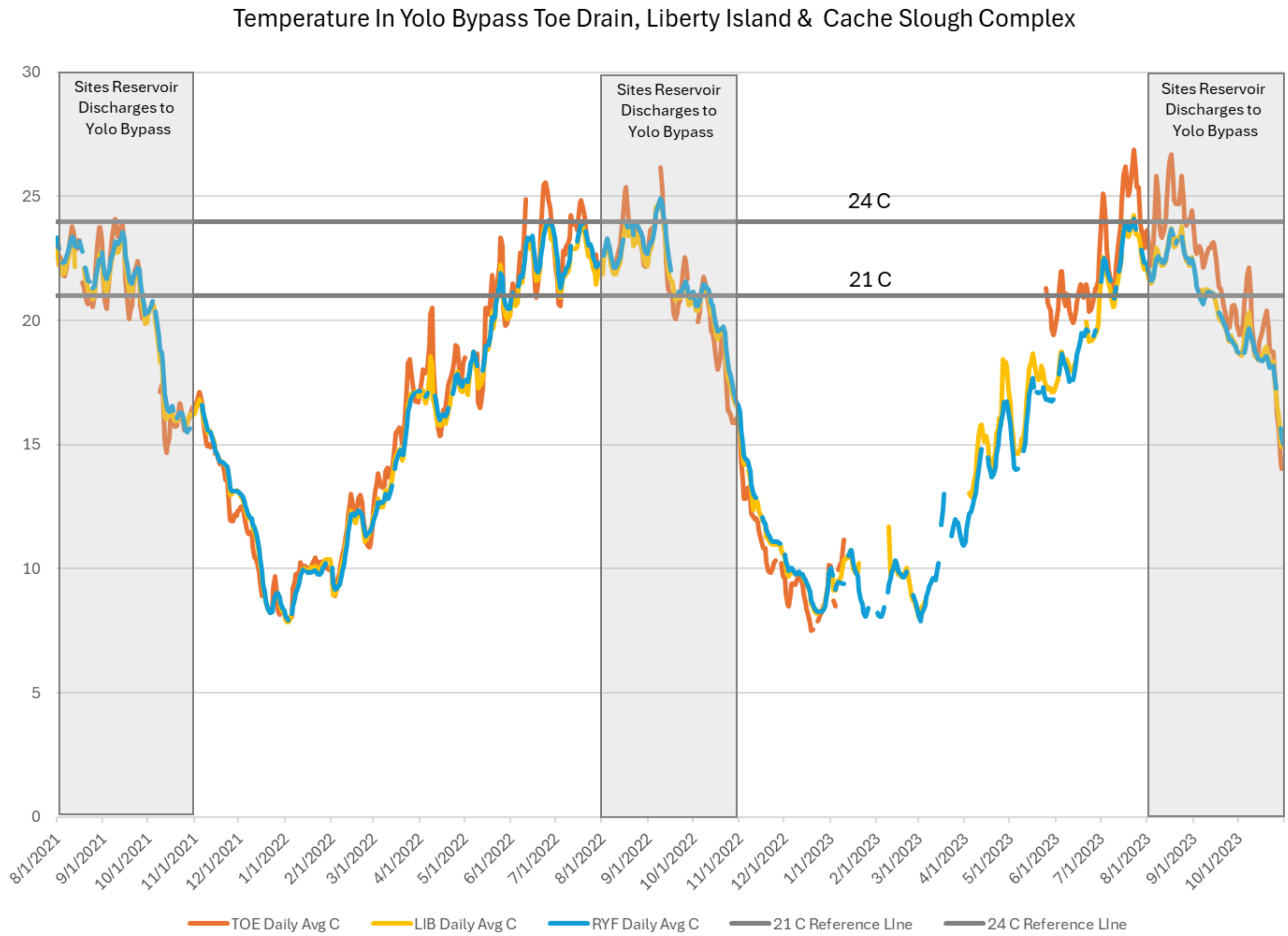


Figure 4-112. Daily average temperatures (°C) in the Yolo Bypass Toe Drain Near Courtland, CA (TOE), Liberty Island (LIB) and Cache Slough Complex (RYF) from 2021-2023. August through October discharge periods are highlighted in grey boxes. Delta Smelt thermal thresholds at 21 and 24 °C reference lines included in dark gray.

4.3.2. Upstream Sediment Entrainment

Changes in the delivery of fine sediment to the Delta associated with the Project have the potential to impact Delta Smelt by reducing turbidity, a critical habitat attribute in the Delta.

Abundance of larval and juvenile DS has been shown to be associated with turbid water (Nobriga et al. 2008; Kimmerer et al. 2009; Sommer and Mejia 2013), as has catch of larval LFS (Brennan et al. 2022). Delivery of suspended sediment to the Delta by the Sacramento River decreased by roughly 50% between 1957 and 2001, due, in part, to the impoundment of sediments in reservoirs (Wright and Schoellhamer 2004; Schoellhamer et al. 2012). Reduced sediment delivery from the

Sacramento River has led to a reduction in Delta turbidity, which has in turn been linked to the declines of both DS (McNally et al. 2010; Thompson et al. 2010; IEP-MAST 2015; Hobbs et al. 2019b) and LFS (Thompson et al. 2010; CDFW 2020b; Brennan et al. 2022) in the SFE.

The ITP Application (Sites Authority 2023) showed that increased diversions of water from the Sacramento River for Sites Reservoir would likely remove a small amount of suspended sediment from the Sacramento River that would not be removed from the river under the NAA. Over the 82-year USRDOM simulation period, an estimated entrainment of 2.6–2.7% of sediment reaching the Red Bluff intake under the Alt3B operational scenario, compared to 1.2% under the NAA. The ITP Application (Sites Authority 2023) estimated that the Hamilton City intake would entrain 2.1% of suspended sediments under Alt3B, compared to 1.8% under the NAA.

While these suspended sediment entrainment estimates are small, they were produced using statistical models (Huang and Greimann 2011) and should thus be considered in the context of their uncertainties. Huang and Greimann (2011) did not provide details of the statistical procedures used in fitting their models, so the standard errors of their parameter estimates, and thus the prediction intervals around estimates of suspended sediment entrainment under the Alt3B, NoSha and NoShaOro operational scenarios and the NAA, cannot be determined. CDFW therefore refit the model to the data provided in Attachment A of Huang and Greimann (2011). CDFW replicated their methods to the greatest extent possible and quantified the uncertainty in estimated suspended sediment entrainment under the NAA and under the Alt3B, NoSha, NoShaOro operational scenarios during the 82-year USRDOM simulation period.

The equation describing the relationship between suspended sediment concentration and Sacramento River flow proposed by Huang and Greimann (2011) is:

Equation 11.

$$C = aQ^b,$$

where C is the suspended sediment concentration (mg L^{-1}), Q is Sacramento River flow (cfs) and a and b are fitted constants. Huang and Greimann (2011) proposed a segmented model (with change points), fitted separately to suspended sediment and flow data recorded at Red Bluff and Hamilton City.

Using the same model formulation, we fit a new segmented regression model using the *segmented* R package (Muggeo 2024). The segmented() function only handles linear models, so Equation 12 had to be linearized before we could fit the model, which we accomplished by taking the natural logarithm of both sides of Equation 11.

Equation 12.

$$\ln(C) = \ln(a) + b \cdot \ln(Q).$$

This was the model fit using the segmented() function in R. Equation 12 can be back-transformed to Equation 11 by exponentiating both sides. As in Huang and Greimann (2011), we fixed the number of change points at two and one for Red Bluff and Hamilton City, respectively; however we allowed the segmented() function to estimate the locations of the change points, rather than fixing them at 10,000 cfs and 20,000 cfs for Red Bluff and at 10,000 cfs for Hamilton City as Huang and Greimann (2011) did.

The new, estimated change points for Red Bluff were 11,305.0 ± 1.04 cfs and 18,638.8 ± 1.06 cfs (estimates ± 1 SE). The new, estimated change point for Hamilton City was 11,103.3 ± 1.27 cfs. The parameter estimates for each segment of the Red Bluff and Hamilton City model fits are given in Table 4-37.

Table 4-37. Parameter estimates (±1 SE) of the fitted segmented regression model of suspended sediment concentration (mg L-1) as a function of Sacramento River flow (cfs) at Red Bluff and Hamilton City. First intercept and slopes (b) are given ±1 SE. The segmented package does not provide a standard error for the second intercept (a). Data from Huang and Greimann (2011), Attachment A.

Sacramento River flow (Q, cfs)	a	b	**Adj. R^2**
Red Bluff	**--**	**--**	**0.61**
Q < 11,305.0	0.016 ± 3.83	0.75 ± 0.15	--
11,305.0 ≤ Q < 18,638.8	0.0	4.21 ± 0.51	--
Q ≥ 18,638.8	0.22	0.66 ± 0.13	--
Hamilton City	**--**	**--**	**0.59**
Q < 11,103.3	0.0 ± 3.6e6	4.79 ± 1.67	--
Q ≥ 11,103.3	0.0012	1.17 ± 0.52	--

Segmented model fits were similar to those of Huang and Greimann (2011) (Figure A; Figure B). Residual variation was high; consequently, the prediction intervals around the predicted time series were large for both the fitted predictions (Figure C; Figure D) and those obtained by substituting USRDOM-simulated Red Bluff and Hamilton City diversions into Equation 12 (Figure 4-113).

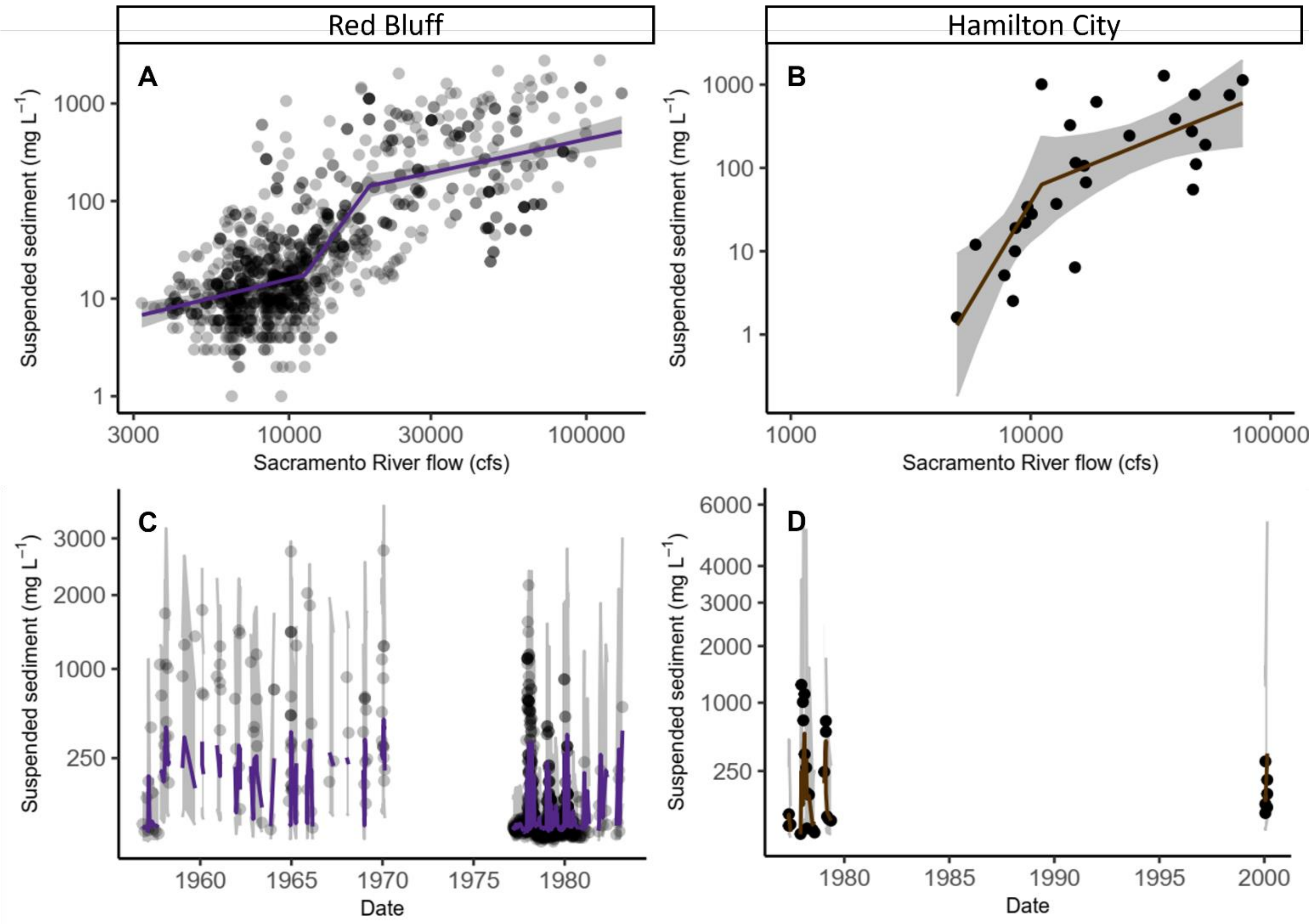


Figure 4-113. Suspended sediment concentration versus Sacramento River flow (black points) at Red Bluff (A) and Hamilton City (B). Violet and brown curves are segmented fits of Equation 12. Shaded regions are 95% confidence bands around model fits. Axes in A and B are on a $\log_{10}$ scale. Panels C and D show the data (black points), fitted models (violet and brown curves) and 95% prediction intervals (shaded regions) as time series for Red Bluff and Hamilton City, respectively. Y-axes in C and D are on a square-root scale. Data provided by Huang and Greimann (2011).

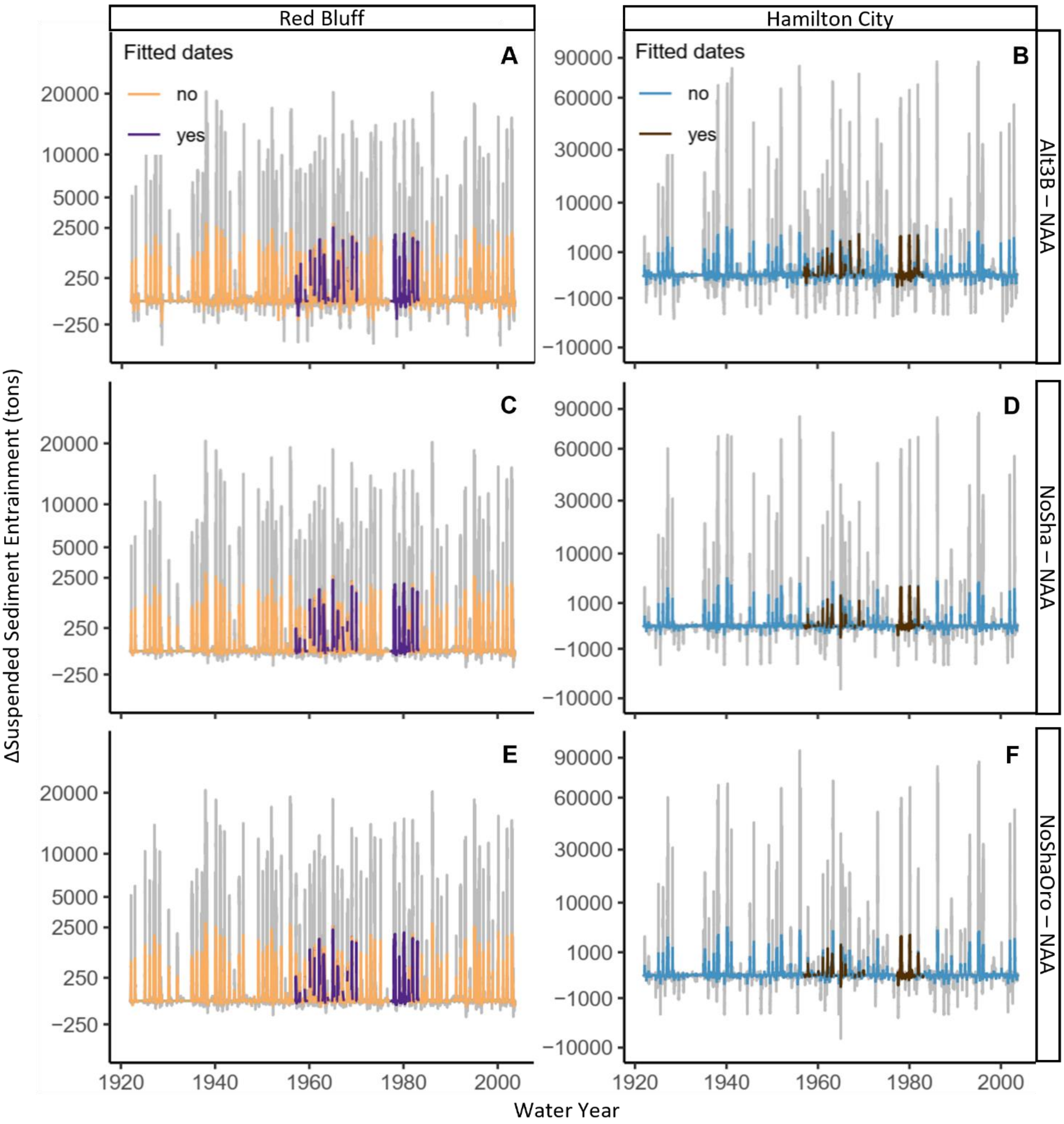


Figure 4-114. Difference in daily suspended sediment concentration between operational scenarios (Alt3B (top), NoSha (middle) and NoShaOro (bottom) and the No Action Alternative (NAA) at Red Bluff (left) and Hamilton City (right)), as predicted by substituting USRDOM-simulated data into the segmented regression models. Shaded regions are the 95% prediction intervals. Violet (left) and brown (right) curves show the dates of sediment and flow data to which Equation 12 was fitted; orange (left) and light blue (right) are predictions outside the date range of the data. USRDOM simulated data provided in the ITP Application (Sites Authority 2023).

Table 4-38. Percentages of suspended sediment entrained over the 82-year Upper Sacramento River Daily Operations Model (USRDOM) simulation period under Project operational scenarios (Alt3B, NoSha and NoShaOro) and the No Action Alternative (NAA), as predicted by Huang and Greimann (2011) and CDFW model fits. Differences between operational scenarios and the NAA are shown in parentheses.

Source	Huang and Greimann (2011)	CDFW (present study)
Red Bluff NAA	1.2%	0.62%
Alt3B	2.6% – 2.7% (1.4% - 1.5%)	3.0% (2.4%)
NoSha	--	2.8% (2.2%)
NoShaOro	--	2.7% (2.1%)
Hamilton City NAA	1.8%	1.4%
Alt3B	2.1% (0.3%)	2.2% (0.8%)
NoSha	--	2.1% (0.7%)
NoShaOro	--	2.1% (0.7%)

The predicted, cumulative sediment entrainment trajectories were also similar to those predicted by Huang and Greimann (2011), as were the estimated total percentages of sediment entrained during the 82-year simulation period (Table 4-38). However, due to the compounding nature of the uncertainties around cumulative sums, these estimates should be interpreted with caution. Total sediment entrainment may be lower than, or may greatly exceed, the predicted values at both Red Bluff and Hamilton City (Figure 4-115).

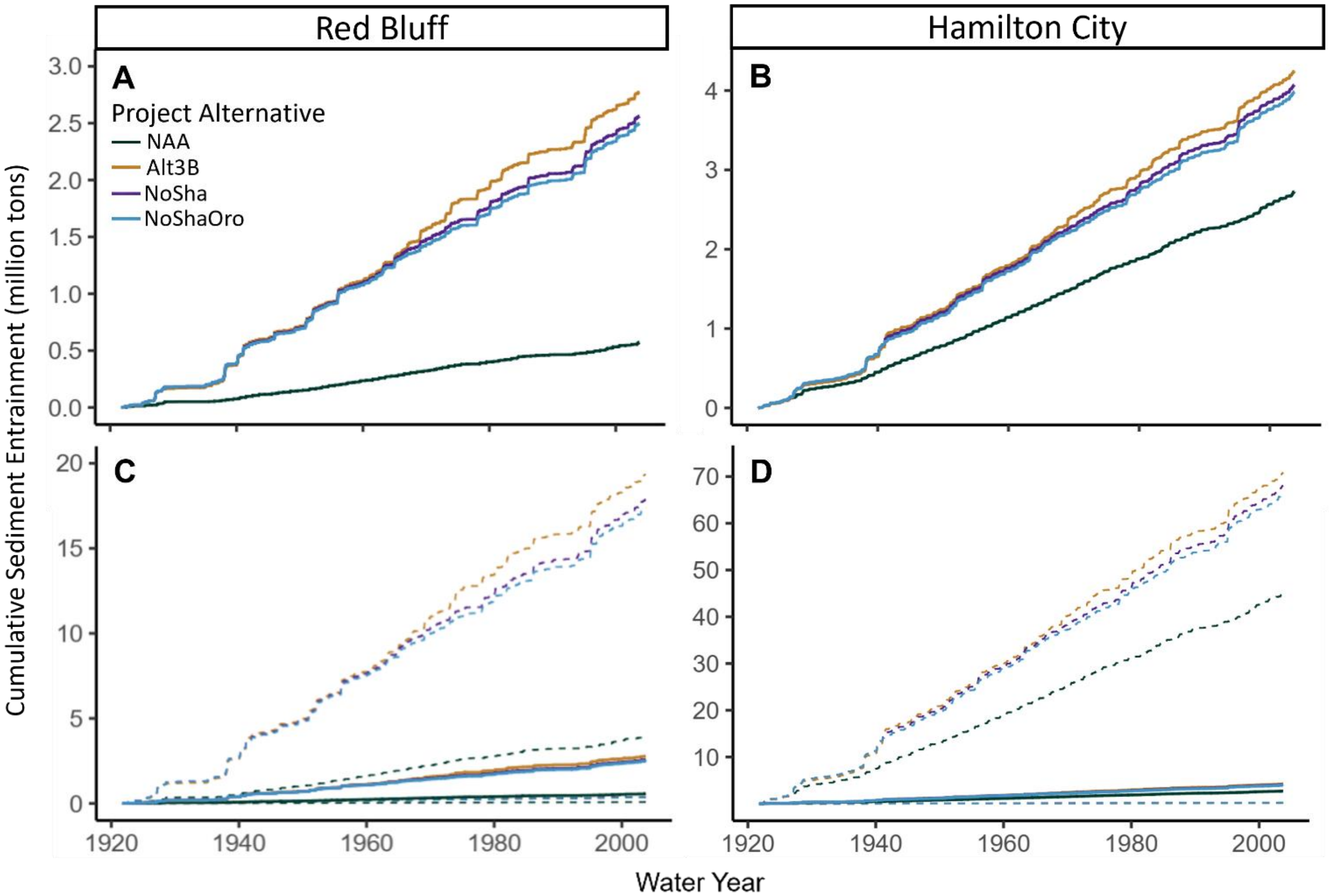


Figure 4-115. Cumulative suspended sediment entrainment at Red Bluff (left) and Hamilton City (right) under the NAA (dark green), Alt3B (gold), NoSha (violet) NoShaOro (cyan) over the 82-year upper Sacramento River Daily Operations Model (USRDOM) simulation period. Panels A and B show only the model predictions, while panels C and D show model predictions with cumulative, 95% prediction intervals (dashed curves). Note that y-axis scales are different across all panels.

Conclusions

Sediment entrainment at Red Bluff and Hamilton City is proportional to the volume of water diverted; thus, the sediment concentration in the Sacramento River immediately downstream of the diversion points will not be changed by increased diversions for Sites under the Project. However, the potential negative impacts of sediment entrainment on DS, and possibly LFS, occur far downstream, in the Delta. The sediment concentration in the Delta is determined by the amount of sediment transported to the Delta and by the total amount of water delivered by tributaries. Reducing the volume of sedimented water in the Sacramento River will reduce the relative contribution of Sacramento River sediment to the total suspended sediment concentration in the combined waters of the Sacramento River and its tributaries downstream of the diversion points. Thus, diversions for Sites under the operational scenarios will reduce Delta turbidity, but the magnitude and timing of this impact are highly uncertain.

4.3.3. First Flush

Diversions from the Sacramento River for the Project may reduce flows that cue Delta Smelt to migrate upstream to spawn, which could reduce reproductive success.

From December through March, the migratory contingent of adult DS disperse upstream into fresh and low-salinity water in preparation for spawning (Bush 2017; Moyle 2002). This movement generally coincides with high Delta outflow and a spike in turbidity associated with winter storms, known as "first flush" events (Bennett and Burau 2015; Grimaldo et al. 2009, Sommer et al. 2011). The concept is that the first substantial winter storm will produce a freshet of turbid water that cues adult DS to disperse upstream. In years when first flush conditions do not occur, adult DS will eventually disperse into spawning habitat by late February or March when water temperatures are warm enough to initiate spawning (Bennett 2005).

Diversions from the Sacramento River to Sites Reservoir in December and January will decrease Delta outflow and have the potential to dampen this "first flush" event and therefore disrupt this important environmental cue for DS. The ITP Application (Sites Authority 2023) used CalSim II and DSM2 to model the change in Delta outflow expected with the Alt3B operational scenario compared to the NAA. Results demonstrated that on average over the full simulation period, December Delta outflow was decreased by 615 cfs and January Delta outflow was decreased by 935 cfs under the Alt3B operational scenario compared to the NAA (Table 4L3-5-2c of Sites Authority 2023). However, results averaged by water year type over the 82-year simulation period showed that this difference was much greater in certain water year types. Some of the largest decreases in Delta outflow were observed between the Alt3B operational scenario and the NAA in December of below normal years, when Delta outflow was 1,329 cfs lower. In January of wet water years, the Alt3B operational scenario estimates that Delta outflow was 1,520 cfs lower than average and in above normal water years Delta outflow was 1,214 cfs lower (Table 4L3-5-2c of Sites Authority 2023).

