

Effects Analysis

State Water Project Effects on Winter-run and Spring-run Chinook Salmon

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Prepared by California Department of Fish and Wildlife

This Effects Analysis was prepared by the following California Department of Fish and Wildlife staff:
Anna Allison, Sheena Holley, Lauren McNabb, Vanessa Kollmar, Kenneth Kundargi, Duane Linander,
Bjarni Serup, Jason Julienne, Matt Johnson, Colin Purdy, Michael R. Harris, Steve Tsao, Trinh Nguyen,
and Brooke Jacobs.

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List of Acronyms and Abbreviations

7DADM	7-day average of the daily maximum
°C	degrees Celsius
°F	degrees Fahrenheit
AMP	Adaptive Management Plan
Banks Pumping Plant	Harvey O. Banks Pumping Plant
BiOp	Biological Opinion
BSOG	Butte Slough Outfall Gates
BSPP	Barker Slough Pumping Plant
Cal. Code Regs.	California Code of Regulations
CalSim II	California Simulation
CAMT	Collaborative Adaptive Management Team
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
CFPS	Clifton Court Forebay Predation Studies
cfs	cubic feet per second
CHNFR	fall-run Chinook salmon
CHNLFR	late fall-run Chinook salmon
CHNSR	spring-run Chinook salmon
CHNWR	winter-run Chinook salmon
cm	centimeter(s)
CNFH	Coleman National Fish Hatchery
CVP	Central Valley Project
CWT	coded-wire tag
D-1641	SWRCB Water Rights Decision 1641
DCC	Delta Cross Channel
DEIR	Draft Environmental Impact Report
Delta	Sacramento-San Joaquin Delta
DOSS	Delta Operations for Salmonids and Sturgeon
DPM	Delta Passage Model
DPS	Distinct Population Segment
DS	Delta Smelt
DSM2	Delta Simulation Model 2
DTUs	Duplicant Temperature Units
DWR	California Department of Water Resources
USEPA	United States Environmental Protection Agency
ESA	Endangered Species Act
Estuary	San Francisco Bay Estuary
ESU	Evolutionary Significant Unit
FEIR	Final Environmental Impact Report
FR	Federal Register
FRFH	Feather River Fish Hatchery

ft	foot (feet)
ft/s	foot (feet) per second
GYSO	Goodyear Slough Outfall
HOR	Head of Old River
HORB	Head of Old River Barrier
ITP	Incidental Take Permit
Jones Pumping Plant	C.W. Bill Jones Pumping Plant
JPE	Juvenile Production Estimate
JPI	Juvenile Production Index
km	kilometer
LAD	length-at-date
LFS	Longfin Smelt
LSNFH	Livingston Stone National Fish Hatchery
m	meter
MAF	million acre-feet
MIDS	Morrow Island Distribution System
mm	millimeter(s)
m/s	meter(s) per second
NFH	Nimbus Fish Hatchery
NMFS	National Marine Fisheries Service
NTU	nephelometric turbidity units
OMR	Old and Middle River
Permittee	California Department of Water Resources
PFRS	Clifton Court Forebay Predator Fish Relocation Study
ppt	parts per thousand
PRES	Clifton Court Forebay Predator Reduction Electrofishing Studies
Project	State Water Project
PTM	Particle Tracking Model
QA/QC	Quality Assurance/Quality Control
QWEST	Net flow on the San Joaquin River at Jersey Point
RBDD	Red Bluff Diversion Dam
Reclamation	United States Bureau of Reclamation
RM	river mile
RPA	Reasonable and Prudent Alternative
RRDS	Roaring River Distribution System
RST	Rotary Screw Trap
SacPAS	Central Valley Prediction and Assessment of Salmon
salvage facilities	John E. Skinner Delta Fish Protective Facility and Tracy Fish Collection Facility
Skinner Fish Facility	John E. Skinner Delta Fish Protective Facility
SJRRP	San Joaquin River Restoration Program
SMSCG	Suisun Marsh Salinity Control Gates
SST	Salmonid Scoping Team

STARS	Survival, Travel Time, and Routing Simulation
SWP	State Water Project
SWRCB	State Water Resources Control Board
TAF	thousand acre-feet
Tracy Fish Facility	Tracy Fish Collection Facility
USFWS	United States Fish and Wildlife Service
WOMT	Water Operations Management Team
X2	The two ppt isohaline location in km from the Golden Gate Bridge
YOY	young-of-year

1. Introduction

In response to the Department of Water Resources (DWR, Permittee) request for authorization for the incidental take of longfin smelt (*Spirinchus thaleichthys*, LFS), Delta smelt (*Hypomesus transpacificus*, DS), winter-run Chinook salmon (*Oncorhynchus tshawytscha*, CHNWR), and spring-run Chinook salmon (*Oncorhynchus tshawytscha*, CHNSR) under the California Endangered Species Act (CESA) for existing and future operations in the Sacramento-San Joaquin Bay-Delta (Delta) of the State Water Project (SWP; Project), we conducted analyses for each species based on DWR's Incidental Take Permit (ITP) Application for Long-term Operation of the Project dated December 13, 2019 (ITP Application), DWR's Draft and Final Environmental Impact Reports (DEIR and FEIR), existing data, and literature. In this document, we provide background information, methodologies and approaches used, and discussions and definitions of the terminology and information available. This document focuses on analyses conducted for CHNWR and CHNSR. Analyses conducted for LFS and DS are provided in a separate Effects Analysis document dated March 2020.