CDFW used estimated flows from DRAT to compare the day of the water year when first flush would have been triggered with the Alt3B and the NAA to see if the Project would prevent first flush from occurring or change the day of the water year on which first flush would occur compared to the NAA (Figure 4-116). This analysis showed that the Project did not prevent first flush from occurring and did not change the day of any first flush events between 2004 and 2019 compared to the NAA. The years used for this analysis were limited due to the years available in DRAT (2000 through 2019) and when the flow gauge at Freeport was installed on the Sacramento River to determine first flush conditions, which was installed in 2004. Although the DRAT is limited to only 20 years, this period contains a wide range of water year types, and this is the only tool that will show results in changes to flow on a daily scale. The other model used in the ITP application (Sites Authority 2023) to evaluate changes in Delta outflow was CalSim II, which shows changes to flow on a monthly scale, making it less useful for looking at the timing of first flush events.

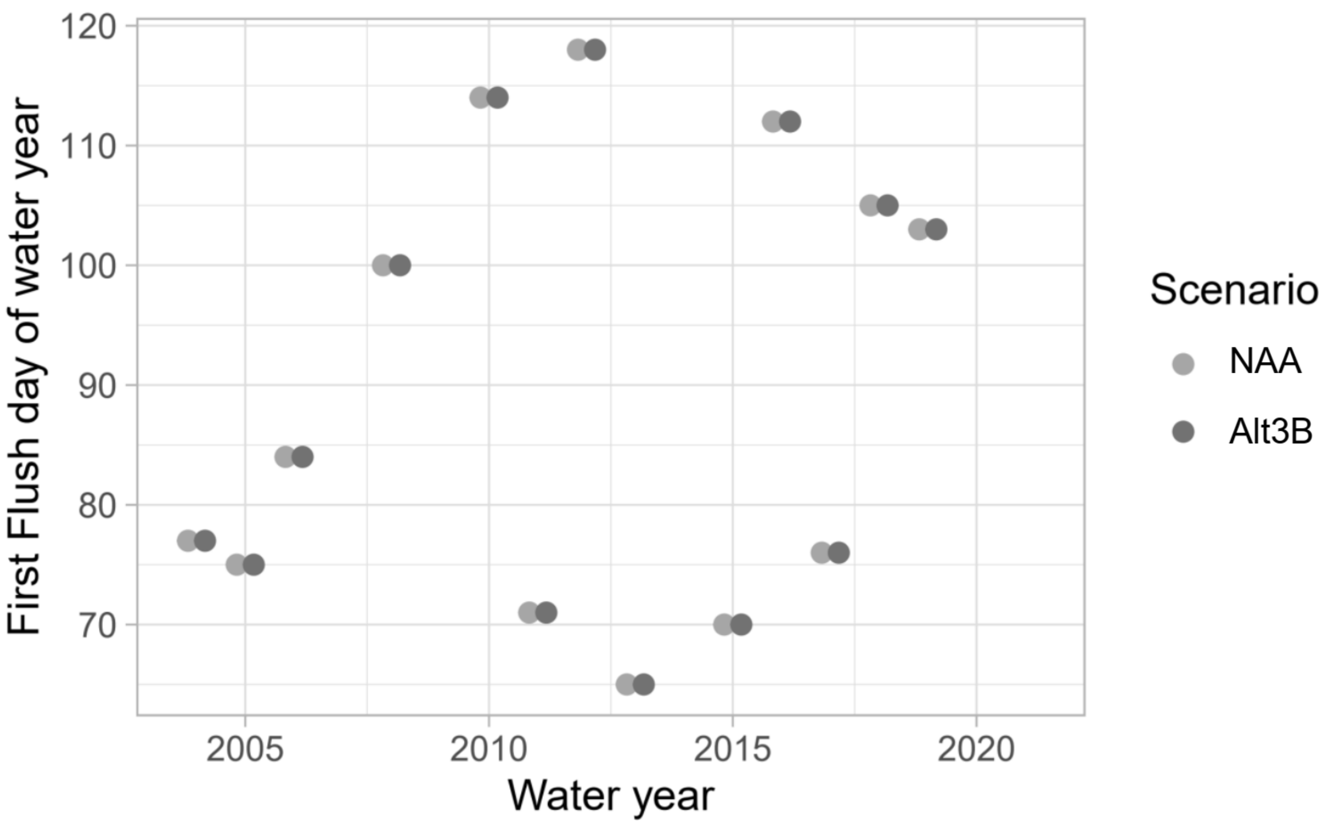


Figure 4-116. Day of the water year first flush would have been triggered from 2004 through 2019 from Diversion Routing Analysis Tool under the Alt3B operational scenario and the No Action Alternative (NAA). Years with no points shown on the graph are water years when first flush conditions did not occur. CDFW used estimated flows from DRAT (a tool developed by CDFW using Sites Daily Divertible Tool and USRDOM.

Conclusions

Based on the information and modeling reviewed, CDFW does not expect the changes to Delta outflow in December and January due to diversions by the Project to affect first flush conditions. CDFW's analysis showed that the Project did not prevent first flush conditions from occurring nor change the day on which first flush occurred in the 2004 through 2019 period examined (Figure 4-

116). However, because limited years were evaluated as part of this analysis, it will be important to periodically assess all factors affecting first flush moving forward.

4.3.4. South Delta Entrainment

If Project operations result in changes to Delta outflow, this would affect the position of X2 as well as local hydrodynamics in the Delta that affect south Delta entrainment risk for Delta Smelt.

The position of X2 from March through June affects where larval and juvenile DS will initially be distributed (Dege and Brown 2004), with higher X2 resulting in higher entrainment rates into lower quality habitat in the south Delta and south Delta export facilities. Modeling results in the ITP Application (Sites Authority 2023) showed that the Alt3B operational scenario would reduce Delta outflow from March through June (Table 4L3-5-2c in Appendix 4L of Sites Authority 2023) compared to the NAA, and therefore the Project would have a small effect on X2 position March through June (Table 4-35 of Sites Authority 2023).

Sites' DSM2 modeling also shows small reductions in X2 compared to the NAA, in most cases less than 2 km, under the Alt3B, NoSha, and NoShaOro operational scenarios (Section 4.0, Delta Conditions). Because the Project will have a small effect on Delta outflow, X2, and Qwest, CDFW concludes that the Project would have a small effect on entrainment risk of larval and juvenile DS.

4.3.5. Food Abundance

Project operations will result in changes to Delta outflow and the position of X2, which could cause changes in food abundance and availability for Delta Smelt, which is negatively correlated with X2.

Food is an important factor in DS population dynamics (Sommer et al. 2007, Baxter et al. 2010, Mac Nally et al. 2010, IEP-MAST 2015); however, food resources have been declining since the late 1980s (Kimmerer and Orsi 1996; Orsi and Mecum 1996; Winder and Jassby 2011), which has likely led to fewer food resources and therefore smaller-sized adult DS (Sweetnam 1999). Both adult size and egg production are important factors in modeled DS population dynamics (Rose et al. 2013a; Rose et al. 2013b). As DS adult size is positively correlated to egg production, the effects of food limitation can therefore have multiplicative effects on DS population dynamics.

Mac Nally et al. (2010) developed strong evidence that low outflow (represented by X2) significantly reduced calanoid copepod biomass in spring and mysid biomass in summer within the LSZ (see also Hennessy and Burris 2017). The abundance of *P. forbesi* in the LSZ during summer and fall is subsidized from upstream and influenced by freshwater outflow (Durand 2010; Hennessy and Burris 2017; Kimmerer et al. 2018). This food subsidy into Suisun Bay replaces some of the local zooplankton production lost to feeding by *P. amurensis* (Kimmerer et al. 2018). These authors note that this subsidy decreases as outflow decreases (reported as X2 advancing upstream; see also Mac Nally et al. (2010)) and decreased outflow also shifts the *P. forbesi* population further east, where it is at greater risk of entrainment and loss to south Delta and in-Delta water exports (Kimmerer et al. 2018).

Sites modeling using CalSim II and DSM2 indicates that the Project (Alt3B operational scenario) will result in minimal changes to Delta outflow, X2 position, and food densities for DS in spring and summer (Sites Authority 2023). Modeling showed slightly lower Delta outflow and slightly greater X2 in March, with smaller differences in April, May, and June (Alt3B operational scenario; Table 4-35 of Sites Authority 2023; Table 4L3-5-2c of Sites Authority 2023 Appendix 4L3; Figure 4-13). The ITP Application (Sites Authority 2023) also indicated that the Project will result in slightly higher Delta outflow in July, August, and September (Alt3B operational scenario; Table 4L3-5-2c of Sites Authority 2023 Appendix 4L3). Sites (2023) also modeled potential changes in X2 position as a result of Project Operations (Alt3B operational scenario) would affect the density of *E. affinis* in spring using the relationship developed by Greenwood (2018). Sites (2023) results demonstrated minimal changes in densities with the Project (Table 4-36 of Sites Authority 2023).

The ITP Application (Sites Authority 2023) also assessed the relationship between changes in Delta outflow due to Alt3B Project operations and the density of *E. affinis* from March through June using the relationship developed by Hennessy and Burris (2017). Results indicated only minimal changes in densities due to Project operations (Alt3B operational scenario; Table 4-37 of Sites Authority 2023). Lastly, the ITP Application (Sites Authority 2023) evaluated the relationship between changes in Delta outflow as a result of Project operations and the density of *P. forbesi* during summer in Suisun Bay using the relationship developed by Hennessy and Burris (2017). Results indicated small increases in *P. forbesi* densities as a result of Project operations (Alt3B operational scenario; Table 4-41 of Sites Authority 2023). Due to the inherent variability of zooplankton data, modeled relationships between zooplankton abundance and Delta outflow or X2 position have high uncertainty (Hennessy and Burris 2017; Sites Authority 2023, Tables 4M-1 – 4M-3), as do predicted abundances.

Although the ITP Application (Sites Authority 2023) did not analyze changes in X2 or outflow to zooplankton for the NoSha and NoShaOro operational scenarios, DSM2 modeling showed similar and small changes in X2 under the Alt3B, NoSha, and NoShaOro operational scenarios; therefore, it is expected that the NoSha and NoShaOro operational scenarios would have similar small effects as Alt3B.

Conclusions

Given that the Project is expected to result in minimal changes to Delta outflow, X2 position, and food densities for DS in spring, CDFW concludes that the Project will cause small negative impacts to DS by reducing food abundance. The ITP Application (Sites Authority 2023) analysis showed small changes in zooplankton abundance due to changes in X2 or outflow between the Alt3B operational scenario and the NAA, although the modeled relationships have high uncertainty (Sites Authority 2023, Tables 4M-1–4M-3). The ITP Application (Sites Authority 2023) compared changes in zooplankton abundance between Alt3B and NAA, however, because the shift in X2 under the Alt3B, NoSha, and NoShaOro operational scenarios will be similar and small, in most cases less than 2 km, CDFW concludes that effects to food densities would be small under all three Project operational scenarios.

4.4. Take and Impacts of Taking on White Sturgeon

WS may be present in the Sacramento River upstream of and near Project diversion facilities, in the Sacramento River downstream of diversions, in areas of the Feather River, and in the Delta. This section describes analyses of take and impacts of the taking due to Project operations at the diversion facilities (i.e., near-field effects) as well as Project-related take and impacts of the taking that occurs elsewhere in the Project area.

4.4.1. Near-Field Effects

4.4.1.1. Entrainment and Impingement

Increased water diversions due to Project operations could increase risk of entrainment of larval and juvenile White Sturgeon into pumping stations and conveyance facilities.

The HCFS consists of two sections, a 470-foot section completed in 1993 and a newer, 630-foot section, completed in 2002. The older section is made of flat-plate stainless steel with a slot size of 2.38 mm, while the newer section, also flat-plate stainless steel, has the more modern slot size of 1.75 mm. The older section of HCFS is protective of fish larger than 30 mm TL, while the newer section is protective of fish larger than 22 mm TL (Turnpenny 1981; Young et al. 1997; Gowan and Garman 2002). These screens likely prevent the entrainment of juvenile WS and all older age classes, but they can potentially entrain larval and small juvenile-sized fish that may occur in the area.

Adult WS have been detected by acoustic telemetry upstream of Bend Bridge on the Sacramento River (Miller et al. 2020) and may spawn in the vicinity of Hamilton City Pump Station from the months of January to June. Larval WS may be as small as 10 mm TL at hatching (Wang et al. 1985) and are vulnerable to entrainment, especially given their tendency toward negative rheotaxis (i.e., they face away from the current and move downstream with the flow) post-hatching. In contrast, Chinook Salmon exhibit positive rheotaxis (i.e., they orient themselves toward the current). The maximum designed approach velocity of the HCFS is 0.33 fps. The average critical swimming velocity (U_{crit}) of a free-swimming larval WS of 30 mm TL is ~0.63 fps; however, U_{crit} for a 30 mm sturgeon may be as low as 0.33 fps (Verhille et al. 2014). Thus, once WS are large enough to avoid entrainment, they are likely able to resist impingement upon the HCFS, provided the approach velocity does not exceed 0.33 fps.

Conclusions

Entrainment may be a significant source of take of larval and juvenile WS at the HCFS if adults are spawning upstream of the intake. It is unclear what the spawning population size is in this reach of the Sacramento River, as monitoring of WS around and upstream of Hamilton City has historically been minimal. CDFW estimates that the number of acoustically tagged spawning-sized sturgeon is approximately 1% or less of the total population (Miller et al. 2020, CDFW 2023b); therefore, the small number of acoustic detections upstream of Hamilton City may represent many more adult WS than the number detected. If WS spawn in the upper Sacramento River, larval and juvenile WS less than 30 mm TL may be present near Hamilton City between January and June. Larval and adult monitoring is needed to verify the frequency of WS presence and potential take due to water diversions for the Project.

4.4.1.2. Predation

Project operations may increase predation of larval and juvenile White Sturgeon near the Hamilton City diversion facilities due to changes in the timing, frequency, and volume of diversions.

High predation of juvenile salmonids has been reported at the Hamilton City Pump Station (Vogel and Marine 1995; Vogel 2007; Vogel 2008), and WS may be at similarly high risk. Project diversions at Hamilton City may increase the density of larval and juvenile WS near the HCFS by increasing flow toward the screens during times of peak hatching and dispersal (i.e., January–June). If predator fish aggregate at or downstream of the fish screens, the increased density of larval and juvenile WS near the screens could lead to high predation losses (Cramer et al. 1992; NMFS 1998).

Aggregation of predator fish near positive-barrier fish screens in the Sacramento River system has been widely reported to cause increased predation of juvenile salmonids near the screens (Hall 1979; NMFS 1998; Vogel 2007; Vogel 2008). Predation may be high near HCFS for several reasons.

First, fish screens present novel structures that may provide favorable habitat for predator fish. Second, small fish, likely including larval and juvenile WS, can become concentrated near fish screens as they are drawn toward the screens and a portion of the volume of water containing them is removed. Third, larval and small juvenile WS could become exhausted by strong diversion flows. These factors make WS near fish screens attractive prey for predator fish like Striped Bass and Sacramento Pikeminnow (Hall 1979; NMFS 1998).

Some predator surveys and juvenile salmon survival studies have been conducted in the Oxbow (Cramer et al., 1992), including several since completion of the extended GCID HCFS in 2002 (Vogel 2006; Vogel 2007; Vogel 2008; Notch et al. 2020b). Vogel (2006) used acoustic telemetry to estimate predation rates near HCFS; Vogel (2007, 2008) combined predator surveys with a juvenile CHNFR mark-recapture study in the oxbow to evaluate predation risk near HCFS; and Notch et al. (2020b) used acoustic telemetry to estimate survival through the Oxbow, relative to the mainstem Sacramento River. Each of these studies is somewhat informative, but none should be taken as a strong predictor of WS predation risk near HCFS during Sites' operations (see below).

Cramer et al. (1992) reported densities of Sacramento Pikeminnow 3–7 times higher in the segment of the Oxbow downstream of HCFS than adjacent to the screen. The Hamilton City Pump Station removes 75%–90% of the water in the oxbow, greatly concentrating juvenile fishes passing through the oxbow and funneling them into the much narrower outflow channel downstream of HCFS. This concentration of prey may attract predators, and likely greatly facilitates predation (NMFS 1998).

During all experiments except those conducted in 2007 (when the flow control weir was removed), Vogel (2007, 2008) observed aggregations of predator fish just downstream of HCFS bypass outfall, where the concrete wall flares into the channel. Additionally, in 2005, underwater videography below the weir revealed an aggregation of Striped Bass just below the flow control weir. Predators likely aggregated below the flow control weir because high flow velocity over the weir prevents passage upstream, and also because prey fish traveling downstream were delivered to that location by the bypass pipelines or were disoriented by passing over the weir into turbulent water. Due to the rapid removal of most of the flow by the diversion, juvenile fish are funneled into a much smaller volume before passing over the weir; high velocities and turbulent conditions below the weir also likely create ideal conditions for predators (Vogel, 2008). The 2007 DIDSON survey also revealed predator fish aggregations at the upstream end of the HCFS. In the upstream location, there is a scour trench along the corrugated sheet piles that retain the concrete footer of the fish screen; Vogel (2008) hypothesized that this scour trench, the sheet piles, and the woody debris that collects in the scour trench create favorable habitat for predators.

Conclusions

Estimates of predation rates of larval and juvenile WS do not currently exist for the upper Sacramento River. Predator density and diet surveys, along with larval monitoring of WS, should be conducted at HCFS to assess whether the screen increases the risk of WS predation loss. However, the predator survey data collected by Cramer et al. (1992) and Vogel (2006, 2007, 2008) suggest that measures to discourage predators from aggregating at the upstream and downstream ends of HCFS would improve WS survival through the oxbow.

4.4.2. Project Effects due to Changes in Flow

Changes in flow as a result of Project operations could reduce White Sturgeon survival and productivity.

Flow alterations can affect aquatic species at all life stages and have cascading effects through altered ecosystem processes (Lytle & Poff 2004; Ruhi et al. 2018). Water diversion and storage, in particular, can significantly modify natural patterns of flow, leading to altered ecological cues and causing species to become decoupled from their natural patterns (Lytle & Poff 2004). Organisms could suffer false alarms by reacting to floods that never arrive or no longer be able to reach prime spawning habitat due to reduced flows. WS have been shown to be sensitive to flow alterations, especially during spawning and larval rearing periods (Hatten et al. 2018; McAdam et al. 2005). The Sacramento River flow analysis in the ITP Application (Sites Authority 2023) using modeled flow outputs from the CalSim II (monthly time-step) and USRDOM (daily time-step) models. Modeled flows for the Sacramento River between Hamilton City and Knights Landing were analyzed to determine how frequently flows are in critical ranges for different life stages and locations for the NAA and Alt3B, NoSha, and NoShaOro operational scenarios.

4.4.2.1. Optimal Spawning Flow

The ITP Application (Sites Authority 2023) included a literature review on flows associated with WS and Green Sturgeon spawning habitat and observed flow conditions, citing Schaffter (1997) for WS and Wyman et al. (2018) for Green Sturgeon. Citing Schaffter (1997), the ITP Application (Sites Authority 2023) proposed an optimal spawning flow range of 6,360 cfs to 12,365 cfs for WS and evaluated the frequency of flows int that range. Results in the ITP Application showed up to an 11% reduction in the number of optimal flow days in some months and water year types due to project operations. CDFW's review of these papers (Schaffter 1997; Wyman et al. 2018) and other relevant scientific literature (Hildebrand et al. 2016; Heublein et al. 2017; Blackburn et al. 2019; Pyros and Culberson 2023) did not find support for an "optimal" spawning flow. Rather than a preferred spawning range, this range most likely represents Sacramento River flows during the observation periods of the cited studies, which are average managed flows in the Sacramento River during months when WS typically spawn.

4.4.2.2. Larval and Juvenile Rearing and Emigration

The ITP Application (Sites Authority 2023) analyzed the effects of the Project on flows during the WS larval and juvenile rearing period, which it defined as April through July. Several studies have demonstrated a significant correlation between increased spring and summer outflow and the successful recruitment of larval and juvenile WS; thus, reductions in flow during those periods may reduce survival of recruiting fish (Kohlhorst 1976, Fish 2010, Blackburn et al. 2019). The ITP Application (Sites Authority 2023) compared modeled average flows from CalSim II during this period for the NAA and Alt3B, NoSha, and NoShaOro operational scenarios. Results in the ITP Application showed that the Alt3B, NoSha, and NoShaOro operational scenarios reduced mean monthly Sacramento River flow in April and May by up to a 8% compared to the NAA (Sites Authority 2023). Average monthly Sacramento River flows in July could also increase up to 25% due to summer water exports and exchanges (Sites Authority 2023); however, flow increases in July would only benefit the latest spawning fish, as larval and juvenile WS disperse rapidly downstream after hatching. A key limitation of analysis in the ITP Application is that it did not evaluate changes in flow from January through March. WS begin spawning as early as January; eggs can hatch 6-14 days after being laid, and larvae migrate downstream quickly (Wang et al. 1985, Deng et al. 2002). Potential impacts to larvae and juveniles in January through March would therefore not have been captured by the ITP Application's analysis.

4.4.2.3. Adult Upstream Migration and Holding

WS initiate their upstream spawning migration as early as December and as late as June, with peak migration between February and April (Schaffter 1997, Miller et al. 2020). The ITP Application (Sites Authority 2023) reviewed scientific literature and identified a low-flow threshold for upstream migration of 5,300 cfs based on Schaffter (1997), who observed upstream migrating WS stop and swim back downstream at those flows. CDFW reviewed Schaffter (1997) and did not find compelling evidence that these observations were related to streamflow or that they affected spawning success. Schaffter (1997) relies on detections from 59 radio-tagged WS, which represents a small sample size, in 1990 and 1991, two Critically Dry water years. More recent studies have used updated tracking technologies over longer time periods and different water year types, which are more representative of the variable hydrologic conditions that WS might experience (Miller et al. 2020). Miller et al. (2020) showed that WS move upstream during every month from December to June regardless of water year type and flow.

The ITP Application (Sites Authority 2023) used modeled USRDOM flows to evaluate the percentage of days by month (Dec–June) and water year type when streamflow in the Sacramento River at Colusa was below 5,300 cfs for the NAA and the Alt3B, NoSha, and NoShaOro operational scenarios. Results ranged from 0% –58%, with percentage of days below the flow threshold generally greater under the Alt3B, NoSha, and NoShaOro operational alternative compared to the NAA. The largest increase in the percentage of days per month below the 5,300 threshold was in December of Dry years, when the NoSha and NoShaOro alternatives showed an 8.6% and 8.1%, respectively, increase in days with flows below 5,300 cfs in the Sacramento River at Colusa.

Conclusions

Even with the limitations noted above, the flow analyses provided in the ITP Application (Sites Authority 2023) suggest that Project operations could result in effects to White Sturgeon related to changes in Sacramento River flow, particularly in spring months. These flow effects are further analyzed in Sections 4.4.3 (Delta Outflow and Recruitment) and 4.4.4.1 (Water Temperature in the Sacramento River Due to Changes in Flow).

4.4.3. Delta Outflow and Recruitment

Changes in Delta Outflow as a result of water diversions for the Project could reduce White Sturgeon productivity and survival.

4.4.3.1. Delta Outflow and Juvenile Recruitment Threshold

A strong relationship between Delta outflow in spring and summer and WS YOY recruitment has been established across multiple studies (e.g., Blackburn et al. 2019; Fish 2010; Rosenfield 2023). CDFW conducted piecewise regressions (R package *segmented*: Fasola et al. 2018) of WS year class strength as a function of mean March–July and April–May Delta outflow,[10] which strongly supported the relationship shown by previous studies. Models using March–July Delta outflow and April–May Delta outflow yielded equivalent fits (dAIC = 2.7); CDFW selected the March – July model because it better represents the full seasonal period during which YOY WS are likely to be migrating through the Delta.

[10] WS year class strength data from CDFW and Delta outflow data from DWR Dayflow (as cited in Sites Authority 2023).

The fitted model using March–July Delta outflow (Figure 4-117) found a significant relationship between March–July Delta outflow and WS year class strength when outflow was >30,639 cfs, but little or no WS YOY recruitment below this threshold.

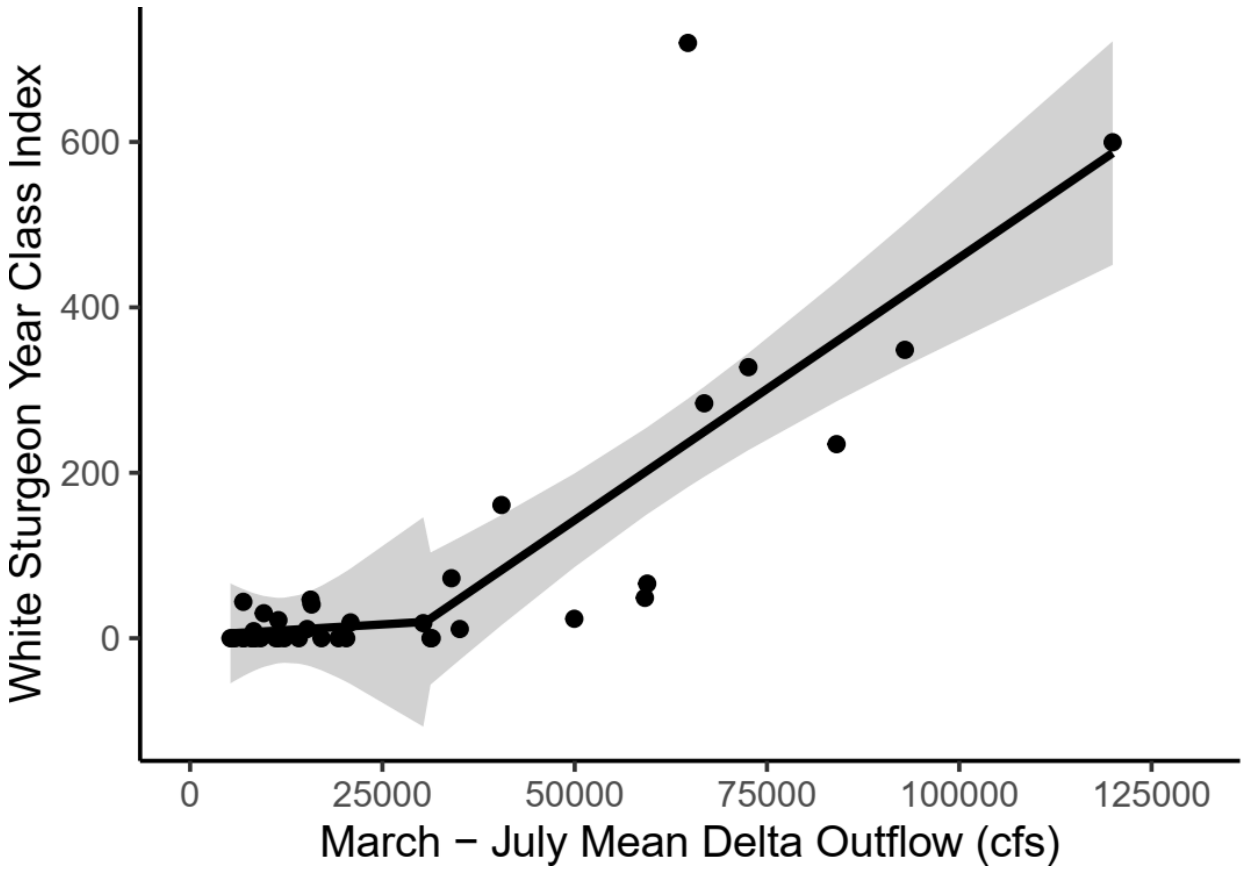


Figure 4-117. White Sturgeon year class strength plotted against mean March–July Delta Outflow (cfs). Black curve is a piecewise regression fit to the plotted data; shaded region shows the 95% confidence band around the model fit. Break point in the piecewise regression is at 30,639 cfs. Model coefficients and model fit information are in Table 4-39.