At the time DWR submitted its ITP Application to CDFW, DWR had completed CalSim II model runs and runs of hydrologic and biological models that incorporate CalSim II outputs, including Delta Simulation Model 2 (DSM2), that characterized operations described in the Proposed Project of the DEIR. After DWR submitted the ITP Application, DWR conducted additional CalSim II modeling to characterize operations described in Alternative 2b of the Draft EIR. DWR provided preliminary results from the Alternative 2b CalSim II runs to CDFW in January 2020 in separate transmittals. After completing Alternative 2b CalSim II runs, DWR ran hydrologic and biological models that incorporate CalSim II outputs, including DSM2, to support the effects analysis for Refined Alternative 2b within the FEIR and the Project Description and associated Conditions of Approval in the ITP. These additional model results were provided to CDFW in separate transmittals and as administrative drafts of the FEIR in February and March 2020. When analyses conducted by DWR are referenced in this document, they refer to the Refined Alternative 2b model runs included in the FEIR.

As part of our analysis, we have considered that Project operations will be consistent with existing water supply contracts, flood control needs, and certain operational criteria and other actions set forth in the FEIR, United States Fish and Wildlife Service (USFWS) Biological Opinion for the Reinitiation of Consultation on the Coordinated Operations of the Central Valley Project and State Water Project issued on October 21, 2019 (USFWS 2019 BiOp; USFWS 2019) and the National Marine Fisheries Service (NMFS) Endangered Species Act Section 7 Biological Opinion on Long-term Operation of the Central Valley Project and the State Water Project (NMFS 2019 BiOp; NMFS 2019). In addition, we considered that the Project will comply with all applicable State, federal, and local laws and regulations in existence or adopted thereafter the issuance of the ITP as well as State Water Resources Control Board (SWRCB) Water Rights Decision 1641 (D-1641; SWCRB 2000).

2. Project Description

DWR will continue to operate the SWP facilities in the Delta and Suisun Marsh. The SWP includes water, power, and conveyance systems, conveying an annual average of 2.9 million acre-feet (MAF)

of water. The principal facilities of the SWP are Oroville Reservoir and related facilities, and San Luis Dam and related facilities, facilities in the Delta, the Suisun Marsh Salinity Control Gates (SMSCG), the California Aqueduct including its terminal reservoirs and the Delta-Mendota Canal/California Aqueduct Intertie (DCI), and the North and South Bay Aqueducts. Permittee holds contracts with 29 public agencies in northern, central, and southern California for water supplies from the SWP. Water stored in the Oroville facilities, along with water available in the Delta (consistent with applicable regulations) is captured in the Delta and conveyed through several facilities to SWP contractors. The SWP is operated to provide flood control and water for agricultural, municipal, industrial, recreational, and environmental purposes.

The Project includes operations of the Harvey O. Banks Pumping Plant (Banks Pumping Plant), the Clifton Court Forebay (CCF), the John E. Skinner Delta Fish Protective Facility (Skinner Fish Facility), the Barker Slough Pumping Plant (BSPP), the South Delta Temporary Barriers, San Luis Reservoir, the DCI, the Georgiana Slough Migratory Barrier, and Suisun Marsh facilities including the SMSCG, Roaring River Distribution System (RRDS), Morrow Island Distribution System (MIDS), and Goodyear Slough Outfall (GYSO).

The Project is located within the following geographic area (Project Area, See Figures 1A and B attached to the ITP):

- Sacramento River from its confluence with the Feather River downstream to the legal Delta boundary at the I Street Bridge in the City of Sacramento;
- Sacramento-San Joaquin Delta (i.e., upstream to Vernalis and downstream to Chipps Island); and
- Suisun Marsh and Bay

Project operations will be in all fish-bearing waterways within the Project Area. The northern edge of the Project Area is located approximately 8.56 km northeast of Knights Landing in Yolo County at approximately 38.785281 latitude, -121.621825 longitude and extends downstream on the Sacramento River to the Delta. To the south and east the Project Area is bounded by the legal boundary of the Delta. To the west the Project Area is bounded by the legal Delta, Suisun Marsh, and Suisun Bay.

Project activities contemplated under the ITP are detailed in the permit and include the following: operations of the Banks Pumping Plant, Skinner Fish Facility, operation of the South Delta Temporary Barriers, predator control and aquatic weed treatment and removal in CCF, Georgiana Slough Migratory Barrier, Barker Slough Pumping Plant, and operations of the SMSCG, RRDS and MIDS, and other activities within the Project Area described in the Project Description section of the ITP.

3. List of Covered Species

The ITP provides Permittee with incidental take authorization for the Project for the following species, referred to collectively as “Covered Species”:

1. Longfin smelt, CESA-listed as Threatened
2. Delta smelt, CESA-listed as Endangered
3. Spring-run Chinook salmon, CESA-listed as Threatened
4. Winter-run Chinook salmon, CESA-listed as Endangered

4. Covered Species Life History

4.1. Winter-run Chinook Salmon

4.1.1. Listing History

On September 22, 1989, the California Fish and Game Commission listed CHNWR as endangered under CESA (See Cal. Code Regs., tit. 14, § 670.5, subd. (a)(2)(M)). The Sacramento River CHNWR evolutionary Significant Unit (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 FR 32085) and subsequently uplisted to endangered on January 4, 1994 (59 FR 440). CHNWR were reaffirmed as endangered on June 28, 2005 (70 FR 37160) and 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).

4.1.2. Population Status and Trends

CHNWR populations were as high as 120,000 fish in the 1960s, but by the 1990s had declined to less than 200 fish (NMFS 2019). From 1967 through 2000, CHNWR escapement estimates were based on counts of salmon passing through the Red Bluff Diversion Dam (RBDD) fish ladders (RM 243). From 1969 through 1985, RBDD was typically operated throughout the entire CHNWR migration period, which allowed for a complete accounting of CHNWR escapement (Killam et al. 2016). In 1986, the operation of RBDD was modified to improve CHNWR migration, with dam gates typically raised from mid-September through mid-May of the following year to allow unimpeded upstream passage of most CHNWR adults (Killam et al. 2016). Beginning in 2001, carcass surveys conducted on the Sacramento River by the USFWS, and CDFW replaced the RBDD counts as the official means to obtain an annual CHNWR population estimate (Killam et al. 2016). Since carcass surveys began in 2001, the highest adult escapement occurred in 2005 and 2006 with 15,839 and 17,296, respectively. From 2007 to 2017, the population has shown a precipitous decline, averaging 2,733 during this period, with a low of 827 adults in 2011. In 2015, the population was estimated at 3,015 adults, just slightly above the 2007 to 2012 average, but well below the high (17,296) for the last 10 years (CDFW 2019b). While the 2018 adult escapement estimate was also relatively low at 2,639, escapement in 2019 rose to 8,033, the highest CHNWR population observed since 2006 (CDFW 2019b). Declining trends observed in CHNWR populations 2007 through 2018 were likely due to a combination of factors such as poor ocean productivity, drought conditions from 2007 to 2009, low in-river survival, and extreme drought conditions from 2012 to 2016 (NMFS 2019).