Table 4-39. Coefficients and standard errors of a piecewise regression of White Sturgeon year class strength as a function of mean March – July Delta outflow. The *segmented* package does not estimate standard error for the intercept of segment 2, nor 95% confidence limits for either intercept. Model df = 35; Model R^2 = 0.68.

Predictor	Est. Coefficient	Std. Error	95% CI
Segment 1 (Outflow < 30,639 cfs)	--	--	--
Intercept	2.91	44.15	N/A
Slope	5.5×10^{-4}	0.0032	(-0.0061, 0.0072)
Segment 2 (Outflow ≥ 30,639 cfs)	--	--	--
Intercept	-174.65	N/A	N/A
Slope	0.0058	0.0034	(0.0043, 0.0084)*
Breakpoint	30,638.7	12,906.1	(4,437.9, 56,839.5)*

* Significant at 95% confidence level.

Using output from Sites' CalSim II model for the NAA and the Alt3B, NoSha, and NoShaOro operational scenarios, CDFW analyzed the months and years from 1922–2003 that show average monthly Delta outflow greater than 30,639 cfs (Figure 4-118). Results generally showed little to no change among scenarios; however, February and March each showed a 2-year decrease in the number of years with flows above 30,639 cfs for the three Project scenarios compared to the NAA (representing 4–5% of the 82 year time series). Specifically, modeled Delta outflows were above 30,639 cfs in the NAA and below 30,639 cfs for the Alt3B, NoSha, and NoShaOro operational scenarios in February 1960 (Critical Water Year Type) and 1966 (Above Normal water year type) and March 1930 (Dry water year type) and 1991 (Critical water year type).

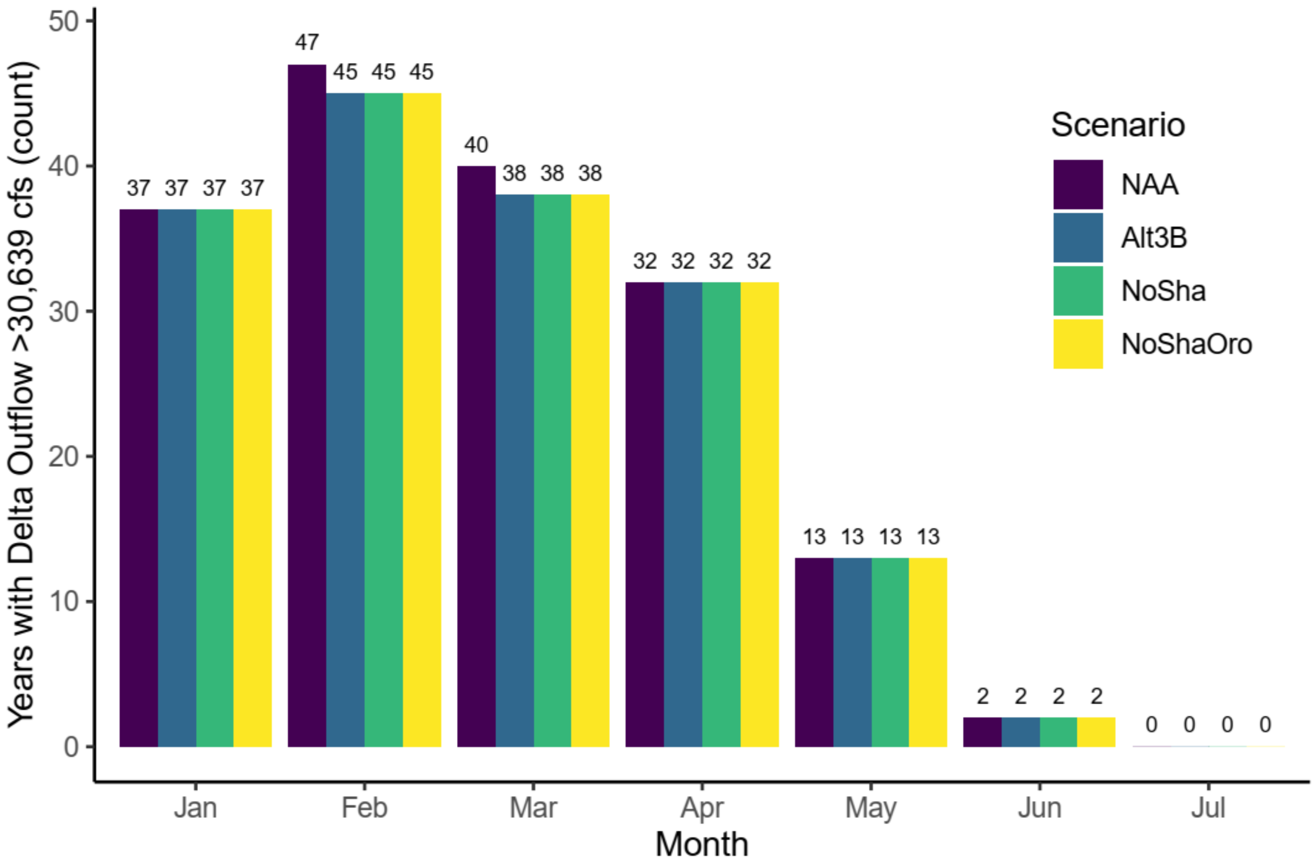


Figure 4-118. Number of years during the 82-year CalSim II simulation period in which Delta outflow was >30,639 cfs in each month from January – June under the NAA (purple), Alt3B (blue), NoSha (green) and NoShaOro (yellow). CalSim II data provided by Sites (2023).

While Project operations rarely caused simulated Delta outflow to drop below 30,639 cfs, this threshold only delineates the outflow below which WS year class strength is expected to be near zero. It may be possible for Project operations to reduce WS recruitment by decreasing Delta outflow when baseline (NAA) outflow is high enough to produce positive recruitment. To test how often and to what degree this occurs, CDFW substituted CalSim II-simulated Delta outflow, provided in the ITP Application (Sites Authority 2023), into the segmented regression to estimate the change in WS year class strength under the NAA and under Alt3B, NoSha and NoShaOro operational scenarios in each of the 82 simulated water years. Changes in year class strength index were mostly negative: reductions in year class strength were predicted in 58%, 67% and 62% of years under Alt3B, NoSha and NoShaOro, respectively. Changes were mostly small in magnitude (Figure 4-119, top); however, baseline year class strength for WS is most often near-zero, and small-magnitude changes resulted in somewhat larger percent changes, with reductions of more than 2% in at least 19 years under all three Project scenarios (23 years under Alt3B), >10% in three years under NoSha and NoShaOro (two years under Alt3B) and >20% in 1978 under all three Project scenarios (Figure 4-119, bottom).

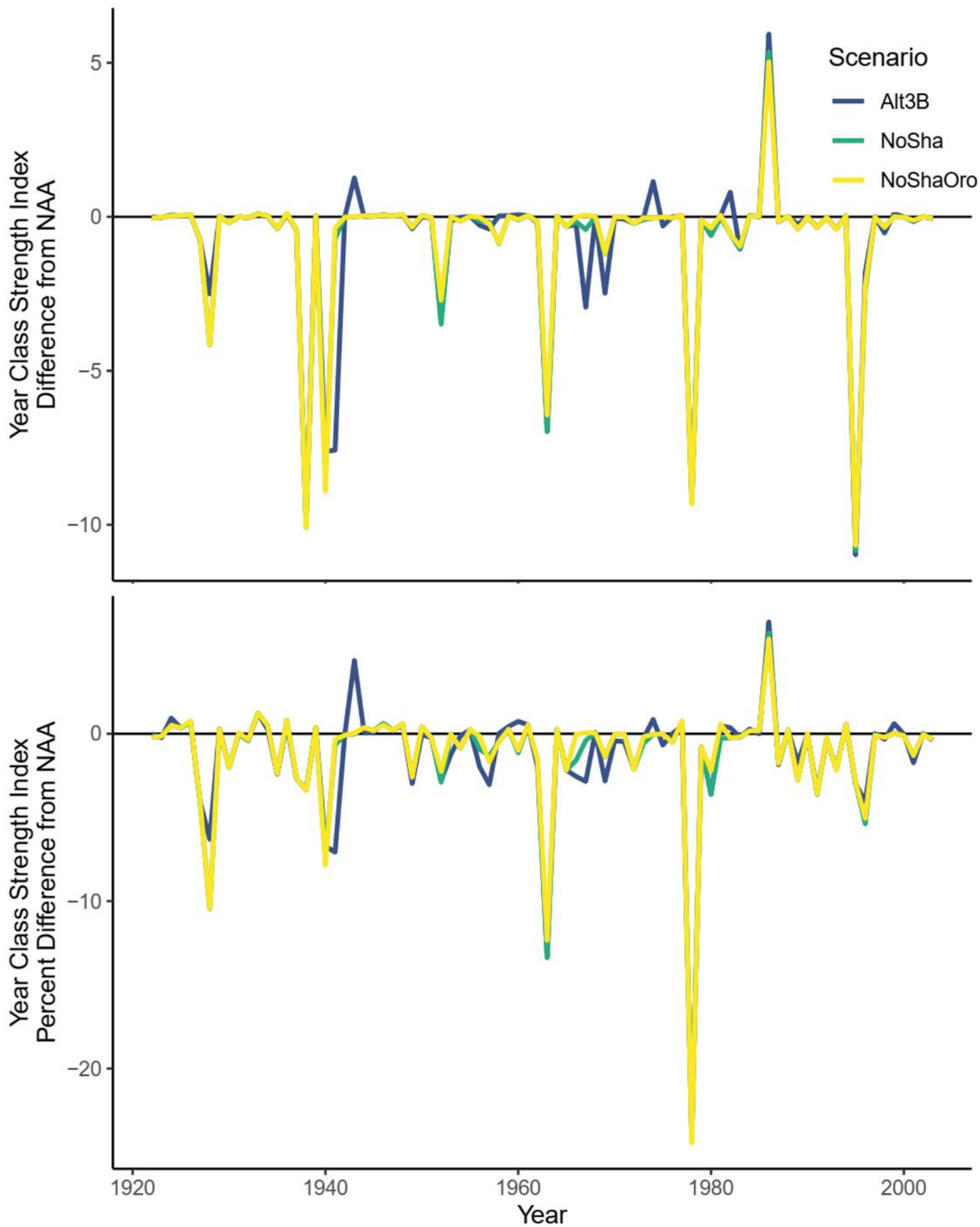


Figure 4-119. Predicted change (top) and percent change (bottom) in white sturgeon year class strength index under Alt3B (blue), NoSha (green) and NoShaOro (yellow), relative to the NAA, in each year of the 82-year CalSim II simulation. CalSim II data provided by Sites (2023).

4.4.3.2. Winter, Spring and Summer Delta Outflow Effects on Young-of-Year White Sturgeon Expected Catch-Per-Unit-Effort

As discussed previously, recruitment of juvenile WS has been shown to be strongly dependent on winter, spring and summer Delta outflow (Section 4.4.2**;** Fish 2010, SWRCB 2017, Blackburn et al. 2019). As a result, successful cohort formation is infrequent for WS, corresponding to years of high winter, spring and summer river flows into and out of the Delta (Moyle 2002, Fish 2010, Kohlhorst et al. 1991, Schaffter and Kohlhorst 1999, SWRCB 2017). An analysis by the SWRCB found that recruitment of juvenile WS only occurs when March–July average flows are above certain thresholds (SWRCB 2017), and that monthly average Delta outflows greater than 37,000 cfs during this period were sufficient to protect of WS recruitment. More recent studies have found a relationship between WS recruitment and Delta outflow greater than approximately 30,000 cfs (see Section 4.4.3.1**;** Rosenfield 2023).

The segmented model presented in Section 4.4.3.1 of this document describes a coarse relationship between average March–July Delta outflow and WS year class strength. To gain a more granular understanding of the effects of seasonal fluctuations in Delta outflow on both monthly and annual YOY WS abundance, CDFW developed a Bayesian model relating Delta outflow (Q_{out}) to expected catch-per-unit-effort (ECPUE) on a monthly timestep, between March and November. Details of model development and application are included in Appendix C. Because this model predicts the effects of the covariate on YOY WS catch probability and CPUE, and because the model includes spatial (*region*) and intra-annual, temporal (*survey* and *season*) random effects, model predictions presented without spatial or temporal separation (Appendix C) can be considered to represent year class strength (YCS), and the effects presented in Appendix C can be considered effects on YCS. To estimate the effects of Project operations on monthly ECPUE and year class strength of YOY WS, CDFW compared ECPUE based on simulated daily Q_{out} (DSM2 simulated data provided by Sites) for the NAA, Alt3B, and NoShaOro scenarios. Monthly and annual ECPUE predictions are presented below.

The model frequently predicted somewhat lower ECPUE under the Project than under the NAA in March through May, though to a lesser degree in critical water years, with the difference between the Project scenarios (Alt3B, NoSha, and NoShaOro) and the NAA converging on zero as the season progressed. Predicted average ECPUE continued to be lower into June, but differences between Project scenarios and the NAA remained near-zero in all months of wet water years. In contrast, predicted ECPUE was mostly higher under the Project in June–November of dryer water years, substantially so in July and August of dry and critical years (Figure 4-120).

While March through June differences in predicted ECPUE averaged less than 5%, there were 30 of the 2,976 simulated months in which predicted ECPUE was more than 10% lower. In March of

1966 (below normal) and November of 1977 (critical), predicted ECPUE was 17% and 21% lower, respectively, under Alt3B than under the NAA. There were 16 months in which ECPUE was more than 45% higher under Alt3B or NoSha than under the NAA, all in dry or critical water years. In August of 1924 (critical), predicted ECPUE was 69% higher under Alt3B than under the NAA; in August of 1929 (also critical), predicted ECPUE was 63% higher under NoSha than under the NAA. Trends under NoShaOro were qualitatively similar to those under Alt3B and NoSha, but both positive and negative differences were slightly smaller (Figure 4-120).

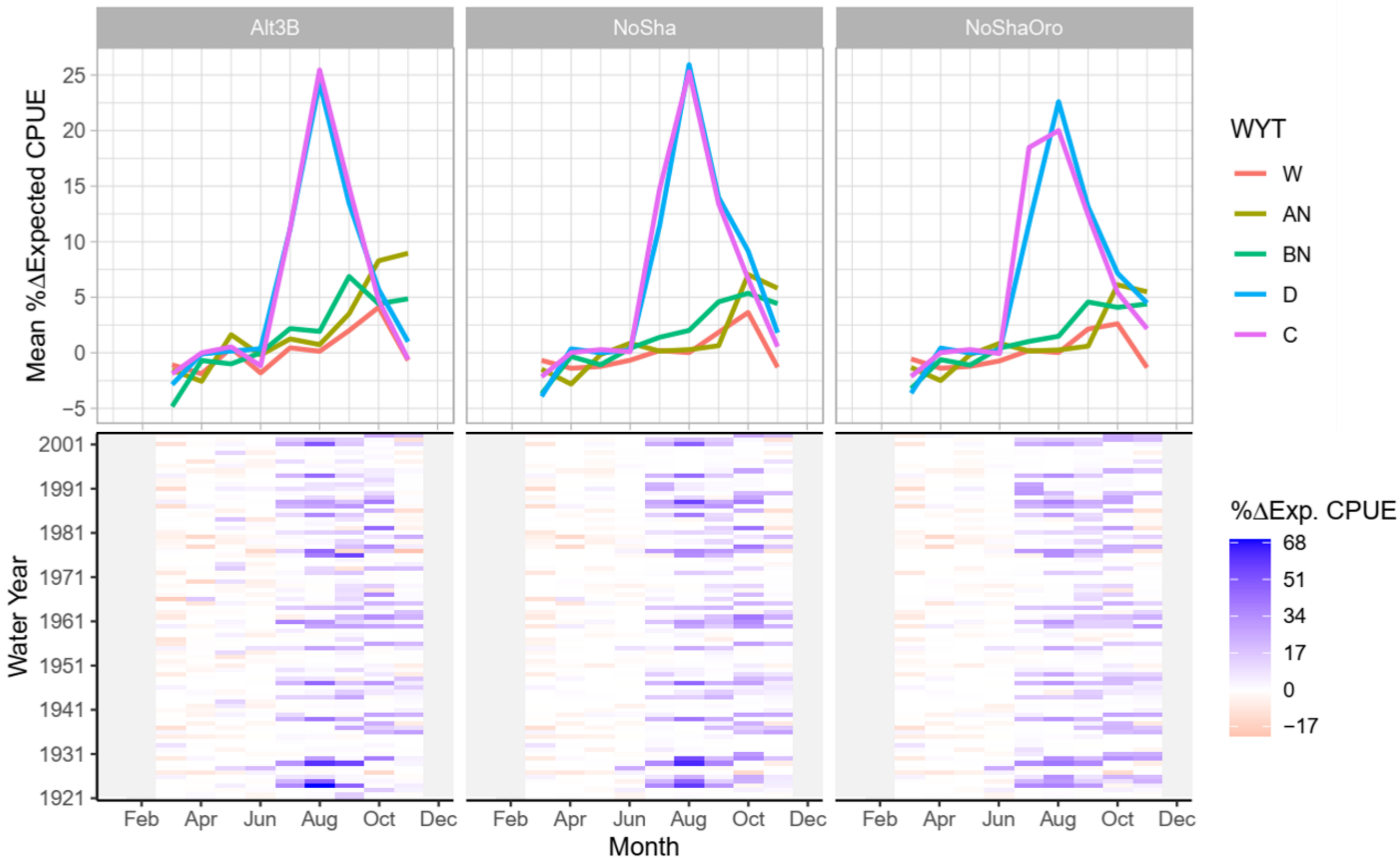


Figure 4-120. (Top) Mean percent difference in expected CPUE (ECPUE) of White Sturgeon young-of-year (YOY) in the 20-mm Survey and San Francisco Bay Study midwater and otter trawl surveys by month (x-axis) and water year type (water year types were classified using the Sacramento Valley Index and noted as Wet (W), Above Normal (AN), Below Normal (BN), Dry (D), and Critical (C)), as predicted when substituting DSM2-simulated Delta outflow under the NAA, Alt3B, NoSha and NoShaOro into Equation 2. (bottom) Percent difference in ECPUE of White Sturgeon YOY by month and water year (y-axis). Red shades indicate that ECPUE was lower under Project Alternatives than under the NAA, while blue shades indicate that ECPUE was higher under the Project Alternatives than under the NAA.

CDFW's Bayesian hurdle model predictions of YOY WS catch probability and CPUE as a function of outflow are consistent with those of the segmented regression model, with negative impacts of changes in Delta outflow on WS ECPUE concentrated in March–June, when Sites would be actively diverting. While the model often predicts higher expected ECPUE in July–September due to increased summer Delta outflow under the Project, the reduction in outflow in March–June, when YOY WS are hatching and migrating, could reduce YCS (and thus total catch) in a given water year, offsetting any benefit of increased summer outflow to YOY WS rearing. Given the well-established importance of winter-spring outflow on WS recruitment (Section 4.4.3.1; Blackburn et al. 2019; Fish 2010; Rosenfield 2023), the Bayesian hurdle model reinforces the importance to WS recruitment of winter-spring Delta outflow.

Conclusions

It is uncertain what ecological factors produce the 30,639 cfs winter-spring outflow threshold for WS recruitment, and the threshold itself may only be useful as a minimum outflow target. Analyses in the ITP Application (Sites Authority 2023) and by CDFW demonstrate that the Project could reduce WS recruitment in some years. Years with successful WS recruitment are increasingly rare. Due to the infrequency of wet and above-normal water-years recently, juvenile WS have only had successful recruitment in 4 of the last 23 years, contributing substantially to their steady population decline (Blackburn 2019). Further reducing Delta outflow during this critical time of year may result in small reductions in WS recruitment in most years, which cumulatively could impact WS population growth in the long term.

4.4.4. Water Temperature

Thermal stress is defined as any temperature change that significantly alters biological function and lowers the probability of survival of fish present (McCullough 1999). WS are most sensitive to temperature during spawning, egg incubation, and larval/juvenile stages (Counihan and Chapman 2018; Heublein et al. 2017; Wang et al. 1985; Webb et al. 1999), whereas adults can tolerate somewhat warmer temperatures outside of spawning periods if there is adequate food supply and water quality (Cech et al. 1984). Sub-lethal effects of increased water temperatures can also indirectly cause mortality, as fish are more susceptible to disease (Fryer et al. 1976; Fryer and Pflecher 1974; Hechinger et al. 2011; Myrick and Cech 2004), contaminants (Adelman and Smith 1972), and predation (Hechinger et al. 2011). Survival studies of WS eggs and larvae have found that survival declines steeply when temperatures exceed 68 °F (20 °C) (Boucher et al. 2014; Heublein et al. 2017; Wang et al. 1985 and 1987). Lower stream flows and warmer water temperatures can also reduce the spatial and temporal extent of rearing and migration habitat and functionally disconnect the migratory corridor, truncating migration and reducing life history and genetic diversity of populations (Munsch et al. 2019; Sturrock et al. 2019; Michel et al. 2021).

4.4.4.1. Water Temperature in the Sacramento River Due to Changes in Flow

The ITP Application (Sites Authority 2023) analyzed modeled water temperatures in the Sacramento River between Hamilton City and Knights Landing using the HEC-5Q model to determine the frequency and magnitude of exceeding one or more water temperature index values for each life stage and location. Modeled water temperatures were averaged by month and water year type for both the NAA and Alt3B, NoSha, and NoShaOro operational scenario. The ITP Application (Sites Authority 2023) considered a temperature change biologically significant when it met both of the following two criteria for a given month, as compared to the NAA: (1) the difference in frequency of exceedance was greater than 5%, and (2) the difference in average daily exceedance was greater than 0.5 °F. Because this approach uses a monthly time step to evaluate long-term average temperature changes, it may obscure potentially important changes in temperature that occur at a sub-monthly timestep or only during some water years (Rose et al. 2024). CDFW notes that a temperature spike exceeding the lethal limit of WS eggs or larvae need only last long enough to raise eggs or larvae to the lethal ambient temperature and keep it there until it expires, which can occur within hours (Wang et al. 1985), likely somewhat longer for larger WS.

CDFW further analyzed the output from HEC-5Q model used in the ITP Application (Sites Authority 2023) to understand the effects of Project operations on flow and temperature in Sacramento River. The HEC-5Q model files provided by Sites Authority were used to re-run temperature simulations for the NAA and the Alt3B, NoSha, and NoShaOro operational scenarios. CDFW made one update to the model files tochange the river water temperature output interval to six hours from one day to estimate daily maximum as well as average daily water temperatures.

Like the analysis in the ITP Application (Sites Authority 2023), this analysis considers a 0.5 °F change in temperature as biologically significant and compares the number of days the daily average temperature (from HEC-5Q) exceeded a biological or regulatory threshold (Table 4-40) at the following locations:

- Sacramento River at Hamilton City (RM 205)
- Sacramento River at Tisdale Weir (RM 119)
- Sacramento River at Knights Landing (RM 90)

CDFW used two criteria for analyzing temperature impacts to WS:

1. The Project increases or decreases temperature past a biological threshold.
2. The Project increases or decreases temperature by more than 0.5°F within a stressful range (i.e., modeled water temperature under the Project increases or decrease water temperature by 0.5 °F or more, AND water temperature exceeds a biological threshold).

Table 4-40. Temperature Criteria used to Compare Proposed Project to No Action Alternative (NAA), White Sturgeon

Location	Temperature (deg F)	Rationale/ Reference	Timing
Hamilton City	62.6 °F (16 °C) [A,1] 68 °F (20 °C) [A,3]	Spawning/Egg Survival[1,3] Larval Survival[1,3]	January–June
Hamilton City	66 °F (18.9 °C) [A,2]	Juvenile Rearing[2]	Year Round
Tisdale Weir	62.6 °F (16 °C) [A,1] 68 °F (20 °C) [A,3]	Spawning/Egg Survival[1,3] Larval Survival[1,3]	January–June
Tisdale Weir	66 °F (18.9 °C) [A,2]	Juvenile Rearing[2]	Year Round
Knights Landing	62.6 °F (16 °C) [A,1] 68 °F (20 °C) [A,3]	Spawning/Egg Survival[1,3] Larval Survival[1,3]	January–June
Knights Landing	66 °F (18.9 °C) [A,2]	Juvenile Rearing[2]	Year Round

[A] Criterion based on the daily average temperature; analysis uses daily averages

[1] Lower bounds of the stressful range based on Wang et al. (1985) and Hildebrand et al. (2016)

[2] Lower bounds of the stressful range based on Israel et al. (2009)

[3] Mortality threshold based on Wang et al. (1985)

CDFW compared the number of days meeting these criteria for Alt3B, NoSha, and NoShaOro operational scenarios to the NAA and summarized the results as the mean and maximum for each month and water year type (Appendix B2). Results of this analysis show mostly small average changes in the number of days the Project causes an exceedance related to the NAA, with Alt3B generally showing greater average increases in exceedances than NoSha and NoShaOro operational scenarios. The maximum changes in days between the NAA and the Alt3B operational scenario were found to be large (at times 100% of the month) and variable (see Appendix B2), suggesting very large differences in some years.

To further evaluate the temperature impacts of the Project, as was done in Section 4.1.2.1 for Chinook Salmon, CDFW compared the differences in exceedance days for each year and month. This additional analysis focused on changes in temperature at Tisdale, as this location is frequently temperature limited, water temperature at this location is affected by flow (Michel et al. 2021), and because CDFW's initial temperature analysis showed it as a location with large changes in temperature between the scenarios. Because there did not appear to be large differences in temperature between NoSha and NoShaOro operational scenarios, CDFW focused on the differences between the NAA and the Alt3b and NoSha operational scenarios.

CDFW compared the number of temperature exceedance days as well as the average flow for each month from for the years 2003–2022, the full time series in Sites' HEC-5Q model. Only the months from April–June are presented in Appendix B2, as January through March had no measurable difference between NAA and Alt3B, NoSha, and NoShaOro. Results for juvenile rearing can be found in Section 4.1.2.1 and Appendix B1, as they are the same threshold for stressful adult migration of Chinook Salmon (66 °F).

Results of CDFW's analysis showed large changes in flow and temperature in some months and years due to Project operations. For example, in June of Critical water year types, 7 of 12 (58%) years are predicted to have a biologically significant increase (defined as a 0.5 °F increase in >5% of days) in temperature within a temperature range that is stressful for WS under the Alt3B operational scenario. During those same years and months for Alt3B, 3 of 12 (25%) years are predicted to have a significant increase in the number of days exceeding 68°F (Table 4-41). The NoSha operational scenario saw fewer temperature impacts (Table 4-42), which suggests that these differences are due to exchanges between Sites and Shasta reservoirs and/or CVP operational flexibility.

Table 4-41. June flow (cfs) and temperature (°F) exceedances at **Tisdale** under Alternative 3B (Alt3B) for critically dry water year types for WS. Changes in days >5% are bolded in red (increase). Changes in flow >5% are bolded in red (decrease).

Water Year	June Average Flows (cfs) NAA	June Average Flows (cfs) Alt3B	Change in Days >62.5°F Alt3B	Days >62.5°F AND >0.5°F change	Change in Days >66°F Alt3B	Days >66°F AND >0.5°F change	Change in Days >68°F Alt3B	Change in Days >68°F AND >0.5°F change
1924	5,368	5,432	0	0	0	0	0	0
1929	6,190	6,132	0	**6**	0	**6**	**2**	**6**
1931	4,860	4,763	0	0	0	0	0	0
1933	5,706	5,722	0	0	0	0	0	0
1934	6,672	6,671	0	**2**	-1	**2**	0	**2**
1976	7,598	7,303	0	**30**	0	**30**	1	**19**
1977	8,311	**7,182**	0	**29**	0	**29**	**10**	**28**
1988	7,930	**6,918**	0	**28**	1	**24**	1	**21**
1990	7,989	7,876	0	0	0	0	0	0
1991	4,885	4,793	0	0	0	0	0	0
1992	6,293	**5,851**	0	**12**	0	**12**	0	**12**
1994	7,342	7,336	0	**4**	0	**4**	**2**	**4**

Table 4-42. June flow (cfs) and temperature (°F) exceedances at **Tisdale** under the No Shasta Exchange Alternative (NoSha) for critically dry water year types for White Sturgeon. Changes in days >5% are bolded in red (increase). Changes in flow >5% are bolded in red (decrease).

Water Year	June Average Flows (cfs) NAA	June Average Flows (cfs) NoSha	Change in Days >62.5°F under NoSha	Days >62.5°F AND >0.5°F change	Change in Days >66°F NoSha	Days >66°F AND >0.5°F change	Change in Days >68°F NoSha	Change in Days >68°F AND >0.5°F change
1924	5,368	5,396	0	0	0	0	0	0
1929	6,190	6,352	0	0	0	0	**-2**	0
1931	4,860	4,780	0	0	0	0	0	0
1933	5,706	5,721	0	0	0	0	0	0
1934	6,672	6,672	0	0	-1	0	0	0
1976	7,598	7,694	0	0	0	0	-1	0
1977	8,311	**7,788**	**0**	**5**	0	**5**	**4**	**5**
1988	7,930	7,950	0	0	0	0	0	0
1990	7,989	7,974	0	0	0	0	-1	0
1991	4,885	4,793	0	0	0	0	0	0
1992	6,293	6,307	0	0	0	0	0	0
1994	7,342	7,346	0	0	0	0	0	0

Conclusions

CDFW's temperature analysis found that, depending on exchanges with Shasta and Oroville reservoirs, the Project could result in significantly different flows and water temperatures in the Sacramento River during periods of WS spawning, egg incubation, and juvenile rearing and migration. Project operations have the potential to increase temperatures to stressful or lethal levels for WS from April through June, and these impacts are most frequent and largest in the Alt3B operational scenario.

CDFW's temperature analysis shows that temperature impacts would be greatest in the reach of the Sacramento River near Tisdale Weir and Wilkins Slough and could therefore impact WS upstream of the Feather River confluence most severely. Temperature impacts could occur in all water year types; however, temperature exceedances in spring months (April–June) would be more frequent in drier year types.

4.4.4.2. Water Temperature of Releases

The ITP Application (Sites Authority 2023) analyzed potential temperature-dependent effects on WS of releases to the Sacramento River at KLOG using the same reservoir and blending temperature models as for CHNWR and CHNSR. CDFW's concerns about the accuracy and utility of those models are described in Section 4.1.2.2. Due to considerable uncertainty around water temperature of releases, CDFW utilized a mass balance approach to assess the potential for Sites' releases to impact water temperatures in the Sacramento River.

CDFW's mass balance analysis demonstrated that releasing 1,000–4,000 cfs at KLOG has the potential to increase Sacramento River water temperatures past biological thresholds for Chinook Salmon from April–June and August–October. Because the temperature range of biological thresholds for WS (62.5–68 °F) is within the range analyzed for CHNWR and CHNSR (60–70 °F), and because WS are likely to be present in the Sacramento River between April and June, releasing 1,000–4,000 cfs at KLOG has the potential to increase Sacramento River water temperatures past a biological threshold for WS between April and June (Figure 4-58).

Conclusions

Given: (1) there is considerable uncertainty around water temperatures of Project releases to the Sacramento River at KLOG; (2) it is not possible for temperature models for Sites Reservoir to be calibrated and validated prior to construction and operation of the Project; (3) water temperatures in the Sacramento River near the discharge location frequently approach or exceed biological thresholds for WS; (4) CDFW's mass balance analysis showed that releasing 1,000–4,000 cfs at KLOG could increase Sacramento River water temperatures past a biological threshold for WS; (5) adult and juvenile WS are expected to be in the Sacramento River near KLOG during the time periods of Project releases, and (6) increasing water temperatures above biological thresholds during critical periods of fish presence is known to harm or kill WS, the proposed releases from Sites Reservoir to the Sacramento River have the potential to take WS.

4.4.5. Adult Upstream Passage at Freemont and Sutter Bypass Weirs

The ITP Application (Sites Authority 2023) analyzed potential impacts of the Project on adult WS upstream passage at weirs in the Yolo and Sutter bypasses by comparing the number of days from 2009–2018 that Green Sturgeon passage criteria are met for the NAA and the Alt3B scenarios based on flows estimated using their Daily Divertible Tool. Results showed small changes in passage days in some years, ranging from 1 more day to 5 fewer days of passage for Alt3B compared to the NAA.

CDFW analyzed changes in weir overtopping and passage for CHNWR and CHNSR in Section 4.1.6.2, finding that decreases in weir overtopping under operations of the Project would likely reduce the number of fish migrating through the bypasses and therefore the number of fish that could be stranded behind weirs. This finding also applies to adult WS.

Conclusions

Project operations are not expected to result in substantial changes in adult stranding behind Fremont Weir or weirs in the Sutter Bypass. Project operations are likely to decrease weir overtopping and increase the rate of flow reductions following overtopping events, thus decreasing the number of WS that may migrate up the bypasses and require upstream passage at the weirs.

4.4.6. Effects on White Sturgeon in the Feather River

Telemetry data and observed aggregations of gravid WS have shown that WS may spawn in the Yuba and Bear Rivers, and have been observed migrating through the lower Feather River (Heublein et al. 2017). Green Sturgeon spawning has been documented in the Feather River below the passage barrier at Sunset Pumps (Seesholtz et al. 2015), but there have not been any confirmed reports of WS spawning in the Feather River (J. Kelly, pers. comm.) As in the Sacramento River, spawning migrations through the lower Feather River are likely triggered by flow pulses in winter and spring, with fewer adults spawning in drier years (Schaffter 1997; Heublein et al. 2017). Seasonal timing of juvenile emigration in the Yuba and Bear Rivers and through the lower Feather River likely corresponds to that in the Sacramento River (Schaffter 1997; Heublein et al. 2017) and likely coincides with large flow events between January and June.

4.4.6.1. Water Temperature in the Feather River

The ITP Application (Sites Authority 2023) used two methods to evaluate effects of the Project on Feather River water temperatures under the NAA and the Alt3B, NoSha, NoShaOro operational scenarios: (1) Physical Model Output Characterization using the Reclamation Temperature Model and (2) Water Temperature Index Value Exceedance Analysis. The ITP Application (Sites Authority 2023) used the Reclamation Temperature Model to evaluate modeled water temperatures on a monthly timestep at three locations on the Feather River—the low-flow channel below the Fish Barrier Dam, the high-flow channel at Gridley, and the mouth of the Feather River. The ITP Application (Sites Authority 2023) analyzed the frequency and magnitude of exceeding one or more water temperature index values (Table 4-40) for each WS life stage and location. Modeled water temperatures were averaged by month and water year type for the NAA and the Alt3B, NoSha, and NoShaOro operational scenarios. Sites considered a temperature change biologically significant if it met both of the following two criteria in a given month, as compared to the NAA: (1) the difference in frequency of exceedance was greater than 5%, and (2) the difference in average daily exceedance per month was greater than 0.5 °F. The limitations of the monthly analysis discussed in Section 4.4.4, "Water Temperature in the Sacramento River Due to Changes in Flow", also apply to the Feather River analysis: evaluating monthly mean changes in temperature cannot capture biologically significant temperature changes that may occur on the order of days or hours.

While neither criterion for a biologically significant temperature change caused by the Project (as defined by Sites) was met in most months and water year types, the ITP Application (Sites Authority 2023) showed that both criteria were met for the 68°F embryo hatching upper limit under the NoSha scenario in June of Dry water years below Thermalito Afterbay Outlet. A single criterion, either a difference ≥0.5 °F in mean degrees per month above the index values between Project scenarios and the NAA, or a difference of >5% of months with temperatures above index values between Project scenarios and the NAA, was infrequently met for embryonic development or juvenile rearing and emigration under each Project scenario at all three locations on the Feather River. This mostly occurred in June of Dry water years for embryonic development and in June and September of dryer water years for juvenile rearing and emigration. Fortunately, few WS spawn as late in the year as June; however, juvenile rearing and emigration does occur in June (Verhille et al. 2014) and may thus be affected by temperature changes in the Feather River caused by the Project. Finally, while months when mean temperatures exceeded index values due to Project operations were rare in the modeled scenarios, sub-monthly temperature variation was not visible in Sites' analysis. Monthly time-step models can average out Project effects and difference between the scenarios (e.g., Rose et al. 2024); therefore, results should be interpreted with some caution.

4.4.6.2. Flow in the Feather River

The ITP Application (Sites Authority 2023) compared modeled mean monthly flows from CalSim II in the Feather River at the Thermalito Afterbay Outlet and at the Feather River's confluence with the Sacramento River under the NAA and the Alt3B, NoSha and NoShaOro operational scenarios. Differences in monthly flow between the three Project scenarios and at both locations were generally small from January through May, when adult WS typically migrate upstream and spawn, and when juvenile WS emigrate; however, CalSim II showed substantial increases in flow (>5%) at the Themalito Afterbay Outlet under Alt3B and NoSha in January of Above Normal water years.

Because some spawning and emigration also occurs in June (Verhille et al. 2014), CDFW also compared modeled monthly flows at both locations in June. June streamflow in Below Normal, Dry and Critical water years were on average >9% lower under Alt3B, with changes at the Thermalito Afterbay Outlet and the confluence (respectively) of -14% and -13% in Dry water years, -11.4% and -9.4% in Below Normal water years and -9.2% and -9.4% in Critical water years. Flows at both locations were substantially increased in August, September and October of several water year types under Alt3B, and in December of Above Normal water years (~7%) under all three Project scenarios, however no WS life stage is likely to be present in the Feather River in August – October.

The ITP Application (Sites Authority 2023) discusses the boulder weir at Sunset Pumps as the primary barrier to upstream migration of adult Green Sturgeon. The weir entirely prevents upstream migration of Green Sturgeon at flows below 6,000 cfs, which occur 82% of the time under the NAA and under all three Project operational scenarios. Sites suggests, reasonably, that the weir may similarly prevent upstream migration of adult WS, restricting spawning to wetter years. CalSim II indicated no differences in the frequency of monthly average flows below 6,000 cfs between the NAA and any of the Project scenarios. While the monthly analysis in the ITP Application (Sites Authority 2023) used the best available tool, CalSim II, effects of sub-monthly changes in flow due to Project operations are unknown and much uncertainty remains.

Conclusions

Monthly average Project effects on water temperature and flow in the Feather River are small in most months and water year types. Based on current scientific knowledge of the species, WS spawning on the Feather River does not occur, or only occurs under very high flows (Heublein et al. 2017). It is possible that WS adults and juveniles migrating into and out of the Yuba and Bear rivers could be present in the lower Feather River, but they are unlikely to be present in June of Dry and Critical water year types.

Modeling impacts at a monthly time step may not capture shorter-term changes in temperature and flow that may affect WS, and monthly averages can obscure impacts by averaging them out (Rose et al. 2024). Additional flow and temperature modeling at a shorter time scale would be valuable if WS are found to spawn in the Feather River.

4.4.7. South Delta Entrainment – Salvage Density Method

Changes in Exports at the State and Federal export facilities as a result of Project operations could result in increased entrainment of larval and juvenile White Sturgeon, leading harm or mortality.

The ITP Application (Sites Authority 2023) used the Salvage-Density Method to estimate the differences in salvage at the CVP and SWP export facilities under the NAA versus under Project operational scenarios (Alt3B, NoSha, and NoShaOro), based on differences in south Delta exports and historical salvage or loss density of fish. The Salvage-Density Method relies on modeled monthly exports from CalSim II and assumes that changes in salvage and loss occur in proportion to changes in the amount of water exported from the south Delta by CVP and SWP.

Results presented in the ITP Application (Sites Authority 2023) showed increases in WS entrainment of 1%–20% in all water year types and months, with the greatest increases in Below Normal and Above Normal water years. Despite some large percent changes in salvage, absolute changes in WS entrainment were small (less than one fish) in all months and water year types.

The Salvage-Density Method provides an entrainment index that reflects export pumping and seasonal abundance of juvenile WS based on historical salvage data. The method does not consider changes in juvenile production, movement, and survival due to flow dynamics. Monitoring has found that catch of yearling juvenile WS in the Delta can be 10 times higher in years following wet water years (Sites ITP Application 2023); therefore, the previous water year type may be as important, or more important for predicting salvage of WS than the current water year type.

Salvage efficiency of WS is also a consideration. Primary channel louver efficiency at the CVP for juvenile WS is estimated at 32.2% (Karp and Bridges 2015). Since CVP louvers are less effective at bringing juvenile WS into the salvage facilities to be counted and recorded, it is possible that salvage and loss of WS at the south Delta export facilities are underestimated.

Conclusions

The Salvage-Density analysis suggests the Project will result in very small changes (less than 1 fish) in salvage of WS, but that the percent change in salvage may be as high as 20%. There is some evidence that WS capture and data collection in the salvage facilities may be less efficient than for other fish species; if this is true, changes in WS salvage due to Project operations may be larger than those estimated here. Based on current knowledge and modeling, CDFW expects minimal changes to WS salvage at the CVP and SWP export facilities as a result of the Project operations.

5. MINIMIZATION OF TAKE AND IMPACTS OF THE TAKING ON COVERED SPECIES

This section describes how Conditions of Approval included in the ITP minimize take and impacts of the taking associated with the Project.

5.1. Winter-run and Spring-run Chinook Salmon and White Sturgeon – Near-field Effects

5.1.1. Condition of Approval 9.1 – No Diversion Without Fish Screens

Positive-barrier fish screens protect fish from entrainment at the Red Bluff and Hamilton City Project diversion locations. Few, if any, juvenile salmonids are small enough to be entrained through the fish screens, though larval WS smaller than 30 mm TL may be at risk of entrainment through the Hamilton City fish screen (HCFS). Neither smelt species is at risk of entrainment due to geographic separation from Red Bluff and Hamilton City. Maintenance activities at either fish screen may occasionally necessitate that one or more fish screen panels be temporarily removed, potentially leading to entrainment of fish of all sizes into pumping and conveyance facilities. Condition of Approval 9.1 avoids and minimizes take of CHNWR, CHNSR and WS from entrainment into the Red Bluff and Hamilton City pumping and conveyance facilities by requiring that fish screen panels be installed, maintained, and fully operational during Project-related diversions.

5.1.2. Condition of Approval 9.2 – Velocity Requirements at Red Bluff Pumping Plant and Hamilton City Pump Station

Maintenance of screening criteria presented in CDFG (2000) will minimize potential take of juvenile salmonids and WS from contact with or impingement on the RBFS and HCFS and will minimize potential take of larval WS smaller than 30 mm TL by entrainment through the HCFS. Previous hydraulic testing at the Red Bluff Fish Screen (RBFS and HCFS has not been sufficient to confirm that the fish screens meet and maintain the protective V_a and V_s criteria established in CDFG (2000) such that the approach velocity (V_a) does not exceed 0.33 fps, and V_a does not exceed half the sweeping velocity (V_s). Condition of Approval 9.2 requires Sites Authority to conduct full-screen, high-resolution, comprehensive hydraulic testing of both RBFS and HCFS on a regular schedule, and to adjust fish screen tuning panels as necessary to minimize V_a and maximize uniformity of V_a across both fish screens.

Several important lessons from the 2017 hydraulic testing of RBFS (USBR 2018) are incorporated into Conditions of Approval 9.2.1–9.2.7 to minimize take of CHNWR, CHNSR, and WS at both RBFS and HCFS:

1) Hydraulic testing of the entire RBFS at a high spatial resolution made it possible to identify both local V_a hotspots and larger-scale trends in V_a and V_s across the length and height of the screen. Identifying these features is necessary to inform tuning baffle adjustment and screen maintenance for optimal screen performance and Va uniformity. Testing a single point at the center of each screen panel cannot adequately characterize spatial variation in V_a and V_s on a large fish screen; even testing at three depths (as suggested by NMFS, 2006) may not be adequate.

2) Even under optimal conditions, V_a and $\frac{V_a}{V_s}$ can locally exceed fish screen design specifications (i.e., hotspots happen).

3) Adjusting tuning baffles can reduce V_a hotspots and increase V_a uniformity across a large fish screen.

4) V_a and V_s at a single point can vary over time, even when diversion and river conditions are relatively constant; thus, testing should be performed at least twice per testing session (see also NMFS 2006). Two further lessons can be drawn from the spatial and temporal variation in V_a observed by NMFS (2006) and CH2M Hill (2008) at HCFS under high and low diversion rates, respectively: spatial variation in V_a depends on the diversion rate and the depth and the horizontal location on the screen, and temporal variation at any location may be high.

Sites Authority will perform hydraulic testing at RBFS and HCFS to reflect these four considerations. These measures will demonstrate that V_a and V_s conform to CDFW standards (CDFW 2000) and will ensure optimal screen performance, thus avoiding take of juvenile CHNWR and CHNSR from impingement and ensuring that impacts of the taking are fully minimized. Specified approach and sweeping velocities will also minimize take of larval and juvenile WS through reduced entrainment and impingement at the fish screens.

5.1.3. Condition of Approval 9.3 – Disinfect Equipment Prior to Entry into Watercourses

To prevent the spread of aquatic invasive species and diseases, Condition of Approval 9.3 requires that gear and equipment, including but not limited to boots, waders, hand tools, and nets, must be decontaminated prior to entry into a watercourse. This condition protects CHNWR, CHNSR and WS near to and downstream of Project fish screens from invasive species and biological contaminants that may otherwise be introduced to the water during monitoring or fish screen maintenance activities, thereby avoiding and minimizing potential Project-related impacts on these species.

5.1.4. Condition of Approval 9.4 – Maximum Annual Diversions

The Project will not divert more than a maximum annual volume of 986 TAF. Condition of Approval 9.4 limits the total volume of water the Project may remove from the Sacramento River annually, which provides a level of protection for water quality and habitat for all Covered Species in the Sacramento River and Delta. This condition also provides a backstop that may, at times, limit diversion rates at the Red Bluff and Hamilton City diversion locations, reducing the risks to CHNWR, CHNSR, and WS associated with exposure to the Red Bluff and Hamilton City fish screens.

5.1.5. Conditions of Approval 9.5 – Red Bluff Pumping Plant Maximum Diversion Rate

The maximum instantaneous Project diversion rate at the Red Bluff Pumping Plant is 2,120 cfs. Condition of Approval 9.5 protects Sacramento River flow for all five Covered Species and specifically limits the approach velocity at the Red Bluff fish screen, which avoids and minimizes take of juvenile CHNWR and CHNSR due to entrainment and impingement associated with Project diversions at Red Bluff Pumping Plant.

5.1.6. Condition of Approval 9.6 – Hamilton City Pump Station Maximum Diversion Rate

The maximum instantaneous Project diversion rate at the Hamilton City Pump Station is 2,070 cfs. Condition of Approval 9.6 protects Sacramento River flow for all five Covered Species and specifically limits the approach velocity at the Hamilton City fish screen, which avoids and minimizes take of juvenile CHNWR and CHNSR and larval WS from entrainment and impingement associated with Project diversions at the Hamilton City Pump Station.

5.1.7. Condition of Approval 9.14 – Flow-Dependent Diversion

The Project will operate to Flow-Dependent Diversion (FDD) criteria, which scale diversions based on how much water is in the river at the diversion location. These criteria limit the proportion of river flow that may be diverted for the Project during lower flows, when CHNWR, CHNSR, and WS are present and at higher risk of take, while allowing maximum diversions when total river flows are high at the diversion site and risk is lower.

The upper Sacramento River, where the Project diversion facilities (RBPP and HCPS) are located, often experiences brief periods of very high pulse flows. Diversion criteria in the ITP Application (Sites Authority 2023) would lead to maximum capacity diversions during periods of relatively low flows (<6,000 cfs) at the diversion locations while preventing diversions from occurring during some periods of very high flows (>30,000 cfs). Those proposed diversion criteria, which are not optimized for the diversion locations, result in high risk of near-field impacts to CHNWR, CHNSR, and WS that may be present near the diversion facilities.

The goal of Flow Dependent Diversion (FDD) is to maintain Project objectives while scaling diversions to flow in the river, with smaller diversions during low flows and larger diversions during high flows. FDD sets a minimum flow threshold at each diversion location, and the allowable diversion rate increases gradually as a function of in-stream flow. This concept limits the proportion of river that may be diverted and is more conservative at lower flows, when diversions are more impactful to aquatic species.

FDD criteria were developed through an iterative process that sought to best minimize the impacts of diversions to CHNWR, CHNSR, and WS during periods of low Sacramento River flows while maintaining the Project's ability to maximize water diversions during higher flows when impacts are smaller. CDFW derived equations to calculate the appropriately protective diversion rates as a function of in-stream flow by finding the second order polynomial equation that went through the targeted minimum and maximum flow criteria under each diversion scenario. CDFW then used DRAT to develop daily flow hydrographs at different locations on the Sacramento River to evaluate how different FDD criteria affected diversions and analyze and compare the impacts of those diversions on CHNWR and CHNSR screen exposure and access to floodplain rearing habitat.

The RBPP maximum allowable diversion rate tables in ITP Condition of Approval 9.14.1 were derived from Equation 5-1 (January–February), Equation 5-2 (March–June and September–December). The FDD criteria in Equation 5-2 are more protective during peak migration of CHNWR and CHNSR near Red Bluff, and more relaxed during January and February when fewer fish are expected to be present. The HCPS maximum allowable diversion rate table in ITP Condition of Approval and 9.14.2 was derived from Equation 5-3 and applies to the full September–June Project diversion window.

Equation 5-1. Flow Dependent Diversion at Red Bluff Pumping Plant (Jan. 1 to Feb. 29)

$$Maximum\ Diversion\ (cfs) = \frac{BND^2}{67{,}200} - \frac{BND}{15.6} + 80$$

Equation 5-2. Flow Dependent Diversion at Red Bluff Pumping Plant (March 1 to June 14 and Sept. 1 to Dec. 31)

$$Maximum\ Diversion\ (cfs) = \frac{BND^2}{104{,}600} - \frac{BND}{23} - 44$$

Equation 5-3. Flow Dependent Diversion at Hamilton City Pump Station (Sept. 1 to June 14)

$$Maximum\ Diversion\ (cfs) = \frac{HMC^2}{241{,}000} - \frac{HMC}{400} - 243$$

where “BND” is the real-time CDEC reported flow in cfs at Bend Bridge (station BND). “HMC” is the real-time CDEC reported flow in cfs at Hamilton City (station HMC), plus any existing diversions because the HMC gauge is downstream of the diversion location. In other words, the HMC flows in the tables assume no existing diversions are occurring. When diversions are occurring, the diversion rate at HCPS should be added to the HMC gauge to obtain an accurate estimate of flow at HMC.