4.1.3. Extinction Risk

The CHNWR population in California consists entirely of a single spawning population in the Sacramento River. This 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, persistence of this population is precarious (NMFS 2014). USFWS operates a conservation hatchery program for CHNWR at the Livingston Stone National Fish Hatchery (LSNFH) located at the base of Shasta Dam. The hatchery consists of both an integrated-recovery supplementation program and a captive broodstock program (USFWS 2015). NMFS (2019) states the average annual hatchery production at LSNFH is approximately 216,015 per year (2001 to 2018 average) compared to the estimated natural production that passes

RBDD, which is 2.9 million per year based on the 2002 to 2018 average (as cited in Poytress and Carrillo 2011 and USFWS 2018).

Lindley et al. (2007) developed extinction risk criteria for Central Valley salmonid populations based on viability parameters for abundance, population decline rate, and hatchery influence. In its latest five-year status review, NMFS concluded the most recent biological information suggests the extinction risk of the CHNWR ESU has increased since the last status review largely due to extreme drought and poor ocean conditions (NMFS 2016b). Juvenile CHNWR production was increased at LSNFH in 2014 and 2015 to buffer against drought conditions. The increased supplementation appeared to have been successful as adult escapement through 2018 met the low extinction risk criterion for abundance (i.e., a census population size of 2,500), however high extinction risk for the population was triggered by the hatchery influence criterion, with a mean of 66% hatchery origin spawners from 2016 through 2018. Although adult CHNWR returns increased in 2018 and 2019, based on the Lindley et al. (2007) criteria, the population remains at high extinction risk in 2019.

4.1.4. Adult Migration

Adult CHNWR enter the San Francisco Bay Estuary (Estuary) in November to begin their upstream spawning migration and continue to proceed up the Sacramento River through August, finally holding near spawning areas in the upper reaches of the river (Yoshiyama et al. 1996; NMFS 1998; Moyle 2002). Boles et al. (1988) cites water temperatures less than 65°F (18.3°C) preferable for adult Chinook salmon migration, and Lindley et al. (2004) report that water temperature acts as a migration barrier and leads to stress when reaching 70°F (21.1°C).

Adult passage through the upper Sacramento River is well documented by historical observations at RBDD. From 1967 to 1986, year-round operation of RBDD provided a comprehensive method of monitoring passage of all four salmon runs in the Sacramento River (Killam et al. 2016). Historical fish passage monitoring at RBDD showed that CHNWR entry into the upper Sacramento River begins in mid-December and continues into early August, with peak passage in mid-March (Hallock and Fisher 1985).

4.1.5. Adult Stranding

Adult CHNWR, like other salmonids migrating through the freshwater environment, require enough flow for passage, olfactory cues, and adequate water quality and temperature (CDFG 1998). Attraction of adults into terminal waterways and migration barriers result in delays or stranding, which ultimately affects spawning success. Flood bypasses and drainage canals are known stranding areas for CHNWR as documented by CDFW fish salvage efforts (Beccio 2016; Gahan et al. 2016; CDFW 2017).

4.1.6. Adult Holding and Spawning

Adult CHNWR entering freshwater are sexually immature and hold in cold water pools for several months until early summer when air temperatures usually approach their yearly maximum (NMFS 2014; Moyle 2002). Among west coast Chinook salmon stocks this spawn-timing is exclusive to CHNWR. The evolution of this spawn-timing was dependent upon cold spring water sources generated from glacier and snow melt percolating through porous volcanic formations surrounding Mt. Shasta and Mt. Lassen, which protected embryos and juveniles from the warm ambient conditions in summer (NMFS 2014; Moyle 2002). These conditions are found in spring-fed tributaries in the upper Sacramento River watershed, especially the McCloud River (Moyle 2002).

Following the construction of Shasta Dam in 1945, CHNWR lost access to their historical spawning habitat in the upper Sacramento River (upstream of Shasta Dam), McCloud River, and Pitt River, restricting them to a single population inhabiting a relatively small cold-water reach just downstream of Keswick Dam (del Rosario et al. 2013; Yoshiyama et al. 1998). Cold water habitat in Battle Creek, a tributary to the Sacramento River located at RM 271, historically supported a population of CHNWR, however construction and operation of hydropower facilities led to extirpation of the population. Current restoration efforts for CHNWR involve reintroducing fish to Battle Creek.

CHNWR, like other spawning salmonids, deposit their eggs within a redd (nest) dug into the substrate of the streambed. Redds are often constructed at the tails of holding pools. Adult fish have been observed spawning in water as shallow as 0.8-foot-deep and in water velocities of 1.2 to 3.5 ft/s. Optimum redd substrate is a gravel/cobble mixture with a mean diameter of 1 to 4 inches and less than 5% fines (CDFG 1998). Incubation, hatching, and subsequent emergence of fry take place within a redd. CHNWR spawn in the mainstem Sacramento River between Keswick Dam and RBDD (NMFS 2014). The adult CHNWR spawning population is composed primarily of age-3 fish (91%), but also includes age-2 fish (1%) and age-4 fish (8%) (Fisher 1994). Average fecundity for CHNWR is 3,743 eggs per female (Fisher 1994). Spawning occurs between late-April and mid-August, with a peak in June and July as reported by CDFW annual escapement surveys (2000-2006) (NMFS 2014). The spawning distribution of CHNWR, as determined by aerial redd surveys conducted by CDFW, is somewhat dependent on the operation of the gates at RBDD (historically), river flow, and water temperature (NMFS 2014). In recent years CHNWR spawning distribution has shifted upstream, and since 2001, most CHNWR redds have occurred within the first 16 km downstream of Keswick Dam (Doug Killam personal communication 1/2020).

4.1.7. Redd Maintenance

4.1.7.1. Temperature Management

The embryo life stage begins with fertilization, then egg incubation, and ends with fry emergence from the gravel. Within the appropriate water temperature range, eggs normally hatch 40 to 60 days after fertilization. Newly hatched fry (alevins) continue to remain in the gravel for an additional four to six weeks until the yolk sac has been absorbed (NMFS 2014). NMFS (2014) describes CHNWR fry emergence occurring from mid-June through mid-October. However, recent monitoring of late spawning CHNWR (from mid-July to mid-August) by CDFW suggests fry emergence occurs through October and into early November (Doug Killam personal communication 1/2020). Water temperature greatly influences the duration of egg incubation and time of emergence in different river drainages, with emergence occurring after the yolk-sac is absorbed (Williams 2006). Approximately 900-1,000 thermal units are required for incubation of Chinook salmon eggs (1 thermal unit = 1°C above freezing x 24 hours) (Raleigh et al. 1986). Research on incubation survival at constant exposure indicates that the optimum water temperature for salmonid egg survival ranges from 6-10°C; complete mortality has been noted at incubation temperatures from 13.9 to 19.4°C (USEPA 2001). Additionally, USEPA (2001) suggests that subsequent mortality may occur in successfully hatched fry from eggs incubated in warm water. For example, coagulated yolk disease, in which a portion of the yolk coagulates and cannot be absorbed by the fry, is responsible for much of the mortality of hatched fry reared in higher than optimal water temperatures (Boles et al. 1988). These effects make water temperature an important environmental influence on salmon survival.

Sacramento River temperatures are artificially maintained through cold water releases in the summer from Shasta Reservoir in order to provide adequate spawning and rearing habitat downstream. Water temperatures in the upper Sacramento River are the result of interactions among ambient air temperature, water volume, water temperature at release from Shasta and Trinity Dams, total reservoir storage, location of reservoir thermocline, ratio of Spring Creek Power Plant release to Shasta Dam release, operation of the Temperature Control Device on Shasta Dam, and tributary inflows (NMFS 2014). In general, water released from Keswick Dam warms as it moves downstream during the summer and early fall months at a critical time for the successful development and survival of CHNWR embryos and emergent fry (NMFS 2014). Reclamation has struggled to maintain an adequate cold water pool in Shasta Reservoir in critically dry water years and extended drought periods in order to maintain suitable temperatures for CHNWR egg incubation, fry emergence, and juvenile rearing in the Sacramento River (NMFS 2016b). While Reclamation has created and implemented improved Shasta Reservoir storage plans beginning in 2010, the threat of warm water releases from Shasta Dam remains a significant stressor to CHNWR, as exemplified by recent extended drought conditions in California from 2012 through 2016, during which water releases from Shasta Reservoir in 2014 and 2015 contributed to 5.6% and 4.2% egg-to-fry survival rates, respectively, to RBDD (NMFS 2016b).

In 2017, in response to the low egg-to-fry survival rates during the drought, NMFS submitted a proposed amendment to RPA Action Suite 1.2 of its 2009 BiOp (NMFS 2009) related to Shasta Reservoir operations to address temperature-dependent mortality of CHNWR embryos (NMFS 2017). Specifically, the RPA amendment recommended temperature-dependent mortality thresholds for CHNWR embryos based on water year type as managed through Shasta Reservoir minimum storage targets for the late spring (April 1 through May 31) and end of September (see NMFS 2017 for more detail regarding the recommended thresholds and storage targets). Additional measures recommended by NMFS (2016b) to reduce temperature-dependent mortality and improve Shasta Reservoir cold water pool management include: improving reservoir, meteorological, and hydrologic modeling and monitoring in order to most efficiently manage the reservoir's limited amount of cold water; installation of additional temperature monitoring stations in the upper Sacramento River to better monitor real-time water temperatures; and enhanced CHNWR redd, egg, and juvenile monitoring.

4.1.7.2. Dewatering

Stable and continuous river flows are important to the early life history (egg incubation to emergence from the gravel) of salmonids. If redds are dewatered or exposed to warm, deoxygenated water, incubating eggs and/or larval fish may not survive. Dewatering can occur anytime a stream flow reduction occurs. On the upper Sacramento River, the transition from summer to winter flow regimes involves flow reductions from September to November as less water is needed for agricultural purposes (Revnak et al. 2017). Late spawning CHNWR (mid-July to mid-August) are of particular concern because redds constructed in shallow areas are susceptible to dewatering under typical flow reduction actions undertaken by Reclamation that occur beginning in late August as agricultural water demands decrease (Revnak et al. 2017). In response, CDFW has increased monitoring of shallow CHNWR redds to allow near real-time management recommendations to protect redds as flows are reduced (Revnak et al. 2017).