For implementation in the ITP Conditions of Approval, CDFW rounded river flows to the nearest 100 cfs and diversion rate to the nearest 10 cfs to create convenient benchmarks with more realistic precision for operators. Minimum bypass requirements for each table were established to minimize the impacts of diversions to CHNWR, CHSR, and WS during periods of lower flows in the Sacramento River. The FDD criteria at Hamilton City begin at a higher bypass flow (10,500 cfs), but they increase to full diversions at a steeper rate. This protects juvenile CHNSR from Antelope, Mill, and Deer creeks, as well as the tributaries upstream of Red Bluff, if they are migrating at lower flows, as well as the Project’s ability to divert when Sacramento River flows are higher.

Minimum bypass flows for FDD criteria include:

- 4,800 cfs at BND from January 1 through February 29;
- 6,300 cfs at BND from September 1 through December 31, and March 1 through June 14; and
- 10,500 cfs at HMC from September 1 through June 14.

Sections 5.1.7.1 through 5.1.7.3, below, demonstrate the effectiveness of these FDD criteria at reducing near-field impacts of Project operations on CHNWR and CHNSR individuals, and Section

5.2.4 demonstrates the effectiveness of FDD at minimizing impacts of Project diversions on floodplain inundation in the Sutter and Yolo bypasses. In addition to these quantifiable effects, CDFW expects that implementation of FDD will also reduce impacts to listed species due to maintenance of a more natural hydrograph (see Section 5.2.4), including the indirect effects of diversions on survival, habitat quality, habitat connectivity, food production, and ecological cues.

Minimization of Fish Screen Exposure with Flow-Dependent Diversion

Water diversion through fish screens locally increases fish densities, which can lead to increased predation risk to CHNWR, CHNSR, and WS. High diversion rates can also cause small fish to be impinged on fish screens, which is often fatal. CDFW's analyses in Sections 4.1.1 and 4.2.1 demonstrate that Project diversions would increase the exposure of juvenile CHNWR, CHNSR, and WS to the fish screens at Red Bluff and Hamilton City, which may result in injury or mortality. Fish screen exposure is likely proportional to the fraction of river flow diverted. Under Alt3B, the fraction of flow diverted could be as high as 55% and 50% at Red Bluff and Hamilton City, respectively, during periods of peak CHNWR and CHNSR outmigration (Section 4.1.1). FDD, required by Condition of Approval 9.14, would substantially reduce this fraction, minimizing take of CHNWR and CHNSR, and likely also WS (although this cannot be quantified), due to fish screen exposure.

5.1.7.1. Flow-Dependent Diversion – Juvenile CHNWR Screen Exposure

In a 15-year (2004–2019) simulation combining DRAT with actual USFWS Red Bluff RST daily passage data (see section 4.1.1.1), Alt3B increased total CHNWR exposure to the RBFS by nearly 150% and exposure to the HCFS by 15.5% over the NAA. The same analysis conducted assuming FDD reduced these differences to 37.6% and 4.2%, respectively, compared to the NAA (Table 5-1, Figures 5-1 and 5-2).

Table 5-1. Total winter-run Chinook Salmon screen exposures (number of fish) at Red Bluff (top) and Hamilton City (bottom) under the No Action Alternative (NAA), Alternate Scenario 3b (Alt3B), and Flow Dependent Diversion (FDD) and percent difference between operational scenarios and the NAA during a 15-year simulation based on DRAT and actual USFWS Red Bluff rotary screw trap passage data.

Table 5-1a. Red Bluff

Alternative	Total Exposures in 15 Years	% Diff from NAA
NAA	761,491	--
Alt3B	1,901,520	149.7
FDD	1,097,198	37.6

Table 5-1b. Hamilton City

Alternative	Total Exposures in 15 Years	% Diff from NAA
NAA	1,066,445	--
Alt3B	1,232,075	15.5
FDD	1,110,838	4.2

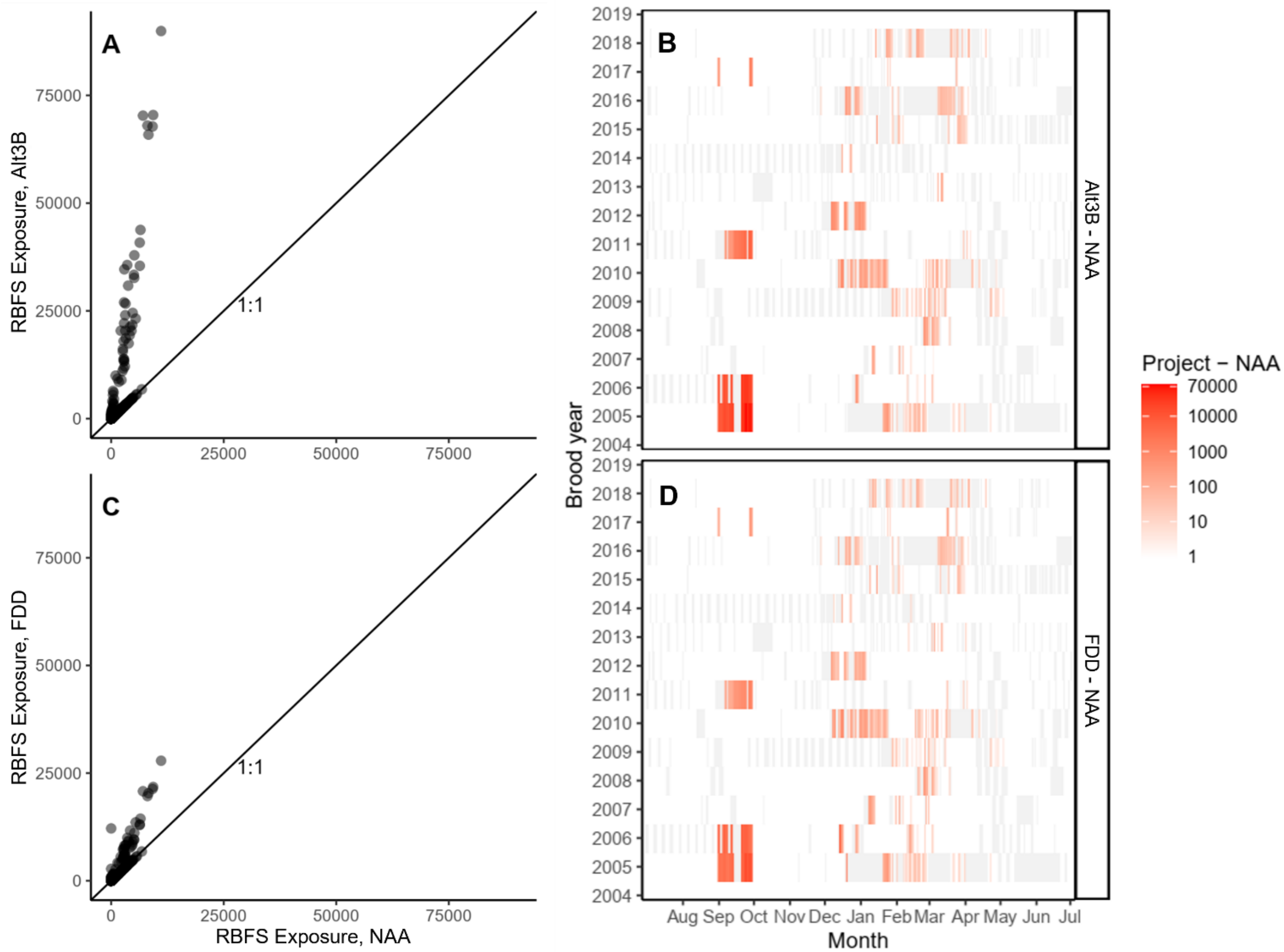


Figure 5-1. (A) Winter-run Chinook Salmon (CHNWR) exposures to the Red Bluff Fish Screen (RBFS) under Alt3B (y-axis) versus the No Action Alternative (NAA; x-axis) during the 15-year simulation. (B) Difference in CHNWR screen exposures at the RBFS between the Alt3B and the NAA by month (x-axis) and water year (y-axis). (C) CHNWR screen exposures at the RBFS under Flow Dependent Diversion (FDD) versus the NAA. (D) Difference in CHNWR screen exposures at the RBFS between FDD and the NAA by month and water year.

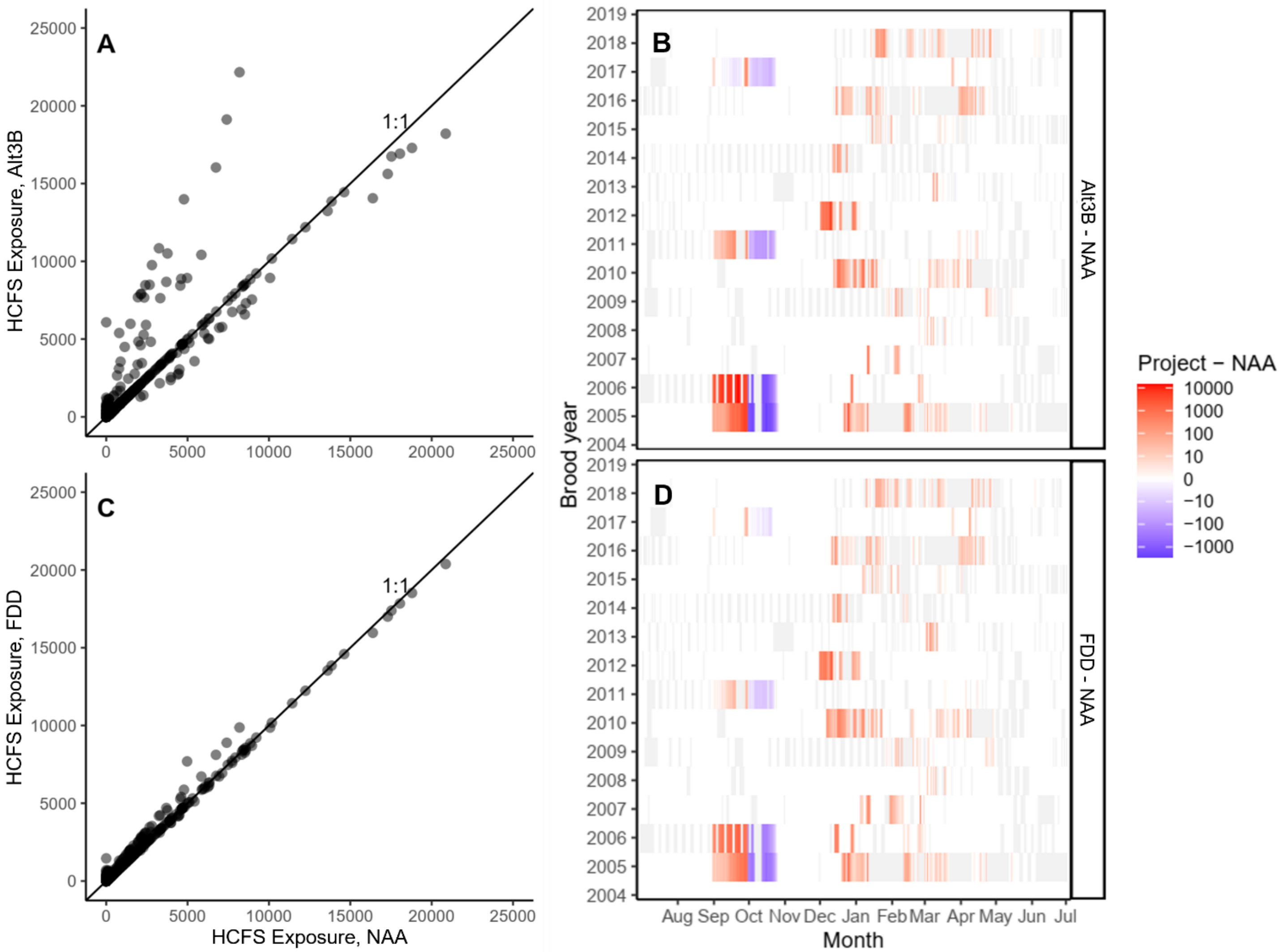


Figure 5-2. (A) Winter-run Chinook Salmon (CHNWR) exposures to the Hamilton City fish screen (HCFS) under Alt3B (y-axis) versus the No Action Alternative (NAA; x-axis) during the 15-year simulation. (B) Difference in CHNWR screen exposures at the HCFS between Alt3B and NAA by month (x-axis) and water year (y-axis). (C) CHNWR screen exposures at the HCFS under Flow Dependent Diversion (FDD) versus the NAA. (D) Difference in CHNWR screen exposures at the HCFS between FDD and the NAA by month and water year.

5.1.7.2. Flow-Dependent Diversion - Juvenile CHNSR Screen Exposure

In the 15-year screen exposure simulation, FDD was not as effective at reducing CHNSR screen exposure as it was at reducing CHNWR screen exposure. Exposure of CHNSR to the RBFS was 291.4% greater under Alt3B than under the NAA, compared to a 269.0% increase over the NAA under FDD. Exposure of CHNSR to the HCFS was 46.5% greater under the Project than under the NAA, compared to a 39.2% increase under FDD (Tables 5-2 and 5-3, Figures 5-3 and 5-4).

Table 5-2. Total spring-run Chinook Salmon screen exposures (number of fish) at Red Bluff under the No Action Alternative (NAA), Alternate Scenario 3B (Alt3B), and Flow Dependent Diversion (FDD) and percent difference between Project and the NAA during a 15-year simulation based on Diversion Routing Analysis Tool and real USFWS Red Bluff rotary screw trap passage data.

Alternative	Total Exposures in 15 Years	% Diff from NAA
NAA	74,523	--
Alt3B	291,712	291.4
FDD	274,963	269.0

Table 5-3. Total spring-run Chinook Salmon screen exposures (number of fish) at Hamilton City under the No Action Alternative (NAA), Alternate Scenario 3B (Alt3B), and Flow Dependent Diversion (FDD) and percent difference between Project and the NAA during a 15-year simulation based on Diversion Routing Analysis Tool (DRAT) and real USFWS Red Bluff rotary screw trap passage data.

Alternative	Total Exposures in 15 Years	% Diff from NAA
NAA	231,462	--
Alt3B	339,102	46.5
FDD	322,276	39.2

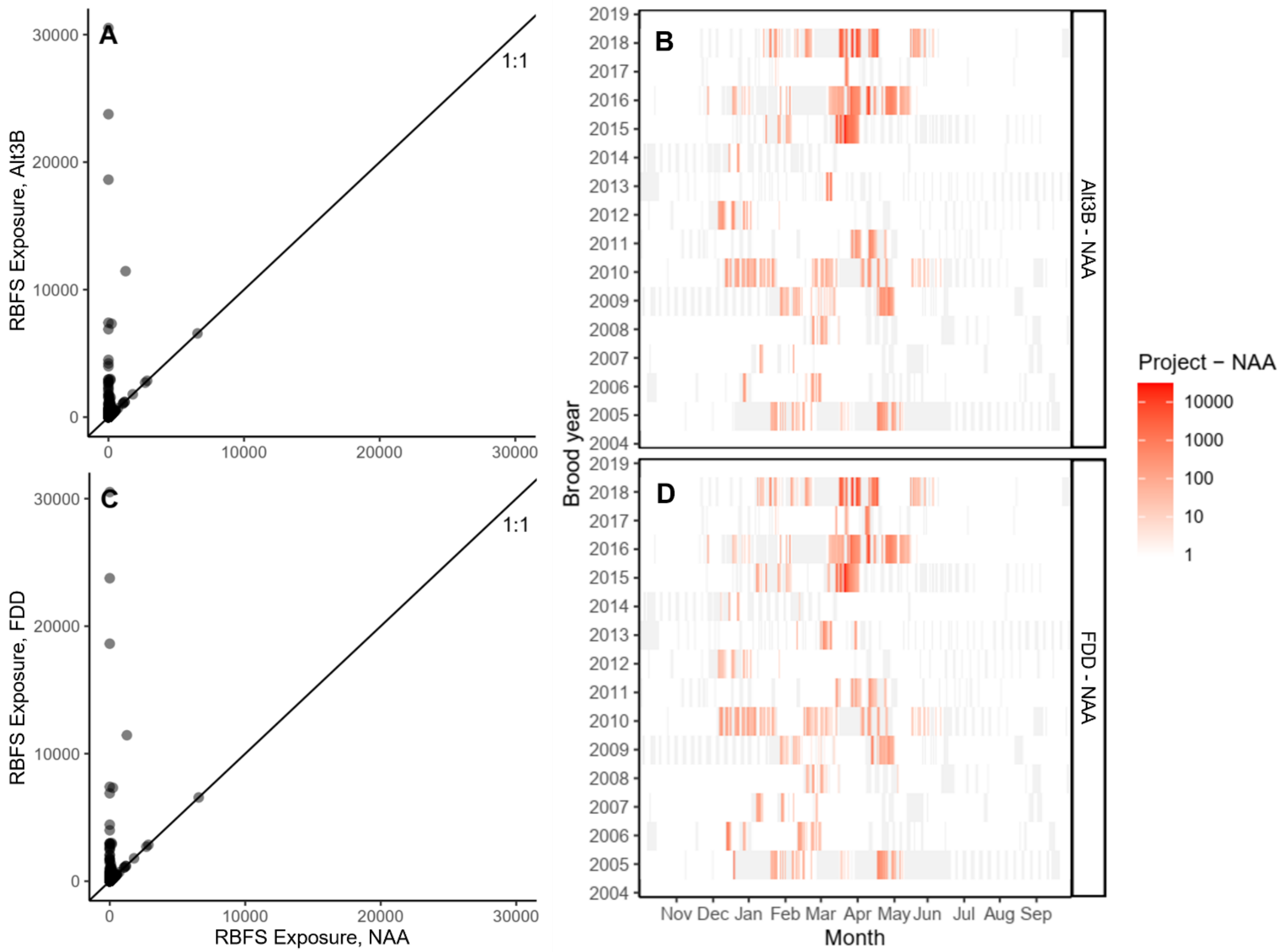


Figure 5-3. (A) Spring-run Chinook Salmon (CHNSR) exposures to the Red Bluff Fish Screen (RBFS) under Alt3B (y-axis) versus the No Action Alternative (NAA; x-axis) during the 15-year simulation. (B) Difference in CHNSR screen exposures at the RBFS between Alt3B and NAA by month (x-axis) and water year (y-axis). (C) CHNSR screen exposures at the RBFS under Flow Dependent Diversion (FDD) versus the NAA. (D) Difference in CHNSR screen exposures at the RBFS between FDD and the NAA by month and water year.

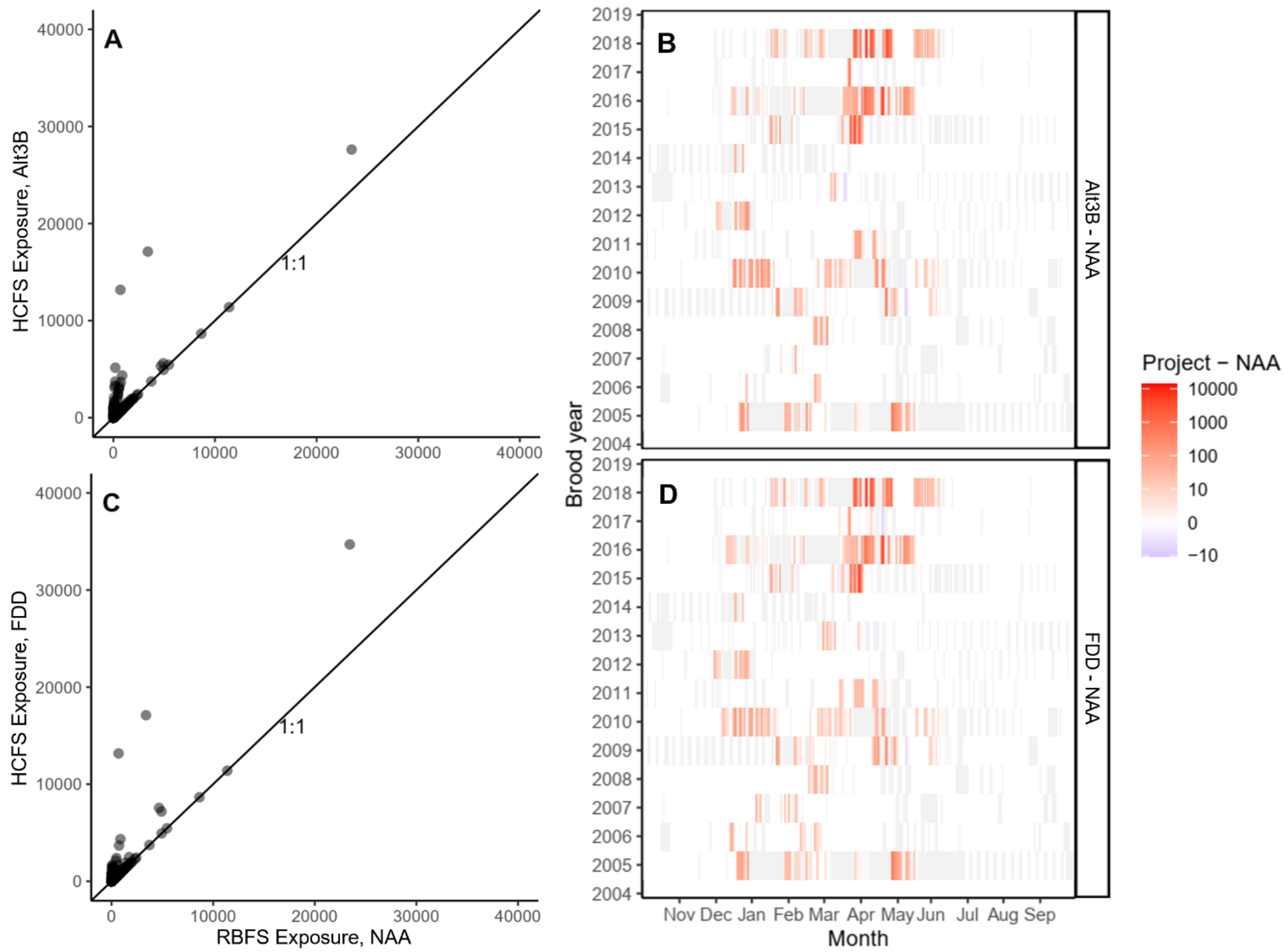


Figure 5-4. (A) Spring-run Chinook Salmon (CHNSR) exposures to the Hamilton City fish screen (HCFS) under Alt3B (y-axis) versus the No Action Alternative (NAA; x-axis) during the 15-year simulation. (B) Difference in CHNSR screen exposures at the HCFS between Alt3B and NAA by month (x-axis) and water year (y-axis). (C) CHNSR screen exposures at the HCFS under Flow Dependent Diversion (FDD) versus the NAA. (D) Difference in CHNSR screen exposures at the HCFS between FDD and the NAA by month and water year.

5.1.7.3. Flow-Dependent Diversion – Survival of Juvenile CHNWR and CHNSR from Red Bluff to Hamilton City

The flow-survival meta-regression models for CHNWR and surrogate CHNSR predicted reductions in survival from Red Bluff to Hamilton City of up to 25% for both CHNWR and CHNSR under the Project, compared to the NAA (Section 4.1.1.1). In contrast, survival of both races from Red Bluff to Hamilton City was only slightly lower under FDD compared to the NAA (Figures 5-5 and 5-6).

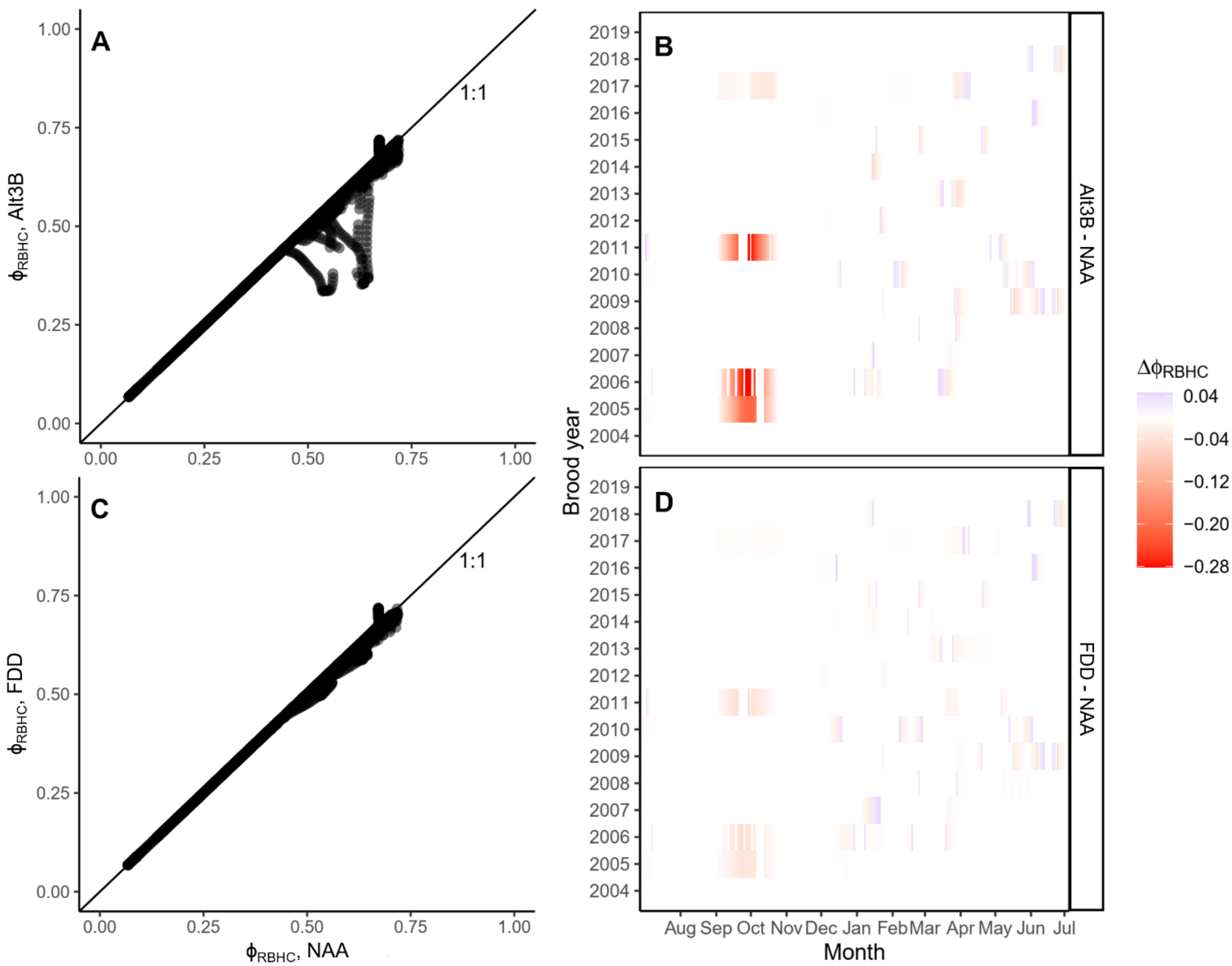


Figure 5-5. (A) Survival of juvenile winter-run Chinook Salmon (CHNWR) from Red Bluff to Hamilton City, as predicted by the flow-survival model shown in Figure 4-32 under Alt3B (y-axis) versus the No Action Alternative (NAA; x-axis). (B) Difference in survival between Alt3B and the NAA by month (x-axis) and water year (y-axis). (C) Survival of juvenile CHNWR from Red Bluff to Hamilton City under Flow Dependent Diversion (FDD) versus the NAA. (D) Difference in survival between FDD and the NAA by month and water year.