4.1.8. Juvenile Migration

CHNWR juveniles primarily express an ocean-type life history pattern, with juveniles leaving spawning areas in the upper Sacramento River as fry. Chinook salmon fry swim or are displaced downstream after emerging from the gravel (Healey 1991). Once downstream movement has commenced, fry either rear in the river for a period that varies from weeks to a year or continue sustained movement downstream until reaching the estuarine environment (Healey 1991). Within the stream environment, fry seek out habitats on channel margins, which provide slower water velocities for resting, and riparian vegetation or other forms of cover that provide avoidance from predators and sources of aquatic and terrestrial invertebrates for food (NMFS 2014). NMFS (2014) describes juvenile salmon downstream movement as primarily crepuscular, while Poytress et al. (2014) notes that rotary screw trap (RST) passage data indicates fry size-class CHNWR exhibit decreased nocturnal passage levels during and around the full moon phase in the fall. Larger CHNWR juveniles (including pre-smolt and smolt) appear to be less influenced by nighttime light levels and much more influenced by changes in stream discharge levels (Poytress et al. 2014).

There is a growing body of research showing that juvenile CHNWR utilize diverse rearing habitats before entering the Delta. Juvenile CHNWR have been documented using non-natal streams located downstream of RBDD for rearing, and a recent analysis of adult CHNWR otolith strontium isotope ratios ($87\text{Sr}/86\text{Sr}$) revealed that 44–65% of adults examined reared in non-natal habitats as juveniles (Phillis et al. 2018; Maslin et al. 1998).

While ephemeral habitat and non-natal tributaries of the Sacramento River provide some rearing habitat for juvenile CHNWR, more than 95% of historical floodplain rearing habitats have been leveed and drained in California's Central Valley. Floodplains and other off channel habitats provide refuge from high flows and sediment loads, reduce competition, increase prey availability, and potentially reduce encounters with predators, all of which can improve rearing conditions and increase growth and survival rates (Jeffres et al. 2008, Moyle et al. 2007; Limm and Marchetti 2003; Sommer et al. 2001). Benefits of floodplain habitat to juvenile CHNWR are discussed further in NMFS (2014), which identifies the restoration and maintenance of functioning floodplains of an appropriate, science-based width to maintain ecologically viable flood prone lands.

4.1.9. Juvenile Stranding

Juvenile CHNWR can become stranded as a result of dam operations, storm events, flood control structures, and other infrastructure that causes abrupt changes in flow (Beccio 2016, CDFW 2017). Sudden changes in flow or unnatural flow patterns may inhibit natural migration cues, causing fish to become trapped in isolated pools or channels that at higher flows were connected to the Sacramento River (Revnak et al. 2017). Stranding can lead to direct mortality when these areas drain or dry up. Indirect mortality can result through increased susceptibility to predation from otters, raccoons, birds, etc. or water quality deterioration in shallow or stagnant stranding locations (Revnak et al. 2017).

CDFW conducted a juvenile stranding monitoring program on the upper Sacramento River from the summer of 2016 to the spring of 2017. Sixty-nine stranding sites were surveyed between Keswick Dam (the uppermost limit of anadromy on the Sacramento River) and Tehama Bridge (a total of 73 river miles). CDFW rescued a total of 240 juvenile CHNWR and returned them to the Sacramento River. One adult CHNWR was observed dead in a stranding pool (Revnak et al. 2017). CDFW has also documented

adult and juvenile CHNSR stranding in the Sacramento and Yolo bypasses following Sacramento River flooding events (Beccio 2016; CDFW 2017). Since 1958, an estimated 4,515 juvenile Chinook salmon, of all races and life stages, have been collected by CDFW staff downstream of the Fremont Weir within the Yolo Bypass. In the Tisdale Bypass, which feeds the Sutter Bypass, an estimated 440 juvenile Chinook salmon, of all races and life stages, have been collected downstream of the Tisdale Weir (Beccio 2016). These numbers do not include un-surveyed swales and pools within the bypass, as rescue efforts were limited to the spill aprons and close adjacent areas of the Fremont and Tisdale Weir (Beccio 2016). It is likely that significant numbers of stranded juveniles are predated upon prior to rescue and significantly more juveniles are stranded than have been identified in un-surveyed waters within the bypasses. Juveniles rearing within the bypasses can experience delayed Delta entry with an increase in their travel distance if they are not allowed to exit the bypasses on the receding hydrograph of the river. This delay may subject juveniles to unfavorable hydraulic conditions in the Delta. Current Sacramento River hydrology is flashy, with large swings in flow over short periods of time. Fish rearing during high flows and exiting as bypass inundation subsides can be exposed to decreased flows and survival (Perry 2010; Notch et al. 2020; Cordoleani et al. 2019). The delay in Delta entry can also lessen the benefit of protections by water operational triggers designed to decrease entertainment of emigrating salmonids into the interior Delta.

4.1.10. Juvenile Passage at Red Bluff Diversion Dam

Emigration of juvenile CHNWR past RBDD may begin as early as mid-July, typically peaks in September, and can continue through as late as March in dry years (NMFS 2014: Poytress et al. 2014; Williams et al. 2011). From 1995 to 1999, all juvenile CHNWR migrating as fry passed RBDD by October, and all migrating pre-smolts and smolts passed RBDD by March (Martin et al. 2001). Total annual passage estimates for juvenile CHNWR based on RST monitoring conducted by the USFWS at RBDD for the period of April 4, 2002 through September 30, 2013 ranged between 848,976 and 8,363,106 juveniles for brood years 2002-2012 ($\bar{y} = 3,763,362$, $CV = 73.2\%$) (Poytress et al. 2014). These data also document that on average, estimated juvenile CHNWR passage at RBDD was composed of 80% fry and 20% pre-smolt/smolt size-class fish (Poytress et al. 2014).

Once CHNWR juveniles pass RBDD, the duration of their residency and habitat use are relatively unknown due to the lack of reliability of the length-at-date (LAD) criteria (Fisher 1992) used to determine juvenile Chinook salmon run (inability to definitively identify CHNWR amongst sampled fish), and because monitoring farther downstream is less intensive (Williams et al. 2011).