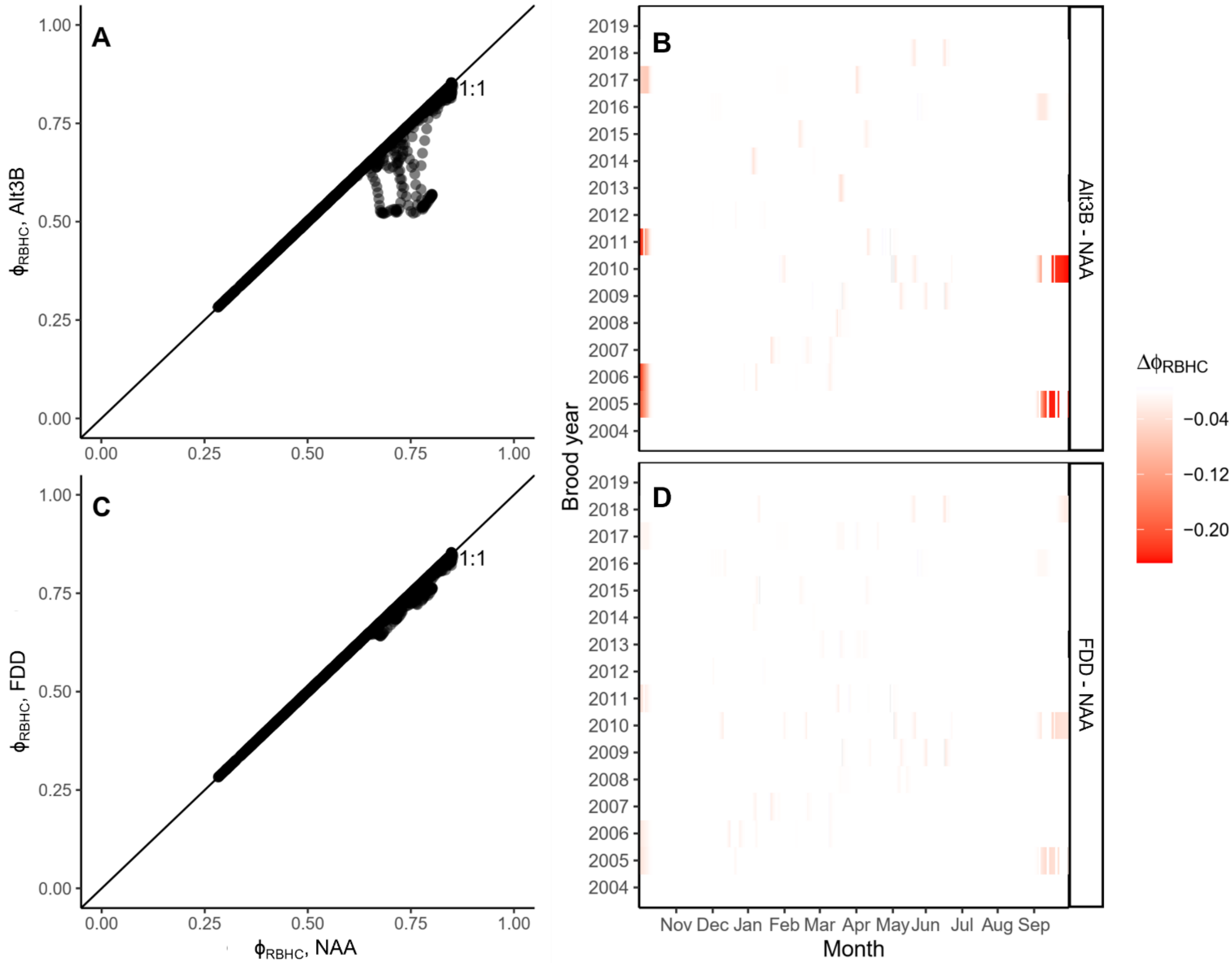


Figure 5-6. (A) Survival of juvenile spring-run Chinook Salmon (CHNSR) from Red Bluff to Hamilton City, as predicted by the spring-run surrogate flow-survival model shown in Figure 4-40 under Alt3B (y-axis) versus the No Action Alternative (NAA; x-axis). (B) Difference in survival between Alt3B and the NAA by month (x-axis) and water year (y-axis). (C) Survival of CHNSR from Red Bluff to Hamilton City under Flow Dependent Diversion (FDD) versus the NAA. (D) Difference in survival between FDD and the NAA by month and water year.

Conclusions – Flow-Dependent Diversion Reduces Screen Exposure

Implementation of FDD will reduce exposure of juvenile CHNWR and CHNSR, and likely also WS, to the RBFS and HCFS, thus reducing the potential for injury or mortality due to predation near and impingement on the fish screens. Under Alt3B, the daily fraction of the Sacramento River diverted by the Project at Red Bluff Pumping Plant and Hamilton City Pump Station could be as high as 55% and 50%, respectively (Figures 4-28 and 4-30). As the fraction of CHNWR and/or CHNSR exposed to the fish screens is proportional to the fraction of Sac flow diverted, scaling diversion rate with Sacramento River flow by implementing FDD substantially reduces CHNWR, CHNSR (to a lesser degree), and likely WS exposure to Project fish screens. Timing of outmigration of each listed Chinook Salmon race relative to the timing of Project diversions likely explains much of the observed difference in the effectiveness of FDD at minimizing screen exposure of CHNWR versus CHNSR. FDD will also substantially temper the degree to which Project operations reduce survival from Red Bluff to Hamilton City by reducing Sacramento River flows between those two locations. CDFW's analysis also estimated that reductions in flow due to Project diversions at Red Bluff under Alt3B would at times reduce predicted survival of CHNWR and CHNSR between Red Bluff to Hamilton City by up to 25%; FDD minimizes these survival reductions to near-zero.

5.1.8. Condition of Approval 8.7 – Winter-run and Spring-run Chinook Salmon Monitoring and Science Requirements

Conditions of Approval 8.7.1–8.7.3 are science actions designed to fill knowledge gaps and inform actions to minimize juvenile CHNWR and CHNSR take at the Red Bluff and Hamilton City fish screens (RBFS and HCFS, respectively). These science actions will be conducted in collaboration with CDFW and other relevant state and federal agencies, as appropriate.

5.1.8.1. Condition of Approval 8.7.1 – Juvenile Salmonid Survival Study Program

Sites Authority will develop and implement a plan to study juvenile CHNWR and CHNSR survival past the HCFS and the RBFS to determine whether juvenile CHNWR and CHNSR experience higher mortality due to fish screen exposure (e.g., due to impingement and increased predation). Survival studies will use either mark-recapture or acoustic telemetry methods at both RBFS and HCFS. Releases upstream of both fish screens will be used to estimate mortality along the screens, though upstream releases at Hamilton City will also estimate survival through the full length of the Hamilton City Oxbow channel. Survival studies in the Hamilton City Oxbow will include targeted releases focused on areas thought to be mortality hotspots, such as the spill area below the flow control weir and fish screen bypass outfall.

Sites Authority will develop specific methods for estimating impingement frequency; methods may include collection of impinged fish using scraping and/or vacuuming instruments as in Dixon (2007). Sampling will be focused on periods of high juvenile CHNWR or CHNSR passage, and studies will be designed to characterize the dependence of impingement on local fish passage, Sacramento River flow (and Hamilton City Oxbow flow at HCFS), diversion rate, time of day, and location on each fish screen. Survival and impingement study data will be used to determine whether and to what degree screen exposure, including injury due to screen contact or impingement, on RBFS and HCFS is a source of juvenile CHNWR and CHNSR take and may inform potential ITP amendments, if warranted.

5.1.8.2. Condition of Approval 8.7.2 – Predator Study Program

Sites Authority will develop a plan to estimate predator abundance and spatial-temporal distributions around RBFS and HCFS to determine whether predators aggregate at or near the screens and associated structures. Predator aggregation and high predation of juvenile salmonids at fish screens, including HCFS, have been observed previously. Predator surveys at both locations will cover the screen faces, footers and surrounding areas. Further surveys at Hamilton City will cover the full length of the Oxbow channel, focusing on areas where high predator densities have previously been observed (Vogel 2006; Vogel 2007; Vogel 2008). Surveys will be conducted during periods of both high and low juvenile Chinook passage to determine whether predators aggregate around fish screens in response to juvenile Chinook presence. Predator surveys at both fish screens will be combined with predator diet studies (e.g., by gastric lavage) to determine the degree to which predators near the fish screens incorporate juvenile CHNWR, CHNSR, and WS into their diets. Predator survey and diet data will be used to determine whether diversions at RBFS and HCFS increase predation of CHNWR, CHNSR, and WS and to inform actions (e.g., predator exclusion, habitat modification) to reduce predation at and near the fish screens. The results of the predator study program will validate analyses of Project effects, ensure that impacts of the taking are minimized, and may inform potential ITP amendments, if warranted.

5.1.8.3. Condition of Approval 8.7.3 – Long-Term Salmonid Monitoring Program in the Hamilton City Oxbow Channel

Sites Authority will reinstate long-term, continuous RST monitoring in the Oxbow. RST monitoring was conducted by CDFW in 1990–2009, and by GCID in 2013–2023. This monitoring was an effective way to monitor passage of juvenile Chinook Salmon and other fish species through the Oxbow. Sites Authority will install and operate one RST in the Oxbow just upstream of the fish screen to estimate juvenile CHNWR and CHNSR passage through the Oxbow. RST monitoring data will be paired with the short-term survival, predation and impingement studies and daily flow and diversion rate data to estimate total take at the Hamilton City fish screen, and to relate passage through the Oxbow to Sacramento River flow and HCPS diversion rate. RST data will also inform patterns of juvenile Chinook passage down the Sacramento River and can be used to inform life cycle models for CHNWR and CHNSR, both which will contribute to the minimization of Project-related take and impacts of the authorized taking, and may inform potential ITP amendments, if warranted.

5.1.9. Condition of Approval 8.8 – White Sturgeon Monitoring and Science Requirements

Conditions of Approval 8.8.1–8.8.4 are science actions designed to fill knowledge gaps and inform actions to minimize WS take at the Red Bluff and Hamilton City fish screens (RBFS and HCFS, respectively). These science actions will be conducted in collaboration with CDFW and other relevant state and federal agencies, as appropriate.

5.1.9.1. Condition of Approval 8.8.1 – Juvenile White Sturgeon Survival Program

Sites Authority will develop a study program to evaluate the effects of Project-related diversions on juvenile WS survival and behavior in the immediate areas of the fish screens, including assessing trends of mortality due to entrainment and/or impingement of larval and juvenile WS less than 30 mm. Project diversions at HCPS have the potential to entrain and impinge larval and juvenile WS smaller than 30 mm (see Section 4.4.1). While limited data indicate that adults may spawn in the region, there is very little specific information on the presence, abundance, distribution, behavior, and survival of young WS near water diversions in the reach. Results from this study may inform potential ITP amendments, if warranted.

5.1.9.2. Condition of Approval 8.8.2 – White Sturgeon Acoustic Telemetry Program

Sites Authority will develop a monitoring program that includes real-time acoustic telemetry receivers at key locations to improve scientific understanding of the routing and movement of adult and juvenile WS near the RBPP and HCPS diversions. Studies indicate that adult WS are sometimes present in the region around RBPP, and adult and juvenile WS have been observed in the region around the HCPS (see Section 3.5.2); however, limited information exists on local WS abundance and spatial and temporal patterns of spawning, rearing, and migration, particularly in the vicinity of the HCPS where proposed Project diversions may impact larval and juvenile WS. Results from the WS acoustic telemetry program will ensure that the effects of Project Operations on WS are minimized and may inform potential ITP amendments, if warranted.

5.1.9.3. Condition of Approval 8.8.3 Seasonal White Sturgeon Larval Monitoring Program

Sites Authority will develop a monitoring program that includes long-term monitoring on the presence and movement of larval and juvenile WS near the HCPS diversion facility. Studies indicate that adult WS may spawn near or upstream of the HCPS diversion facility (see Section 3.5.2). Larval and small juvenile WS are vulnerable to impingement and entrainment due to their small size and limited swimming ability (see Section 4.4.1); however, there is very little information about their presence, spatial distribution, movement, and behavior. Results from this WS larval monitoring program will provide vital data on larval and juvenile WS near Hamilton City to confirm analyses of Project take, ensure that Project-related impacts of the taking are minimized, and may inform potential ITP amendments, if warranted.

5.1.9.4. Condition of Approval 8.8.4 White Sturgeon Predator Study Program

Sites Authority will develop a study program to estimate predator abundance and spatial-temporal distributions at and near RBFS and HCFS to determine whether predators aggregate at or near the screens and associated diversion structures. Predator aggregation and high predation of juvenile salmonids at fish screens, including HCFS, have been observed previously (see Section 4.4.1.2.) Predator survey and diet data will be used to determine whether diversions at RBFS and HCFS encourage predator aggregation and increased predation of CHNWR, CHNSR, and WS and to inform potential actions (e.g., predator exclusion, habitat modification) to reduce predation at and near the fish screens. The results of the predator study program will validate analyses of Project effects and ensure that impacts of the taking are minimized, and may inform potential ITP amendments, if warranted.

5.2. Winter-run and Spring-run Chinook Salmon and White Sturgeon – Far-Field Effects

Conditions of Approval 8.7.4–8.7.7, 9.8–9.9, 9.12–9.15, 9.18–9.21, and 9.27–9.28 are wide ranging measures that minimize impacts to protected species downstream of Project diversion facilities.

5.2.1. Condition of Approval 9.12 – Sacramento River Bypass Flow Criteria at Wilkins Slough

To minimize take of CHNWR and CHNSR from reductions in streamflow during juvenile migration, Sites will not divert if Sacramento River flows at Wilkins Slough are below or would decline below 10,930 cfs, the higher (50%) threshold for survival identified by Michel et al. (2021). The ITP Application (Sites Authority 2023) assumed a "real-time" bypass flow at Wilkins Slough of 10,700 cfs, as well as instantaneous downstream flow responses as a result of Project diversions. These assumptions are unrealistic and could result reducing flows at Wilkins Slough below 10,700 cfs when accounting for travel delays of upstream Project diversions. If accounting for attenuation and downstream travel time, diversions at Hamilton City and Red Bluff result in reductions of up to 250 cfs for 72 hours after diversions have ceased. For this reason, CDFW reassessed simulated diversions from the ITP Application (Sites Authority 2023) using the 3-day forecasted flow at

Wilkins Slough, finding that it would significantly reduce the risk of Project operations reducing river conditions below the higher (50%) survival threshold for Chinook Salmon migration.

The flow-survival relationship described by Michel et al. (2021) is currently the best available science for predicting juvenile Chinook Salmon migration survival in the Sacramento River. Michel et al. (2021) tested many non-linear relationships between flow and survival, and the best fit was a threshold model in which flows at Wilkins Slough above 10,700 cfs result in higher migration survival. Wilkins Slough was chosen because it is located downstream of most major diversions on this stretch of the Sacramento River and best accounts for the variation in river flow experienced by migrating fish. The 10,700 cfs threshold in Michel et al. (2021) comes from model averaging all the threshold models with ΔBIC < 2.0, where ΔBIC is a metric of relative model fit and models with values <2 are considered similarly well supported by the data. However, there is a degree of uncertainty around the exact flow threshold where survival pivots from around 20% to around 50%. For example, all five of the top models with ΔBIC < 1.0 found the flow threshold that produced maximum survival to be 10,930 cfs (Michel et al. 2021, Supp. Mat.; Section 4.1.5). For the goal of species conservation, rather than precise predictions, the 10,930 cfs flow threshold at Wilkins Slough should be the target for protecting salmon migration survival.

The Sacramento River bypass flow measure at Wilkins Slough, which includes a forecasting requirement, will minimize Project impacts on survival of out-migrating juvenile CHNWR and CHNSR by ensuring that Project Diversions do not reduce river flows to below the beneficial threshold of 10,930 cfs. This condition is expected to also provide some ancillary minimization for WS, LFS, and DS by ensuring that Project diversions do not occur when Sacramento River flows are very low.

5.2.2. Condition of Approval 9.13 – Allowable Diversions During Simultaneous Use at Red Bluff Pumping Plant and Hamilton City Pump Station

Condition of Approval 9.13 requires Sites Authority to maintain a minimum bypass flow of 10,930 cfs at Wilkins Slough when the Permittee and non-Permittee users are diverting simultaneously at the RBPP or HCPS. The Sites Authority is required to cease diversions of non-Permittee diversions and Permittee diversions combined would be expected to reduce Wilkins Slough bypass flows to fall below 10,930 cfs. This measure minimizes adverse effects to CHNWR, CHNSR, and WS that would happen if Sacramento River flows decreases below 10,930 cfs due to multiple diversions, which included the Project.

5.2.3. Condition of Approval 9.15 – Cessation of Diversions at Red Bluff Pumping Plant and Hamilton City Pump Station

Condition of Approval 9.15 requires Sites Authority to immediately initiate diversion ramp down procedures when real-time or forecasted flows at Wilkins Slough decrease below 10,930 cfs. This condition ensures that Project operations do not reduce flows below 10,930 cfs at Wilkins slough, which avoids or minimizes adverse effects to CHNWR, CHNSR, and WS from unfavorable low flow conditions that reduce survival.

5.2.4. Condition of Approval 9.14 – Flow Dependent Diversion

The Flow-Dependent Diversion (FDD) concept was designed with the primary goal of reducing near-field impacts at fish screens by minimizing diversions during lower flow conditions and during periods of higher abundance of protected species (see Section 5.1.7, above); however, downstream benefits are also expected. FDD scales diversions at both diversion facilities as a function of the Sacramento River flow at each location, thereby better maintaining the shape of the natural hydrograph and reducing impacts during sensitive lower flow periods. Condition of Approval 9.14 will minimize impacts to juvenile salmon floodplain rearing habitat availability and migration mortality. This measure is also expected to benefit WS larvae and juveniles by better protecting the shape of the natural hydrograph and reducing project impacts at sensitive lower flow periods.

5.2.4.1. Access to Yolo and Sutter Bypass Floodplains

Seasonal floodplain habitat use is a life history strategy that increases growth and survival of juvenile Chinook Salmon, and the Project is expected to reduce floodplain habitat access and availability for CHNWR and CHNSR by reducing weir overtopping and reducing floodplain habitat quantity and temporal availability (see Section 4.1.7). The bypass weirs are many miles downstream of the diversion facilities, and thus FDD is expected to have a less immediate impact on weir spills than on near-field impacts such as screen exposure.

CDFW analyzed the effectiveness of FDD at reducing adverse effects of Project operations on floodplain availability using the same methods described in Section 4.1.7.1, comparing both the Alt3B and FDD operational scenarios to the NAA. Results are shown in Figures 5-7 through 5-8 and Tables 5-4 through 5-15.

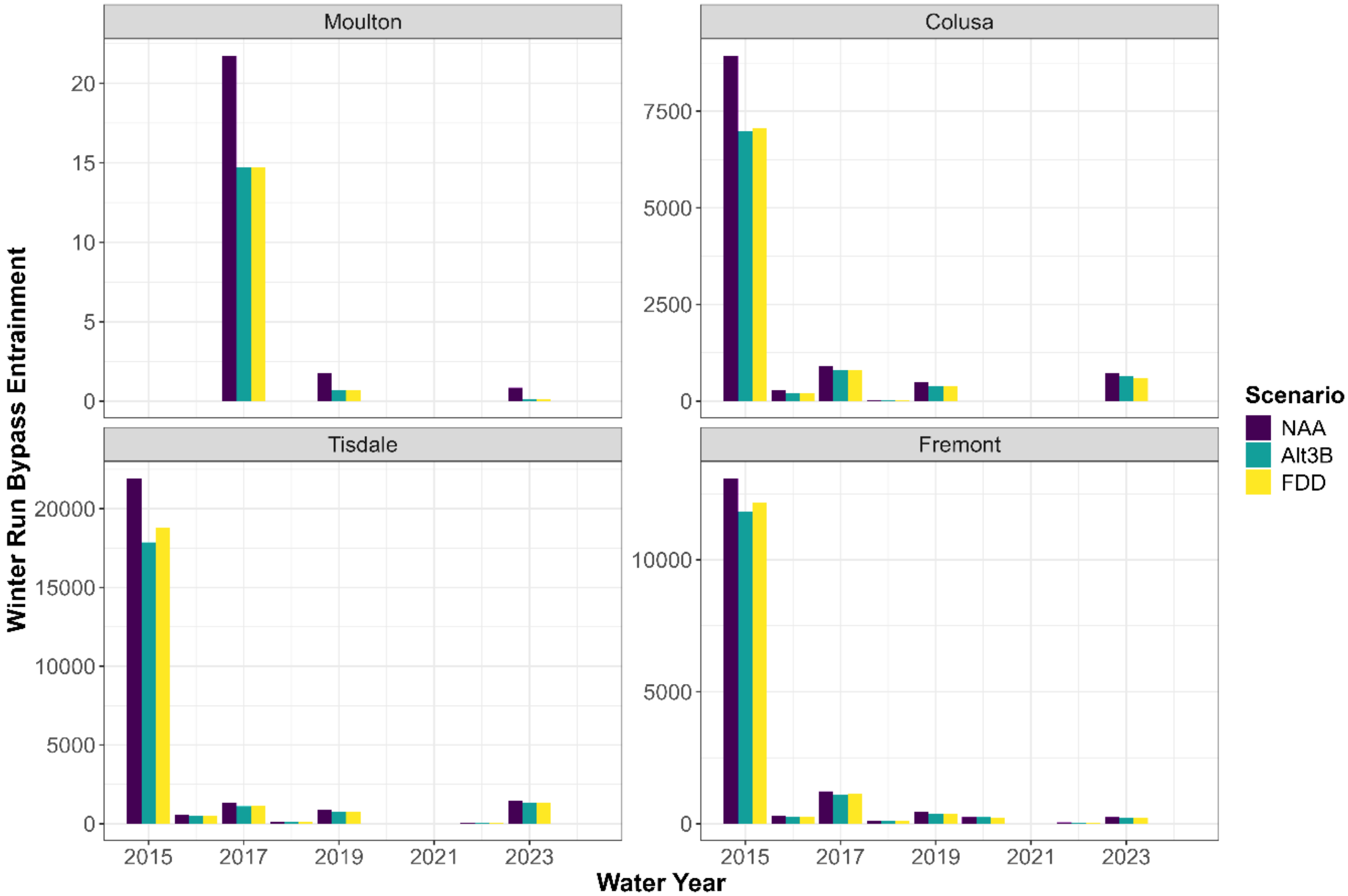


Figure 5-7. Estimated CHNWR bypass entrainment at each weir under the No Action Alternative ('NAA') and the Project scenarios ('Alt3B' and 'FDD'). Note: y-axis scales differ to allow more effective comparison between scenarios.

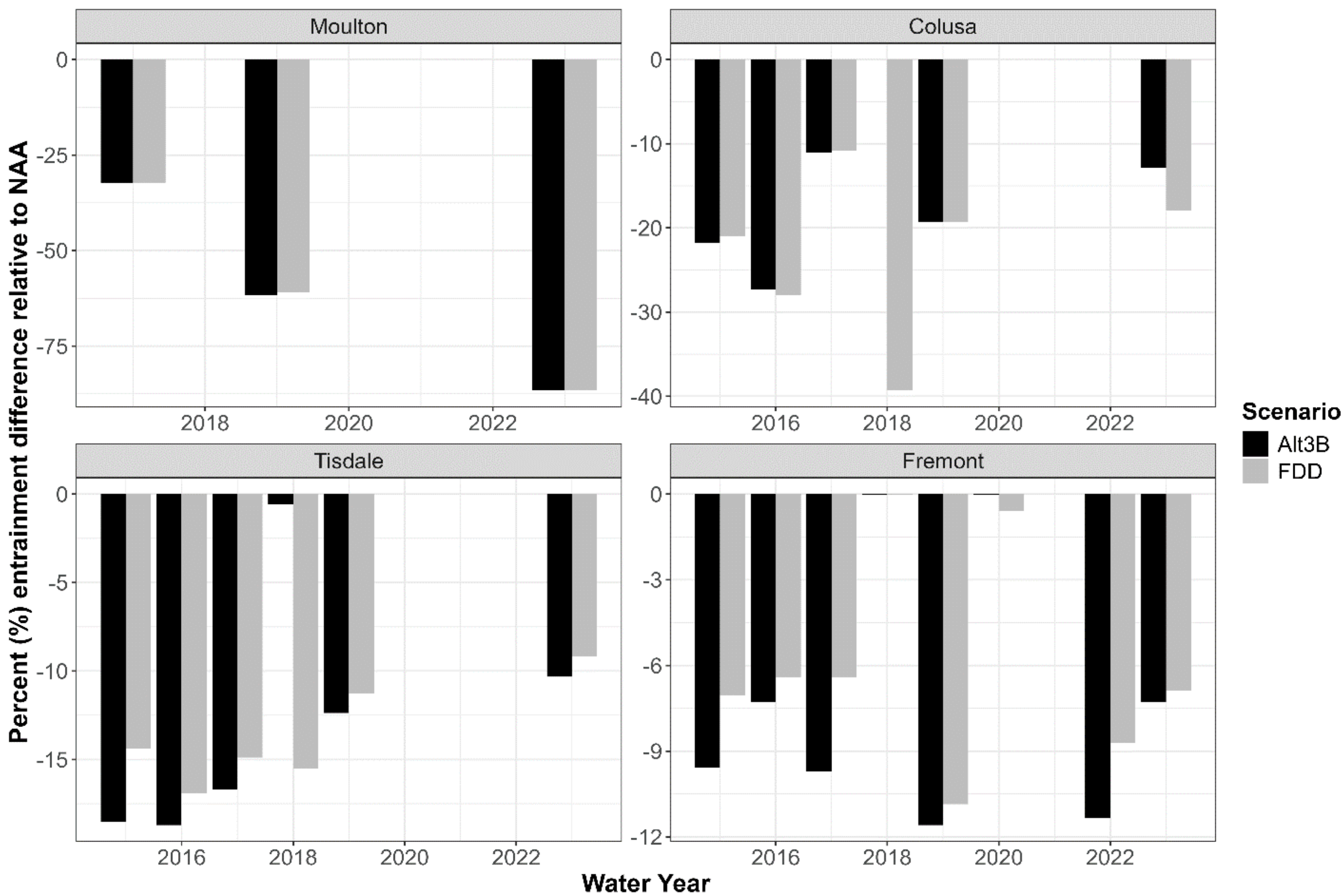


Figure 5-8. Estimated percentage difference in CHNWR bypass entrainment at each weir under each Project scenario ('Alt3B' and 'FDD') relative to the No Action Alternative ('NAA').

Table 5-4. Differences in yearly estimated CHNWR bypass entrainment at Moulton Weir. 'Arriving' is the number of CHNWR that survived to reach each weir. 'NAA' is the number of CHNWR estimated to be entrained over the weir under the NAA scenario. The project scenario names represent the difference in entrainment between the NAA and the project scenario. Negative values represent reductions in entrainment relative to NAA; positive values represent increases in entrainment. Numbers based on averages; thus, fractional individuals are possible.

Water Year	Arriving	NAA	Alt3B	FDD
2015	1,255,137	0	0 (0%)	0 (0%)
2016	180,071	0	0 (0%)	0 (0%)
2017	149,117	22	-7 (-32%)	-7 (-32%)
2018	175,531	0	0 (0%)	0 (0%)
2019	302,976	2	-1 (-62%)	-1 (-61%)
2020	503,262	0	0 (0%)	0 (0%)
2021	560,265	0	0 (0%)	0 (0%)
2022	126,416	0	0 (0%)	0 (0%)
2023	56,439	1	-1 (-87%)	-1 (-87%)

Table 5-5. Differences in yearly estimated CHNWR bypass entrainment at **Colusa Weir**. 'Arriving' is the number of CHNWR that survived to reach each weir. 'NAA' is the number of CHNWR estimated to be entrained over the weir under the NAA scenario. The project scenario names represent the difference in entrainment between the NAA and the project scenario. Negative values represent reductions in entrainment relative to NAA; positive values represent increases in entrainment. Numbers based on averages; thus, fractional individuals are possible.

Water Year	Arriving	NAA	Alt3B	FDD
2015	1,231,060	8,939	-1948 (-22%)	-1879 (-21%)
2016	167,411	280	-76 (-27%)	-78 (-28%)
2017	137,278	893	-99 (-11%)	-96 (-11%)
2018	174,250	17	0 (0%)	-7 (-39%)
2019	281,878	485	-94 (-19%)	-93 (-19%)
2020	470,601	0	0 (0%)	0 (0%)
2021	518,261	0	0 (0%)	0 (0%)
2022	118,866	0	0 (0%)	0 (0%)
2023	51,418	736	-95 (-13%)	-132 (-18%)

Table 5-6. Differences in yearly estimated CHNWR bypass entrainment at **Tisdale Weir**. 'Arriving' is the number of CHNWR that survived to reach each weir. 'NAA' is the number of CHNWR estimated to be entrained over the weir under the NAA scenario. The project scenario names represent the difference in entrainment between the NAA and the project scenario. Negative values represent reductions in entrainment relative to NAA; positive values represent increases in entrainment. Numbers based on averages; thus, fractional individuals are possible.

Water Year	Arriving	NAA	Alt3B	FDD
2015	1,264,332	21,934	-4,062 (-19%)	-3,153 (-14%)
2016	137,357	593	-111 (-19%)	-100 (-17%)
2017	112,455	1,340	-224 (-17%)	-200 (-15%)
2018	167,515	111	-1 (-1%)	-17 (-16%)
2019	237,924	871	-108 (-12%)	-98 (-11%)
2020	401,568	0	0 (0%)	0 (0%)
2021	433,197	0	0 (0%)	0 (0%)
2022	104,882	71	0 (0%)	0 (0%)
2023	45,068	1,483	-153 (-10%)	-136 (-9%)

Table 5-7. Differences in yearly estimated CHNWR bypass entrainment at **Fremont Weir**. 'Arriving' is the number of CHNWR that survived to reach each weir. 'NAA' is the number of CHNWR estimated to be entrained over the weir under the NAA scenario. The project scenario names represent the difference in entrainment between the NAA and the project scenario. Negative values represent reductions in entrainment relative to NAA; positive values represent increases in entrainment. Numbers based on averages; thus, fractional individuals are possible.

Water Year	Arriving	NAA	Alt3B	FDD
2015	1,283,096	13,090	-1251 (-10%)	-922 (-7%)
2016	108,026	293	-21 (-7%)	-19 (-6%)
2017	87,213	1,227	-119 (-10%)	-79 (-6%)
2018	159,615	110	0 (0%)	0 (0%)
2019	193,132	440	-51 (-12%)	-48 (-11%)
2020	317,113	243	0 (0%)	-1 (-1%)
2021	310,025	4	0 (0%)	0 (0%)
2022	89,312	52	-6 (-11%)	-5 (-9%)
2023	10,729	245	-18 (-7%)	-17 (-7%)

Table 5-8. The cumulative differences in the number of juvenile CHNWR entrained into **Sutter Bypass**. 'Arriving' is the number of CHNWR that survived to reach each weir. 'NAA' is the number of CHNWR estimated to be entrained over the weir under the NAA scenario. The project scenario names represent the difference in entrainment between the NAA and the project scenario. Negative values represent reductions in entrainment relative to NAA; positive values represent increases in entrainment. Numbers based on averages; thus, fractional individuals are possible.

Water Year	Arriving	NAA	Alt3B	FDD
2015	3,750,529	30,873	-6010 (-19%)	-5032 (-16%)
2016	484,839	872	-187 (-21%)	-179 (-20%)
2017	398,850	2,255	-329 (-15%)	-303 (-13%)
2018	517,297	127	-1 (0%)	-24 (-19%)
2019	822,778	1,358	-203 (-15%)	-193 (-14%)
2020	1,375,431	0	0 (0%)	0 (0%)
2021	1,511,723	0	0 (0%)	0 (0%)
2022	350,164	71	0 (0%)	0 (0%)
2023	152,925	2,219	-248 (-11%)	-269 (-12%)

Table 5-9. The cumulative differences in the number of juvenile CHNWR entrained into **Yolo Bypass**. 'Arriving' is the number of CHNWR that survived to reach each weir. 'NAA' is the number of CHNWR estimated to be entrained over the weir under the NAA scenario. The project scenario names represent the difference in entrainment between the NAA and the project scenario. Negative values represent reductions in entrainment relative to NAA; positive values represent increases in entrainment. Numbers based on averages; thus, fractional individuals are possible.

Water Year	Arriving	NAA	Alt3B	FDD
2015	1,283,096	13,090	-1251 (-10%)	-922 (-7%)
2016	108,026	293	-21 (-7%)	-19 (-6%)
2017	87,213	1,227	-119 (-10%)	-79 (-6%)
2018	159,615	110	0 (0%)	0 (0%)
2019	193,132	440	-51 (-12%)	-48 (-11%)
2020	317,113	243	0 (0%)	-1 (-1%)
2021	310,025	4	0 (0%)	0 (0%)
2022	89,312	52	-6 (-11%)	-5 (-9%)
2023	10,729	245	-18 (-7%)	-17 (-7%)

Table 5-10. The percentage difference in CHNSR bypass entrainment at **Moulton Weir** under each project scenario relative to the NAA scenario. ‘Arriving’ is the number of CHNSR estimated to reach the weir from the simulated starting population of 4,000,000 individuals. 'NAA' represents the number of entrained individuals under the NAA scenario. The project scenario names represent the number and percentage difference in entrainment relative to the NAA scenario. Negative values represent reductions in entrainment.

Water Year	Arriving	NAA	Alt3B	FDD
2015	0	0	0 (0%)	0 (0%)
2016	2	0	0 (0%)	0 (0%)
2017	2,267,835	163	-42 (-26%)	-42 (-26%)
2018	2,738,739	0	0 (0%)	0 (0%)
2019	0	0	0 (0%)	0 (0%)
2020	2,578,917	0	0 (0%)	0 (0%)
2021	1,312,035	0	0 (0%)	0 (0%)
2022	2,517,720	0	0 (0%)	0 (0%)
2023	2,466,365	52	-46 (-89%)	-46 (-89%)

Table 5-11. The percentage difference in CHNSR bypass entrainment at **Colusa Weir** under each project scenario relative to the NAA scenario. 'Arriving' is the number of CHNSR estimated to reach the weir from the simulated starting population of 4,000,000 individuals. 'NAA' represents the number of entrained individuals under the NAA scenario. The project scenario names represent the number and percentage difference in entrainment relative to the NAA scenario. Negative values represent reductions in entrainment.

Water Year	Arriving	NAA	Alt3B	FDD
2015	0	0	0 (0%)	0 (0%)
2016	1	0	0 (0%)	0 (0%)
2017	2,164,570	127,453	-64,293 (-50%)	-64,113 (-50%)
2018	2,593,760	3,273	0 (0%)	-1,287 (-39%)
2019	0	0	0 (0%)	0 (0%)
2020	2,483,259	0	0 (0%)	0 (0%)
2021	1,060,786	0	0 (0%)	0 (0%)
2022	2,323,375	0	0 (0%)	0 (0%)
2023	2,192,464	23,668	-3,567 (-15%)	-3,589 (-15%)

Table 5-12. The percentage difference in CHNSR bypass entrainment at **Tisdale Weir** under each project scenario relative to the NAA scenario. 'Arriving' is the number of CHNSR estimated to reach the weir from the simulated starting population of 4,000,000 individuals. 'NAA' represents the number of entrained individuals under the NAA scenario. The project scenario names represent the number and percentage difference in entrainment relative to the NAA scenario. Negative values represent reductions in entrainment.

Water Year	Arriving	NAA	Alt3B	FDD
2015	0	0	0 (0%)	0 (0%)
2016	1	0	0 (0%)	0 (0%)
2017	1,532,739	317,419	-60,483 (-19%)	-53,126 (-17%)
2018	2,094,720	17,488	-98 (-1%)	-3,482 (-20%)
2019	0	0	0 (0%)	0 (0%)
2020	2,183,985	0	0 (0%)	0 (0%)
2021	796,272	0	0 (0%)	0 (0%)
2022	1,666,088	1	0 (0%)	0 (0%)
2023	1,287,580	48,812	-15,528 (-32%)	-10,905 (-22%)

Table 5-13. The percentage difference in CHNSR bypass entrainment at **Fremont Weir** under each project scenario relative to the NAA scenario. 'Arriving' is the number of CHNSR estimated to reach the weir from the simulated starting population of 4,000,000 individuals. 'NAA' represents the number of entrained individuals under the NAA scenario. The project scenario names represent the number and percentage difference in entrainment relative to the NAA scenario. Negative values represent reductions in entrainment.

Water Year	Arriving	NAA	Alt3B	FDD
2015	0	0	0 (0%)	0 (0%)
2016	0	0	0 (0%)	0 (0%)
2017	815,669	106,040	-18,677 (-18%)	-17,170 (-16%)
2018	1,653,334	342	0 (0%)	0 (0%)
2019	0	0	0 (0%)	0 (0%)
2020	1,944,169	2,848	0 (0%)	-79 (-3%)
2021	665,988	30	0 (0%)	0 (0%)
2022	1,274,661	4,419	-720 (-16%)	-538 (-12%)
2023	664,318	9,897	-967 (-10%)	-793 (-8%)

Table 5-14. The cumulative number of juvenile CHNSR entrained into **Sutter Bypass** in each year under the No Action Alternative ('NAA'). The project scenario names represent the difference in entrainment between the NAA and the scenario. Negative values represent reductions in entrainment relative to NAA.

Water Year	Arriving	NAA	Alt3B	FDD
2015	0	0	0 (0%)	0 (0%)
2016	4	0	0 (0%)	0 (0%)
2017	5,965,144	445,035	-124,819 (-28%)	-117,281 (-26%)
2018	7,427,219	20,762	-98 (0%)	-4,769 (-23%)
2019	0	0	0 (0%)	0 (0%)
2020	7,246,161	0	0 (0%)	0 (0%)
2021	3,169,093	0	0 (0%)	0 (0%)
2022	6,507,183	1	0 (0%)	0 (0%)
2023	5,946,409	72,532	-19,142 (-26%)	-14,540 (-20%)

Table 5-15. The cumulative number of juvenile CHNSR entrained into **Yolo Bypass** in each year under the No Action Alternative ('NAA'). The project scenario names represent the difference in entrainment between the NAA and the scenario. Negative values represent reductions in entrainment relative to NAA.

Water Year	Arriving	NAA	Alt3B	FDD
2015	0	0	0 (0%)	0 (0%)
2016	0	0	0 (0%)	0 (0%)
2017	815,669	106,040	-18677 (-18%)	-17170 (-16%)
2018	1,653,334	342	0 (0%)	0 (0%)
2019	0	0	0 (0%)	0 (0%)
2020	1,944,169	2,848	0 (0%)	-79 (-3%)
2021	665,988	30	0 (0%)	0 (0%)
2022	1,274,661	4,419	-720 (-16%)	-538 (-12%)
2023	664,318	9,897	-967 (-10%)	-793 (-8%)

Results demonstrate that the FDD scenario reduces impacts to juvenile CHNWR and CHNSR bypass entrainment in most years. One notable exception was in 2018, when very little weir overtopping occurred. The diversion criteria for Alt3B were such that diversions did not occur during the brief window of weir overtopping during this particular year, while diversions did occur under FDD. For this reason, FDD was estimated to result in a large proportion of reduction in bypass entrainment relative to the very small number of fish that would have been able to enter that year, which did not occur under Alt3B. Overall, the FDD scenario consistently reduced impacts to CHNWR and CHNSR entrainment into Sutter and Yolo Bypasses while preserving Project diversions.

FDD is expected to result in moderate increases to floodplain access and availability for CHNWR and CHNSR compared to Alt3B, particularly at Tisdale and Freemont weirs to the Sutter Bypass. While the effects of FDD on minimizing Project impacts on floodplain entrainment are less obvious than the effects of FDD on screen exposure risk (Section 5.1.7), the results of CDFW's bypass entrainment simulations at Sutter and Yolo Bypasses consistently found improvements to entrainment under FDD relative to Alt3B, demonstrating that FDD helps minimize impacts to CHNWR and CHNSR floodplain habitat access.

5.2.4.2. Maintaining More Natural Hydrograph

Additional benefits to listed species that are difficult or impossible to quantify are also expected under the FDD criteria relative to Alt3B. For example, maintaining the natural shape of the hydrograph by avoiding sudden shifts in diversion rates is expected to preserve ecological cues, e.g., natural changes in flow that trigger juvenile Chinook Salmon or WS migration. Scaling diversions to flow in the Sacramento River are also expected to reduce potential impacts related to juvenile stranding, habitat connectivity, food production, and overall habitat quality for CHNWR, CHNSR, WS, LFS, and DS.

Several studies have linked greater discharge rates with improved juvenile out-migration survival (e.g. Michel et al. 2021, Notch et al. 2020a, Perry et al. 2010), but additional evidence suggests that the shape and timing of the hydrograph contributes to other aspects of Chinook Salmon biology. The seasonal timing of low-flow periods may be an important factor in reproductive success of Chinook Salmon. Warkentin et al. (2022) found that seasonal shifts in water availability affected salmon productivity. Arthaud et al. (2010) similarly found that salmon populations in a river system with a hydrograph altered by agricultural irrigation experienced reduced salmon productivity (i.e., egg to adult return rates) than a nearby system with an unaltered hydrograph. Perhaps most notably, in a modeling exercise aimed at assessing risks of extirpation of Central Valley Chinook salmon, Zeug et al. (2011) found that changes to the timing and shape of the hydrograph may contribute to the extirpation of CHNSR in the Sacramento River.

Because FDD scales diversion rate to flow in the Sacramento River, it better maintains the shape and timing of the hydrograph downstream of Sites' diversion locations than the diversion criteria proposed in the ITP Application (Sites 2023), and therefore implementing FDD will contribute to minimizing impacts of Project diversions on Covered Species in the Sacramento River and Delta.

5.2.5. Condition of Approval 9.8 – Diversions During Excess Conditions

Sites Authority may only divert water from the Sacramento River when DWR and Reclamation have determined that the Delta is in excess conditions. Condition of Approval 9.8 allows the SWP and CVP to meet user demand while maintaining their regulatory requirements, including the protection of Delta outflow in winter and spring, an important rearing and migration period for CHNWR, CHNSR, and WS. This Condition of Approval contributes to minimizing impacts to CHNWR, CHNSR, and WS by protecting river flows during dry periods until the Delta achieves excess conditions.

5.2.6. Condition of Approval 9.9 – Temporary Urgency Change Order for Delta Water Quality Objectives

Condition of Approval 9.9 restricts the Project from during times when Bay-Delta Water Quality Control Plan requirements for Delta Outflow, X2 (Spring), Rio Vista, Emmaton, Jersey Point, and Delta Export to Inflow (E:I) ratio are modified by a Temporary Urgency Change Petition/Order and the CVP or SWP are operating to the modified conditions. This measure contributes to minimizing Project-related impacts on CHNWR, CHNSR, and WS by ensuring that the Project does not reduce Sacramento River flow and Delta outflow at times when flows are already critically low.

5.2.7. Conditions of Approval 9.18–9.20 – Operational Exchanges

Conditions of Approval 9.18, 9.19, and 9.20 govern Project-facilitated operational exchanges, including exchanges with Shasta and Oroville reservoirs. Condition 9.18 requires that any exchanges or transfers facilitated by Sites Authority will comply with all Conditions of Approval in the ITP to minimize impacts to CHNWR, CHNSR, WS, LFS and DS. Condition of Approval 9.19 ensures that the Permittee will not facilitate an exchange with Shasta Reservoir if that exchange results in Reclamation not meeting its regulatory requirements, which include actions to protect CHNWR, CHNSR, LFS, DS, Central Valley steelhead, and Green Sturgeon. Condition of Approval 9.20 ensures that the Permittee will not facilitate an exchange with Oroville Reservoir if that exchange results in DWR not meeting its regulatory requirements, which include actions to protect CHNWR, CHNSR, WS, LFS, and DS. These actions and species protection requirements include and overlap with protections for CHNWR, CHNSR, and WS and thereby minimize potential impacts of Project-related exchanges and transfers, including exchanges with Shasta and Oroville reservoirs.

5.2.8. Condition of Approval 9.21 – Water Exchange and Temperature Management Requirement

CDFW's water temperature analyses for Chinook Salmon (Section 4.1.2.1) and WS (Section 4.4.4.1) found that Project-related exchanges with Shasta Reservoir, CVP operational flexibility, and/or real-time exchanges and transfers could result in changes in Sacramento River flows by up to 1,000 cfs between Hamilton City and Knights Landing during some months. Lower streamflow would be most likely in drier year types in April, May, and June, and could significantly increase the number of days when water temperatures near Tisdale Weir (Tisdale) would exceed stressful or lethal biological thresholds for CHNWR, CHNSR, and WS. CDFW's temperature analysis found that late summer and fall Sacramento River flows between Hamilton City and Knights Landing could increase or decrease under Project operations. Flow decreases and temperature increases would be more common in Wet and Above Normal water year types, and flow increases and temperature decreases would be more frequent in Critical, Dry, and Below Normal water year types. Increases in temperature exceedance were largest and most frequent under the Alt3B operational scenario, and much less common under the NoSha and NoShaOro operational scenarios. This will be minimized through development and implementation of a Water Exchange and Temperature Management Plan

Sites Authority will work with CDFW to develop, calibrate, and validate a water temperature model to evaluate the influence of changes in flow due to operational exchanges on temperature in the Sacramento River between Hamilton City and Knights Landing. The study will investigate the role of exchange timing, exchange volume, water year type, and other factors. Results will be used to develop a Water Exchange and Temperature Management Plan that describes how Sites Authority will manage exchanges with Shasta Reservoir, Oroville Reservoir, CVP operational flexibility, and real-time exchanges and transfers to minimize water temperature impacts. The final model, study plan, and Water Exchange and Temperature Management Plan will be reviewed and subject to CDFW approval prior to Project operations. The Project will operate to the plan to avoid and minimize exchange-related temperature impacts to CHNWR, CHNSR, and WS.

5.2.9. Condition of Approval 9.27 – Wallace Weir Upstream Attraction Flows

Sites Authority will not release water to the Yolo Bypass if adult salmonids are present at the Wallace Weir Fish Rescue Facility (WWFRF). Increases in Yolo Bypass flows due to Sites' releases may cause upstream migrating CHNSR to stray into the Yolo Bypass instead of the Sacramento River. If this occurs, CHNSR must turn around and swim back to the Sacramento River, or they must be captured at the WWFCF and transported back to the Sacramento River. This deviation from their normal spawning migration can result in take during fish rescue ("catch" or "capture") and potential mortality ("kill"), particularly if water temperatures are high (see Section 4.1.6.1).

Sites will also conduct monitoring to determine whether releases to the Yolo Bypass attract salmonids and cause straying, and fund additional operations at the WWFCF, including staff, maintenance costs, and genetic testing. Operating the WWFCF during releases will capture CHNSR that stray to that location, and monitoring of straying elsewhere in the Yolo Bypass will provide data to inform flow or rescue actions, if necessary, and ensure that the impacts of releases on CHNSR straying in the Yolo Bypass are minimized. This Condition of Approval will minimize CHNSR straying into the Yolo Bypass particularly when high temperatures increase risk of mortality, inform actions to minimize straying, maximize the success of rescue operations, and may inform potential ITP amendments.

5.2.10. Condition of Approval 9.28 – Winter-run Chinook Salmon Protections (Winter-Run Life Cycle Model)

The Winter-run Life Cycle Model (WRLCM) is currently the best available science for illuminating and understanding interactions and trade-offs between modeled operational scenarios' effects on CHNWR. This Condition of Approval requires the Sites Authority to demonstrate that proposed operations will not result in a decrease in average annual escapement as compared to a no-Project scenario using modeling from the WRLCM or other best available science, as reviewed and approved by CDFW. This measure will avoid or minimize impacts CHNWR by evaluating the suite of project operations and potential impacts on each life stage and location through time to confirm assessments of Project impacts and determine actions or operational adjustments that may provide benefits for CHNWR. Findings from this measure may also inform potential ITP amendments involving CHNSR due to the similarities in life history and ecology to CHNWR.

5.2.11. Condition of Approval 8.7.4 – Juvenile Salmonid Sutter Bypass Entrainment and Survival Program

The Sutter Bypass constitutes a large and significant floodplain rearing habitat that juvenile CHNWR and CHNSR may access when Sacramento River flows are high enough to inundate portions of the bypass area. However, diversions proposed by the ITP Application (Sites Authority 2023) may change Sacramento River flows such that bypass inundation frequency may be reduced, impacting the opportunity for juvenile Chinook Salmon to access the floodplain. Under this Condition of Approval, Sites Authority will develop a telemetry study that will inform the general understanding of CHNWR and CHNSR routing, survival, and utilization (i.e., entrainment) of the Sutter Bypass, and impacts that Project operations may have on routing, survival, and opportunities for access (i.e., entrainment) to the Sutter Bypass. The results of this study will be used to confirm or update CDFW's understanding of Project effects on floodplain access, potentially inform actions to improve floodplain access, provide data that may be used to improve life cycle models for CHNWR and CHNSR, and may inform potential ITP amendments, if warranted.

5.2.12. Condition of Approval 8.7.5 – Pre-Smolt Juvenile Survival Program

While advances in otolith microchemistry have shed light on the complex and variable rearing strategies CHNWR and CHNSR juveniles (e.g., Phillis et al. 2018, Cordoleani et al. 2021), investigating behavior and survival for smaller fish remains a challenge due to the size of currently available acoustic telemetry tags (see Section 4.1.5). Techniques to evaluate survival of smaller fish, such as passive integrated transponder (PIT) tag mark-recapture or genetic tagging, have their own limitations, and large spatial range of rearing habitat used by CHNWR make them difficult to implement effectively. Studies that can elucidate the flow-survival relationship of smaller migrant salmon, specifically from listed CHNWR and CHNSR stocks are greatly needed.

Acoustic telemetry is a valuable tool for estimating in-river survival of migrating juvenile Chinook Salmon because of the high rate of "recapture" relative to effort and handling stress. However, there are shortcomings with this method as well. The largest of which is the minimal size requirement for fish before they can safely handle the acoustic transmitter. The minimum size for JSATS tagging juvenile Chinook Salmon is currently about 80 mm FL. Tagging fish that are >80 mm FL results in survival studies that focus on fish that are larger and beginning migration later in the season than most natural Chinook Salmon, meaning that survival estimates are based on these larger, later migrating fish. Studies that can derive estimates of survival without these strong size and temporal biases are needed to fill this gap.

Estimates of migratory survival of juveniles less than 80 mm FL will provide important context for the survival rates of smaller individuals that begin migrating earlier in the season. Improving our estimates of migration survival for smaller, earlier migrating fish will confirm CDFW's understanding of Project impacts to these individuals, while also providing data to improve life cycle models for CHNWR and CHNSR and inform potential ITP amendments, if warranted.