4.1.11. Juvenile Migration Survival

Juvenile salmon mortality during migration to the ocean is a critical component of salmon population dynamics (Williams 2006; Healey 1991). The Sacramento River's hydrology has been highly modified and releases from Keswick Reservoir are generally lower than unimpaired conditions in the winter and spring and higher in the summer and fall (SWRCB 2017). Juvenile salmonids migrating through altered habitats may experience prolonged exposure to predators as well as decreased predator evasion due to stress. Predation is recognized as a probable contributing factor in the declines of many populations of both Chinook salmon and steelhead (*Oncorhynchus mykiss*) in California's Central Valley (NMFS 2014). Numerous studies have and continue to be conducted in the Sacramento River to understand the effects of predation on salmonid populations (NMFS 2016b). Based on preliminary results of acoustic telemetry studies of LSNFH CHNWR smolts from 2013 to 2015, survival rates to the ocean varied from 5% to 12%

with the lowest survival occurring in the middle Sacramento River every year (Ammann personal communication 2015, as cited in NMFS 2016b).

Recent acoustic tagging studies show that significant mortality of juvenile Chinook salmon occurs upstream of the Delta (Cordoleani et al. 2019; Iglesias et al. 2017; Michel et al. 2012 and 2015; Notch et al. 2020). Flow has repeatedly been cited as the most important factor affecting overall survival of Chinook salmon in the Central Valley (Iglesias et al. 2017; Kjelson and Brandes 1989; Michel et al. 2015; Notch et al. 2020; Zeug et al. 2014), likely because of concurrent increases in habitat and food availability, temperature suitability, velocity, and turbidity effects associated with flow that directly improves the ability of juvenile salmon to avoid predation. Iglesias (2017) found that smolt mortality during migration in the Sacramento River is spatially heterogeneous, with certain reaches exhibiting elevated levels of mortality. This finding is likely a result of the dynamic nature of the Sacramento system and the effects of hydrologic alterations across the 302-mile migration corridor. Modification of the natural hydrograph, including suppression of winter pulse flows, has resulted in contraction of migratory windows, reducing the variability in migration timing, and suppressing full expression of CHNWR life histories (Sturrock et al. 2015). The resulting reduction in life history diversity could significantly reduce the resiliency of CHNWR and increase the risk of a temporal mismatch with favorable ocean conditions (Satterthwaite et al. 2014).

4.1.12. Juvenile Delta Entry

RST monitoring conducted on the Sacramento River at Knights Landing (RM 89.5) provides information on the timing of juvenile CHNWR entry into the Delta. CHNWR juveniles have been recorded at Knights Landing as early as August and as late as April, with most catches recorded between October and April (Jason Julienne personal communication 1/2020; CalFish 2019). While the timing of migration varies somewhat due to changes in river flows, dam operations, and water year type, peak time of entry is strongly associated with the first high flows of the migration season (del Rosario et al. 2013; NMFS 2014). Specifically, del Rosario et al. (2013) noted the first day of flows of at least 14,125 cfs at Wilkins Slough (RM 118) on the Sacramento coincided with the first day that at least 5% of the annual total catch was observed at Knights Landing. Observed differences in timing of cumulative catch at Knights Landing and Chipps Island (the downstream boundary of the Delta) indicate that residence time in the Delta ranges from 41 to 117 days, with longer apparent residence times for juveniles arriving earlier at Knights Landing (del Rosario et al. 2013). While Delta residency is apparent, the importance of the Delta in the life history of Sacramento River CHNWR is not well understood (NMFS 2014).

During their migration, some fish are entrained into the interior Delta. These fish experience increased mortality and travel times compared to juveniles that maintain course migrating in the Sacramento River or those that are routed into Steamboat Slough, a branch of the Sacramento River (Perry 2010; Newman and Brandes 2010). The Delta Cross Channel (DCC) and Georgiana Slough are the primary routes of entrainment to the interior Delta from the Sacramento River. The DCC is a man-made, gated canal that links the Sacramento River with the Lower Mokelumne and San Joaquin Rivers. When the DCC gates are open, water flows from the Sacramento River through the canal to improve poor water quality and water circulation associated with Project (and CVP) export operations. Operations of both the Project and CVP contribute to the routing of CHNWR and other salmonids migrating down the mainstem Sacramento River into the interior Delta through the open DCC gates (NMFS 2016b).

Much like the DCC, Georgiana Slough is another junction to the Sacramento River where water flows into the interior Delta, however this waterway lacks a control gate. Sacramento River flows at the entrance of the DCC and Georgiana Slough are both unidirectional and bidirectional depending on Sacramento River flows and tidal oscillation. CHNWR passing the junctions to the DCC and Georgiana Slough have a potential to become entrained in the interior Delta. When the DCC gates are closed, the potential is decreased. However, the free-flowing Georgiana Slough remains an opportunity for fish to become entrained regardless of DCC gate operations.

Instead of CHNWR migrating directly along the outer Estuary, when routed through the DCC gates or Georgiana Slough, these juveniles end up in the highly altered interior Delta and are subjected to pollution, increased predation, and altered food webs that can cause either direct mortality or impaired growth (NMFS 2016b). Routing into the interior Delta also causes migration delays or entrainment of fish into CCF and thence Project salvage facilities.

4.1.13. Juvenile Ocean Entry

Migration of juvenile salmon from the lower Sacramento River and Delta into San Francisco Bay is monitored using trawl surveys at Chipps Island. USFWS trawl data collected at Chipps Island shows juvenile CHNWR leaving the Delta from December to May with a peak in March and April (del Rosario et al. 2013).