5.2.13. Condition of Approval 8.7.6 – Spring-run Chinook Salmon Life Cycle Model

While it was not available to inform the ITP Application (Sites Authority 2023), a life cycle model for CHNSR is currently under development, as required by the SWP ITP No. 2081-2019-066-00 (CDFW 2020a). When the SRLCM is available, Sites Authority will analyze the Project, including exchanges with Shasta and Oroville Reservoirs, real-time exchanges and transfers, and CVP operational flexibility. Model assumptions, data sources, and scenarios will be determined in consultation with CDFW and will incorporate new science, as appropriate. Using the SRLCM, Sites will quantify Project impacts and compare with the impacts identified in the ITP Application (Sites Authority

2023) and this Effects Analysis. Results of the SRLCM will be used to verify Project impacts and inform potential ITP amendments, if warranted.

5.2.14. Condition of Approval 8.7.7 – Protection of the Yolo Bypass Salmonid Habitat Restoration and Fish Passage Project Objectives

The Yolo Bypass is a large, off-channel floodplain that provides important habitat for juvenile CHNWR and CHNSR. This floodplain is currently only accessible to juveniles when flows on the Sacramento River are high enough to overtop Fremont Weir at the northern end of the floodplain. Through modifications at Fremont Weir, the Yolo Bypass Habitat Restoration and Fish Passage Project aims to increase the connectivity of the Yolo Bypass to the Sacramento River for improved juvenile salmon access and rearing and improved upstream passage for migrating adult salmon.

The first objective of the Yolo Bypass Salmonid Habitat Restoration and Fish Passage Project is to increase the availability of floodplain rearing habitat for juvenile CHNWR, CHNSR, and Central Valley steelhead. This action can also improve conditions for Sacramento splittail and Central Valley fall-run Chinook salmon. Specific biological goals include:

1. Improve access to seasonal habitat through volitional entry
2. Increase access to and acreage of seasonal floodplain fisheries rearing habitat
3. Reduce stranding and presence of migration barriers
4. Increase aquatic primary and secondary biotic production to provide food through an ecosystem approach

The second objective of the Yolo Bypass Salmonid Habitat Restoration and Fish Passage Project is to reduce migratory delays and loss of fish at Fremont Weir and other structures in the Yolo Bypass. Specific biological goals include:

1. Improve connectivity within the Yolo Bypass for passage of salmonids and sturgeon.
2. Improve connectivity between the Sacramento River and the Yolo Bypass to provide safe and timely passage for CHNWR, CHNSR, Central Valley steelhead, Green Sturgeon, and WS during specified time periods and river flows.

The Salmonid Habitat Restoration and Fish Passage Project includes the construction of a new gated notch in Fremont Weir located in the northern Yolo Bypass and channel that parallels the existing east levee of the Yolo Bypass. The gated notch and channel have the ability to convey flows up to 6,000 cfs, depending on the Sacramento River, to provide open channel flow for adult fish passage, juvenile fish emigration, and floodplain inundation. This alternative also includes a supplemental fish passage facility on the west side of Fremont Weir and improvements to allow fish to pass through Agricultural Road Crossing 1 and the channel north of Agricultural Road Crossing 1.

Diversions proposed in the ITP Application (Sites Authority 2023) would reduce Sacramento River flows such that they reduce frequency and duration of overtopping at Fremont Weir and the area of flooded habitat in the Yolo Bypass. These reductions have the potential to adversely affect connectivity goals and objectives of the Yolo Bypass Salmonid Habitat Restoration and Fish Passage Project once Fremont Weir modifications are complete. Under this measure, Sites Authority will develop a study to determine if Project operations may diminish the ability of the Yolo Bypass Salmonid Habitat Restoration and Fish Passage Project to achieve its goals and objectives and provide CDFW the study to determine whether an ITP amendment is necessary.

5.3. Winter-run and Spring-run Chinook Salmon and White Sturgeon – Water Quality Effects

Discharges from Sites Reservoir to the Sacramento River at KLOG, and to the Yolo Bypass via the Knights Landing Ridge Cut have the potential to alter the quality of recipient waters in ways that are harmful to CHNWR, CHNSR, and WS (see Section 4.1.3). Based on analyses described in Section 4, actions that may degrade water quality in recipient areas include 1) the discharge of reservoir releases with harmful characteristics or constituents (e.g. low dissolved oxygen, elevated metals), 2) the mobilization and transport of blocks of water and suspended sediment with harmful characteristics to discharge locations (e.g. low dissolved oxygen, high pesticides), 3) changes to the physical characteristics of water as it travels from the reservoir to discharge locations (e.g. temperature increases), and 4) water exchanges or transfers with partners. The following measures will avoid and minimize potential water quality impacts to Covered Species due to operation of the Project.

5.3.1. Condition of Approval 9.23 – Knights Landing Outfall Gates Water Releases Temperature Requirements Prior to Operations

High temperatures and abrupt increases in temperature can result in stress or mortality to CHNWR, CHNSR, and WS, and Project-related releases at KLOG could cause water temperature to exceed harmful thresholds (see Section 4.1.2.2). Under this Condition of Approval, Sites Authority will demonstrate that Project-related releases at KLOG will not cause Sacramento River temperature increases that are harmful to CHNWR, CHNSR, or WS through monitoring and a study that will inform the relationship between project release actions and water temperatures in the Sacramento River. The study plan will be reviewed and approved by CDFW before it is conducted. Temperature stations will be identified, installed, and maintained to support the study and ongoing monitoring (Condition of Approval 9.23.1). The Project will only release water at the KLOG after demonstrating that releases will not cause Sacramento River temperatures to increase more than 0.5 degrees F when Sacramento River temperatures are between 60 degrees F and 70 degrees F during the months of April through June and August through October. This Condition of Approval will ensure that any impacts to CHNWR, CHNSR or WS due to temperature changes caused by releases at the KLOG to the Sacramento River are minimized.

5.3.2. Condition of Approval 9.24 – Knights Landing Ridge Cut (Yolo Bypass) Water Releases Temperature Requirements

High temperatures and abrupt increases in temperature can cause harm to CHNSR that may stray into the Yolo Bypass instead of the Sacramento River (see Section 4.1.6.1). To avoid potential impacts to CHNSR, Sites Authority will not release water at KLRC to the Yolo Bypass if resulting water temperatures would exceed 70 °F at the Wallace Weir Fish Collection Facility. This measure will minimize potential temperature impacts to CHNSR resulting from Project-related water releases to Yolo Bypass.

5.3.3. Condition of Approval 9.25 – Knights Landing Outfall Gates Water Releases Dissolved Oxygen Requirements

Concentrations of DO in the CBD near KLOG are often very low, regularly dropping below 3 mg/L, a level that causes mortality in CHNWR, CHNSR, and WS. Sites Reservoir water is also expected to exhibit low DO at times due to organic matter decomposition (see Section 4.1.3.1). Thus, water with very low DO may be discharged at KLOG due to low DO water in the reservoir itself and the mobilization of low DO water in the CBD. CHNWR, CHNSR, and WS adults and juveniles may be present immediately downstream of KLOG and downstream in the Sacramento River, and these fish may be harmed if releases cause recipient waters to drop below levels that cause impairment, approximately 5 mg/L.

Condition of Approval 9.25 requires Sites Authority to develop and conduct a study that will inform the relationship between releases and DO at the KLOG and in the adjacent Sacramento River. For data that will inform the study and future monitoring, the Sites Authority will also install two (2) dissolved oxygen monitoring stations. Sites will only release water at KLOG after demonstrating that releases will not cause dissolved oxygen to drop below 5.0 mg/L. The study plan and monitoring station locations will be reviewed and approved by CDFW. Implementation of this measure will minimize potential impacts of low DO from Project releases on CHNWR, CHNSR, WS, and may also inform actions to minimize low DO impacts.

5.3.4. Condition of Approval 9.26 – Knights Landing Ridge Cut (Yolo Bypass) Water Releases Dissolved Oxygen Requirements

Water with very low DO may be discharged at Knights Landing Ridge Cut to the Yolo Bypass due to low DO water in the reservoir itself and the mobilization of low DO water in the CBD. Discharges may cause DO in the Yolo Bypass to drop abruptly, or drop below 5 mg/L, which is a level harmful to CHNSR (see Section 4.1.3.1). To avoid potential impacts to CHNSR, Sites Authority will not release water at KLRC to the Yolo Bypass if DO concentrations in the CBD at Ridge Cut Slough are 5.0 mg/L or lower. If the current monitoring station at Ride Cut Slough ceases to function, Sites Authority will install and maintain a new station with CDFW approval. This condition will minimize low DO impacts to CHNSR and any other Covered Species that may be present in the Yolo Bypass during discharge periods.

5.3.5. Condition of Approval 9.22 – Timing of Releases to the Yolo Bypass

The presence of CHNWR, CHNSR, and WS in the Yolo Bypass is dependent on time of year. As such, the species and life stages impacted by Sites Authority releases to the Yolo Bypass will depend heavily on the time of year releases are conducted. Condition of Approval 9.22 specifies that the Project only release water to the Yolo Bypass from August 1 to October 31, and it operates in concert with other conditions related to water releases to Knights Landing Ridge Cut and the Yolo Bypass (8.10, 8.11, 9.24, 9.26, 9.27) to ensure that releases will pose minimal impacts to CHNWR, CHNSR and WS that may be present in the region during the time of year releases are made.

5.3.6. Condition of Approval 8.10 – Water Quality Monitoring Plan for Pesticides at the Knights Landing Outfall Gates to the Sacramento River and the Knights Landing Ridge Cut to the Yolo Bypass

Concentrations of pesticides are very high in the CBD near the KLOG and the Knights Landing Ridge Cut. Discharges by the Project may mobilize this pesticide-laden water and suspended sediment, moving them into the Sacramento River and Yolo Bypass, impacting CHNWR, CHNSR and WS (see Section 4.1.3.2). Sites Authority will develop a monitoring plan to evaluate whether harmful concentrations of pesticides are transported and discharged in water or suspended sediment to the Sacramento River or Yolo Bypass where CHNWR, CHNSR, and WS are found. Details of the monitoring plan, including but not limited to specific sampling sites, sample collection timing and frequency, collection methods, sample analysis, and reporting frequency will be developed in consultation with CDFW (Conditions of Approval 8.10.1–8.10.3). The monitoring plan will be implemented by Sites Authority after review and approval from CDFW, and monitoring will continue through the term of the ITP. Results from the monitoring plan will be used to inform actions and ensure potential pesticide impacts to CHNWR, CHNSR, and WS are avoided or minimized.

5.3.7. Condition of Approval 8.11 – Detrimental Metals Monitoring Plan

Sites Reservoir will constitute a new source of metal and metalloid contaminants that could be transported and released to the Sacramento River or Yolo Bypass where CHNWR, CHNSR, and WS are present (see Section 4.1.3.3). Under this Condition of Approval, Sites Authority will develop a monitoring plan to evaluate whether harmful concentrations of metals are transported or discharged in water or suspended sediment to the Sacramento River or Yolo Bypass. Details of the monitoring plan, including but not limited to specific sampling sites, sample collection timing and frequency, collection methods, sample analysis, and reporting frequency, will be developed in consultation with CDFW. The monitoring plan will be implemented by Sites after review and approval from CDFW, and monitoring will continue through the term of the ITP. Results from the monitoring plan will be used to determine if discharges should be ceased to ensure detrimental impacts to CHNWR, CHNSR, and WS are avoided.

5.4. Minimization of Take and Impacts of the Taking on Longfin Smelt and Delta Smelt

5.4.1. Condition of Approval 9.4 – Maximum Total Annual Diversions

Condition of Approval 9.4 limits the Project to a maximum diversion of 986 thousand acre-feet (TAF). This measure provides a backstop that may, at times, restrict diversions from the Sacramento River that would have resulted in lower net Delta outflow, thereby avoiding and/or minimizing indirect Project-related impacts to LFS and DS habitat and food production.

5.4.2. Condition of Approval 9.8 – Diversions During Excess Conditions

Condition of Approval 9.8 specifies a diversion criterion that the Project may only divert when DWR and Reclamation have determined the Delta to be in “excess” conditions, and the Net Delta Outflow Index (NDOI) has increased by an additional 3,000 cfs after the determination of excess conditions. This measure allows the SWP and CVP to meet user demand while maintaining their regulatory requirements, including the protection of Delta outflow in winter and spring, a critical time in the life histories of LFS and DS. Through maintenance of salinity in the Delta, this measure minimizes impacts of the taking on DS and LFS habitat quality and quantity.

5.4.3. Condition of Approval 9.9 – Temporary Urgency Change Order for Delta Water Quality Objectives

Condition of Approval 9.9 restricts the Project from during times when Bay-Delta Water Quality Control Plan requirements for Delta Outflow, X2 (Spring), Rio Vista, Emmaton, Jersey Point, and Delta Export to Inflow (E:I) ratio are modified by a Temporary Urgency Change Petition/Order and the CVP or SWP are operating to the modified conditions. This measure contributes to minimizing Project-related impacts on LFS and DS by ensuring that the Project does not reduce Sacramento River flow and Delta outflow at times when flows are already critically low.

5.4.4. Condition of Approval 9.12 – Sacramento River Bypass Flow Criteria at Wilkins Slough

The Sacramento River bypass flow measure at Wilkins Slough, which includes a forecasting requirement, will minimize Project impacts on survival of out-migrating juvenile CHNWR and CHNSR by ensuring that Project Diversions do not reduce river flows to below the beneficial threshold of 10,930 cfs. This condition is expected to also contribute to minimizing Project impacts on LFS and DS by preventing Project diversions when Sacramento River flows are low, thereby avoiding reductions in Delta outflow at those times and minimizing adverse effects to LFS and DS habitat and food production.

5.4.5. Condition of Approval 9.13 – Allowable Diversions During Simultaneous Use at Red Bluff Pumping Plant and Hamilton City Pump Station

Condition of Approval 9.13 requires Sites Authority to account for other diversions at RBPP and HCPS when implementing the Sacramento River Bypass Flow Criteria at Wilkins Slough. This ensures that Project-related diversions will not reduce river flows to below the beneficial threshold of 10,930 cfs when RBPP and/or HCPS are simultaneously being used by other entities than the Permittee. Like Condition of Approval 9.12, Condition of Approval 9.13 is expected to provide protections for LFS and DS by limiting Project diversions when Sacramento River flows are low, thereby avoiding reductions in Delta outflow at those times and minimizing adverse effects to LFS and DS habitat and food production.

5.4.6. Condition of Approval 9.14 – Flow-Dependent Diversion

Conditions of Approval 9.14, 9.14.1 and 9.14.2 set minimum bypass flow criteria for Red Bluff and Hamilton City and require that the Project divert water in proportion to Sacramento River flow at each location (Flow-Dependent Diversion or FDD). Tables included in Conditions of Approval 9.14.1 and 9.14.2 specify the maximum diversion rate at each location across a specified range of river flow. These conditions protect the shape of the natural hydrograph of the Sacramento River and limit the instantaneous fraction of Sacramento River flow that may be diverted. FDD provides protections for all five Covered Species; importantly, it preserves seasonal and short-term trends in Sacramento River inflow to the Delta during winter and spring, when freshwater flow through the Delta is most needed for LFS and DS food production and for maintenance of their spawning and rearing habitat, thereby minimizing some potential impacts of Project diversions on LFS and DS and their habitat.

5.4.7. Conditions of Approval 9.18–9.20 – Operational Exchanges

Conditions of Approval 9.18, 9.19, and 9.20 govern Project-facilitated operational exchanges, including exchanges with Shasta and Oroville reservoirs. Condition 9.18 requires that any exchanges or transfer facilitated by Sites Authority will comply with all Conditions of Approval in the ITP to minimize impacts to CHNWR, CHNSR, WS, LFS, and DS. Condition of Approval 9.19 ensures that the Permittee will not facilitate an exchange with Shasta Reservoir if that exchange results in Reclamation not meeting its regulatory requirements, which include actions to protect CHNWR, CHNSR, LFS, DS, Central Valley steelhead, and Green Sturgeon. Condition of Approval 9.20 ensures that the Permittee will not facilitate an exchange with Oroville Reservoir if that exchange results in DWR not meeting its regulatory requirements, which include actions to protect CHNWR, CHNSR, WS, LFS, and DS. These actions and species requirements include and overlap with benefits for LFS and DS and therefore minimize potential impacts of Project-related exchanges and transfers, including exchanges with Shasta and Oroville reservoirs.

5.4.8. Condition of Approval 9.24 – Knights Landing Ridge Cut (Yolo Bypass) Water Releases Temperature Requirements

Discharges to Knights Landing Ridge Cut may cause water temperatures in the Yolo Bypass to increase to levels harmful for DS that may be in the vicinity, although CDFW's analysis in Section 4.3.1.3 found that risk to be small. Under this Condition of Approval, Sites Authority will not release water at KLRC to the Yolo Bypass if the resulting water temperature will exceed 70 °F at the Wallace Weir Fish Collection Facility. This measure minimizes potential temperature impacts to CHNSR as a result of Project-related water releases to Yolo Bypass and is also expected to avoid adverse effects to DS by ensuring that Project releases do not abruptly increase the water temperature on the Yolo Bypass at a time when DS may be present.

5.4.9. Condition of Approval 9.26 – Knights Landing Ridge Cut (Yolo Bypass) Water Releases Dissolved Oxygen Requirements

Water with very low DO may be discharged at Knights Landing Ridge Cut to the Yolo Bypass due to low DO water in the reservoir itself and/or the mobilization of low DO water in the CBD. Discharges may cause DO in the Yolo Bypass to decrease abruptly or below 5 mg/L (see Section 4.3.1.2). To avoid potential impacts to DS, Sites Authority will not release water at Knights Landing Ridge Cut to the Yolo Bypass if DO concentrations in the CBD at Ridge Cut Slough are 5.0 mg/L or lower. If the current monitoring station at Ride Cut Slough ceases to function, Sites Authority will install and maintain a new station with CDFW approval. This condition will avoid potential Project-related impacts related to low DO in the Yolo Bypass during releases by preventing releases into the Yolo Bypass when DO is very low.

5.4.10. Condition of Approval 8.9 – Longfin Smelt and Delta Smelt Science Requirements

Conditions of Approval 8.9.1–8.9.2 are science actions designed to fill data gaps and ensure that adverse effects to DS and LFS due to Project operations are identified and fully minimized, as described in Sections 4.3 and 4.4 of this Effects Analysis. These science actions will be conducted in collaboration with CDFW and other relevant State and Federal agencies, as appropriate.

5.4.11. Condition of Approval 8.9.1 – Longfin Smelt Life Cycle Model

Within one year after the Longfin Smelt Life Cycle Model (LFSLCM) is available for public use, Sites Authority will use it to evaluate how Project operations affect Delta flows, salinities, and LFS productivity. Sites Authority will use the LFSLCM to compare LFS life stage abundances and vital rates among at least three Project scenarios depicting a wide range of possible operations. Results will be used to verify CDFW's understanding of Project impacts to LFS and may inform potential ITP amendments, if warranted.

5.4.12. Condition of Approval 8.9.2 – Sediment Monitoring Plan

Reductions in suspended sediment delivery and water turbidity have been linked to the decline of DS. Diversions proposed in the ITP Application (Sites Authority 2023) are likely to remove suspended sediment from the Sacramento River, reducing turbidity in the Delta. Under this condition of approval, Sites will develop a sediment monitoring plan to quantify the entrainment of sediment due to Project diversions at the Red Bluff Pumping Plant and Hamilton City Pump Station and assess the effect on DS abundance, recruitment, and spatial distribution. If significant impacts are found, Sites Authority will develop a sediment reintroduction plan. This condition may also provide protection for LFS and their habitat, as larval LFS catch has been statistically associated with turbidity (Brennan et al. 2022). The sediment monitoring plan and, if necessary, sediment reintroduction plan will minimize potential Project-related impacts on fine-sediment transport and delivery to the Delta.

5.4.13. Condition of Approval 8.10 – Water Quality Monitoring Plan for Pesticides at the Knights Landing Outfall Gates to the Sacramento River and the Knights Landing Ridge Cut to the Yolo Bypass

Concentrations of pesticides are very high in the CBD near KLOG and the Knights Landing Ridge Cut. Water released by the Sites Authority has the potential to mobilize this pesticide-laden water and suspended sediment into the Sacramento River and Yolo Bypass, impacting DS (see Section 4.3.1.1). Condition of Approval 8.10 requires Sites Authority to develop a monitoring plan to evaluate whether harmful concentrations of pesticides are transported and discharged in water or suspended sediment to the Sacramento River or Yolo Bypass where DS are found. Details of the monitoring plan, including but not limited to specific sampling sites, sample collection timing and frequency, collection methods, sample analysis, and reporting frequency, will be developed in consultation with CDFW (see Conditions of Approval 8.10.1-8.10.3). Results from the monitoring plan will be used to ensure that potential pesticide impacts to DS are avoided or minimized. The monitoring plan will be implemented by Sites Authority after review and approval from CDFW, and monitoring will continue through the term of the ITP in order to avoid and minimize potential impacts of pesticide contamination related to Project operations.

5.4.14. Condition of Approval 8.11 – Detrimental Metals Monitoring Plan

Sites Reservoir will constitute a new source of metal and metalloid contaminants that may be transported and released to Yolo Bypass where DS are present (see Section 4.3.1). Under this Condition of Approval, Sites Authority will develop a monitoring plan to evaluate whether harmful concentrations of metals are transported or discharged in water or suspended sediment to the Sacramento River or Yolo Bypass. Details of the monitoring plan, including but not limited to specific sampling sites, sample collection timing and frequency, collection methods, sample analysis, and reporting frequency, will be developed in consultation with CDFW. Results from the monitoring plan will be used to ensure that potential metal impacts from project discharges to DS are avoided and minimized. The monitoring plan will be implemented by Sites after review and approval from CDFW, and monitoring will continue through the term of the ITP in order to avoid and minimize the potential impacts of metal and metalloid contamination due to Project operations.

6. MITIGATION OF TAKE AND IMPACTS OF THE TAKING

6.1. Condition of Approval 10.1 – White Sturgeon Spawning Area Supplementation Program

Sites Authority will develop and fund a plan to supplement gravel, cobble, and/or boulders to improve habitat at known WS spawning locations in the Sacramento River (see Section 3.5). DWR is currently undergoing an initial scoping process to identify and evaluate potential habitat restoration sites within the Sacramento and San Joaquin River, as required by ITP No. 2081-2019-066-00, Amendment 9 (CDFW 2024a). Sites Authority will coordinate with DWR to be included as a potential partner. Within a year of publishing of DWR's final report on spawning area supplementation, Sites Authority will identify one or more restoration projects in DWR's report to implement and include the scope, cost, and timeline in a White Sturgeon Spawning Area Supplementation Program (WSSASP).

6.2. Condition of Approval 10 – Longfin Smelt and Delta Smelt Compensatory Habitat

Sites Authority will permanently protect and manage habitat to fully mitigate Project-related impacts of the taking on LFS and DS. Sites Authority will either purchase 13.2 acres of tidal habitat for LFS and DS from a CDFW-approved mitigation or conservation bank, and/or provide for the permanent protection and management of the acres of Habitat Management (HM) lands. Purchase of credits and/or permanent protection and funding for management of HM lands will be complete prior to the initiation of Project operations, or Sites Authority will provide a Security to CDFW as specified in the ITP. Sites Authority may be required to permanently protect and manage additional acres of compensatory mitigation if the 13.2 acres does not support both LFS and DS, based on CDFW review and approval.

6.3. Condition of Approval 10 – Winter-run and Spring-run Chinook Salmon Compensatory Habitat

Sites Authority will permanently protect and manage habitat to fully mitigate Project-related impacts of the taking on CHNWR and CHNSR. Sites Authority will either purchase 356 acres of off-channel rearing habitat for CHNWR and CHNSR; and 9.2 acres of wetland bench habitat for CHNWR and CHNSR of Covered Species credits from a CDFW-approved mitigation or conservation bank, and/or provide for the permanent protection and management of the acres of HM lands. Purchase of credits and/or permanent protection and funding for management of HM lands will be complete prior to the initiation of Project operations, or Sites Authority will provide a Security to CDFW as specified in the ITP. Based on CDFW review and approval, Site Authority may provide dual or "stacked" CHNWR and CHNSR habitat from a CDFW-approved mitigation or conservation bank or HM Lands as compensatory habitat of 178 acres of off-channel rearing habitat and 4.6 acres of wetland bench habitat, if the habitat benefits both CHNWR and CHNSR.

7. REFERENCES

5 United States Code § 553(e). Rule Making.

16 United States Code § 1533(b). Determination of endangered species and threatened species.

40 Code of Federal Regulation § 131.38. Establishment of numeric criteria for priority toxic pollutants for the State of California.

50 Code of Federal Regulation § 424.14. Petitions for listing endangered and threatened species and designating critical habitat.

54 Federal Register 32085. (August 4, 1989). Endangered and threatened species; critical habitat; winter-run Chinook Salmon.

58 Federal Register 12854. (March 5, 1993). Endangered and threatened wildlife and plants; determination of threatened status for the Delta Smelt.

58 Federal Register 33212. (June 16, 1993). Designated critical habitat; Sacramento River winter-run Chinook Salmon.

59 Federal Register 440. (January 4, 1994). Endangered and threatened species; status of Sacramento River winter-run Chinook Salmon; final rule.

59 Federal Register 65256. (December 19, 1994). Endangered and threatened wildlife and plants; critical habitat determination for the Delta Smelt.

63 Federal Register 11482. (March 9, 1998). Endangered and threatened species: proposed endangered status for two Chinook Salmon ESUs and proposed threatened status for five Chinook Salmon ESUs; proposed redefinition, threatened status, and revision of critical habitat for one Chinook Salmon ESU; proposed designation of Chinook Salmon critical habitat in California, Oregon, Washington, Idaho.

64 Federal Register 50394. (September 16, 1999). Endangered and threatened species; threatened status for two Chinook Salmon evolutionarily significant units (ESUs) in California.

70 Federal Register 37160. (June 28, 2005). Endangered and threatened species: final listing determinations for 16 ESUs of west coast salmon, and final 4(d) protective regulations for threatened salmonid ESUs.

70 Federal Register 52488. (September 2, 2005). Endangered and threatened species; designation of critical habitat for seven evolutionarily significant units of Pacific Salmon and Steelhead in California.

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