4.1.14. Increased LSNFH Production

Due to prolonged extreme drought conditions that resulted in increased water temperatures in the upper Sacramento River, CHNWR egg-to-fry survival to RBDD were 5.6% and 4.2% in 2014 and 2015, respectively (NMFS 2016b). In anticipation of much lower than average egg to fry survival in 2015, additional adult CHNWR trapped at Keswick Dam were taken into LSNFH and production of juvenile CHNWR was tripled (i.e., 612,056 released) to offset the impact of the drought (SWRCB 2014). In 2014, LSNFH hatchery production represented 83% of the total in-river juvenile CHNWR production (NMFS 2019). Extreme drought conditions persisted through 2015, and in that year observed CHNWR egg-to-fry survival at RBDD was the lowest on record at approximately 4% due to the inability to release cold water from Shasta Dam (NMFS 2019). LSNFH again increased production of CHNWR juveniles to approximately 400,000 fish. Returns of adult CHNWR in 2017 and 2018 were low, as expected, due to poor in-river conditions for juveniles from brood year 2013 to 2015 during drought years (NMFS 2019). As a consequence of increased juvenile CHNWR production at LSNFH, the adult population of 977 fish in 2017 was composed of 85% hatchery-origin fish while the 2018 adult CHNWR return of 2,639 was composed of 82.5% hatchery-origin fish (CDFW 2019b; Killam and Mache 2018; Killam 2019).

4.1.15. Stressors

4.1.15.1. Pathogens

Since CHNWR comprise a single population with low abundance, naturally occurring pathogens pose a greater threat to this population than to other Central Valley salmon runs. If CHNWR population abundance were to decline even further, the probability would increase that disease outbreak could significantly impact the remaining population (NMFS 2016b). Migrating juveniles may be particularly susceptible to the effects of pathogens since those effects may be magnified by environmental changes that have occurred in the Sacramento River and Delta over the last 100 years.

During California's recent drought, the USFWS conducted a pilot sentinel trial in late September 2015 to assess potential disease risk to CHNWR fry (Foott 2016). Results of this study showed that sentinel juvenile late fall run Chinook salmon (CHNLFR) exposed to the Sacramento River for five days in late September at Balls Ferry and Red Bluff were infected with *Ceratonova shasta* (*C. shasta*), an intestinal parasite of salmonids that is a significant contributor to mortality of fish in the Pacific Northwest (Bartholomew et al. 1997). An additional eighty juvenile CHNWR were collected at the RBDD RST between October 15 and November 19, 2015 and sampled for histological examination. *C. shasta* was observed in 15% of the samples (Foott 2016). NMFS (2016b) concluded that *C. shasta* infection could have impaired survival of emigrating CHNWR fry in 2015 as *C. shasta* is a progressive disease and the early stage infections could go to a disease state over time.

4.1.15.2. Contaminants

Contamination can lead to either acute toxicity, resulting in death when concentrations are sufficiently elevated, or more typically, to chronic or sublethal effects that reduce the physical health of the organism when concentrations are lower (NMFS 2016b). Despite improvements to water quality in the Sacramento River and Delta, water pollution remains a threat for the conservation and recovery of all runs of Chinook salmon and their habitat (Macneale 2010; Meador 2013), and many potentially harmful chemicals and contaminants of emerging concern (pharmaceuticals) have yet to be addressed (NMFS 2016b).

4.1.15.3. Predation

Predation is an ongoing threat to juvenile CHNWR throughout the Sacramento River and Delta where both non-native and native species prey on juvenile salmon (NMFS 2016b). Altered and simplified habitats, the presence of man-made structures, and altered flow regimes including Shasta Reservoir operations and water diversions in the Sacramento River and Delta contribute to increased predation levels by favoring predatory species and predator contact rates with prey (NMFS 2016b). Grossman et al. (2013) state there is clear evidence juvenile salmon are consumed by fish predators, and that the population of predators in the freshwater migratory corridor of juvenile CHNWR is large enough to effectively consume all juvenile salmon production. However, it is not clear what proportion of juvenile mortality can be directly attributed to fish predation. Specifically, in the context of extreme modification of the Sacramento River's natural flow regime, altered habitat conditions, native and non-native fish and avian predators, temperature and dissolved oxygen limitations, and overall reduction in historical salmon population size, predation may serve as the proximate mechanism of mortality in a large proportion of the population, but the ultimate causes of mortality and declines in productivity are less clear (Grossman et al. 2013). For example, stress caused by harsh environmental conditions or toxicants will render fish more susceptible to all sources of mortality including predation, disease, or physiological stress, and Grossman et al. (2013) offer that the most productive management strategy for decreasing predation on Chinook salmon and other Delta fishes is to restore natural habitat and flows, especially in predation hot spots.

4.2. Spring-run Chinook Salmon

4.2.1. Listing History

On February 5, 1999, the California Fish and Game Commission listed CHNSR of the Sacramento River drainage as threatened under CESA (See Cal. Code Regs., tit. 14, § 675.5, 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 as to be listed as endangered by NMFS on March 9, 1998 (63 FR 11482), following CHNSR extirpation from the San Joaquin River Basin. During 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 Feather River Fish Hatchery (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 (70 FR 37160). During the 2005 status review, FRFH CHNSR were included in the ESU (70 FR 37160). Critical habitat for CHNSR includes the Sacramento River Basin and the Yolo Bypass (70 FR 52488).

4.2.2. 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 Deer, Mill, and Butte Creeks, with small populations found in the Feather and Yuba Rivers as well as in Battle, Antelope, Clear, Big Chico, and Beegum Creeks (tributary to Cottonwood Creek) (CDFG 1998; CDFG 1990). Hatchery sustained populations are present on the Feather River and San Joaquin Rivers (via the San Joaquin River Restoration Program; SJRRP) (CDFW 2019a).

Genetic analyses have shown that natural and hatchery origin CHNSR within Mill, Deer, and Butte Creeks retain their genetic integrity (Garza et al. 2008; Good et al. 2005). However, the Feather River populations have shown introgression from fall-run Chinook salmon (CHNFR) due to overlaps in spatial and temporal run timing which are constrained by Oroville Dam (Cavallo et al. 2011; Garza et al. 2008; Good et al. 2005).

4.2.3. Sacramento River Basin

NMFS (2016a) concluded that CHNSR run sizes are declining over time, with exceptions in Clear, Battle, and Butte Creeks which have seen recent growth. Increases in Butte Creek are attributed partially to extensive habitat restoration, including increasing floodplain accessibility in the Sutter-Butte Bypass (NMFS 2016a).

From December 2011 to March 2017, CDFW documented critically low adult CHNSR returns in Mill and Deer Creeks as a result of severe, prolonged droughts in the Central Valley. Populations remained low with returns below 500 adults for four consecutive years between 2015 and 2018. The final 2018 escapement estimates for Mill and Deer Creeks were 152 and 159 adult CHNSR, respectively (CDFW 2019a). Preliminary data from 2019 indicate a further decline in adult returns in Mill Creek and a double in returns in Deer Creek from 2018 to 2019 (CDFW 2019a).

Additional preliminary data from 2019 estimate 6,252 adult spawners in Butte Creek, 40 adult spawners in Battle Creek, and more than 60 adult spawners in Clear Creek (Garman 2020). Feather River adult returns have increased following the recent drought, from a low of 762 adults in 2017 to over 7,200 adults in 2018. Preliminary data suggests that 2019 adult returns may be double that of 2018 in the Feather River (NMFS 2019).

4.2.4. San Joaquin River Basin

The San Joaquin River run is suggested to have once been one of the largest runs of any Chinook salmon on the West Coast, with estimates averaging 200,000 to 500,000 adults returning annually (CDFG 1990). However, naturally produced CHNSR were extirpated from the San Joaquin River in the late 1940s, with only remnants of the run persisting through the 1950s in the Merced River (Yoshiyama et al. 1998). There is some recent evidence of Chinook salmon occurring in the Stanislaus and Tuolumne Rivers, tributaries to the San Joaquin River; however, it is unclear if these salmon are residuals of the CHNSR population or if they are strays from other river basins (Franks 2013; NMFS 2016a; NMFS 2019).

As a result of the 2006 *National Resources Defense Council (NRDC), et al. v. Kirk Rodgers, et al.* settlement, the federal Implementing Agencies (United States and the Central Valley Project (CVP) Friant Division contractors) were directed to implement the SJRRP to established a nonessential experimental population of CHNSR in the San Joaquin River below Friant Dam (78 FR 251; SJRRP 2015). NMFS prepared a 10(j)/4(d) rule pursuant to the ESA so that reintroduction would not impose more than “de minimus water supply reductions, additional storage releases, or bypass flows on unwilling third parties.” Under the settlement, third party is defined as persons or entities diverting or receiving water pursuant to applicable State and Federal laws; this includes CVP contractors outside of the Friant Division of the CVP and SWP contractors (Pub. L. 111-11, 123 Stat. 1349 (2009)).

4.2.5. 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 (2014) Recovery Plan for CHNSR identified ongoing threats to the federal ESU as small population sizes, loss of habitat, water operations, climate variation, and low 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 of individual populations and the ESU.

The few remaining populations of CHNSR are small, isolated, and lack spatial diversity. The three demographically independent populations of CHNSR, in Butte, Deer, and Mill 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.

NMFS (2016a) 5-year Species Review for CHNSR determined that the ESU remains at a moderate risk of extinction based on the severity of the drought and low observed escapements, as well as increased pre-spawn mortality in Butte, Mill, and Deer Creeks in 2015. Declines in escapement data collected in Mill and Deer Creeks indicate an increased risk that these independent populations will be at a high extinction risk in the coming years (CDFW 2019a; NMFS 2016a; Lindley et al. 2007). In response to declines in escapement, NMFS and CDFW have developed a draft Emergency CHNSR Action Plan, which aims to identify and outline targeted efforts vital for stabilizing populations most at risk (i.e., Mill, Deer, and Butte Creeks) (NMFS 2019).

4.2.6. Adult Migration

Adult CHNSR leave the Pacific Ocean to begin their upstream spawning migration typically at age-3, with a smaller proportion leaving at age-2, age-4, and, to a lesser extent, age-5 (Palmer-Zwahlen et al. 2019; NMFS 2000b). Boles et al. (1988) cites water temperatures less than 18.3°C as preferable for adult Chinook salmon migration, and Lindley et al. (2004) report that water temperature reaching 21.1°C (70°F) acts as a migration barrier and leads to stress. Adult CHNSR enter the Estuary in late January to begin their upstream migration and continue to proceed up the Sacramento River through October (Yoshiyama et al. 1996; NMFS 1998; Moyle 2002). CHNSR are sexually immature when they enter freshwater, with their gonads maturing over the summer holding period (Moyle 2002; Marcotte 1984).

Migrating CHNSR utilize the Delta, Sacramento River below Keswick Dam, and tributaries to access their natal tributaries and find over-summer holding habitat. CDFW and USFWS currently monitor CHNSR salmon tributary entry on the Yuba River and on Butte, Deer, Mill, Antelope, Clear, Battle, and Cottonwood Creeks. Based on hydroacoustic and video monitoring in Mill Creek, DWR and Reclamation (2012) predict adult CHNSR migration timing near Fremont Weir to occur between January and mid to late May (Johnson et al. 2011). Recent video monitoring efforts in tributaries of the upper Sacramento River show CHNSR entry into Sacramento River tributaries occurs as early as late February and as late as mid-July, with a peak in presence in May (Killam et al. 2015; Killam 2012; YCWA 2014).

CDFW has documented adult Chinook salmon exhibiting CHNSR migration behavior in the San Joaquin Basin since the early 2000s. During the summer of 2000, 28 adult Chinook salmon were captured using gill nets in the Stanislaus River (CDFG 2003). Eight of these fish were adipose fin clipped. Five coded-wire-tags (CWT) were retrieved, and all showed Feather River origin (CDFG 2003). CDFW staff have also observed live adult salmon and recovered adult salmon carcasses in the Tuolumne River during the summers of 2006, 2009, and 2013 (CDFW 2020a). Video monitoring has been operated at the weir on the Stanislaus River (RM 32) since 2003 and at the weir on the Tuolumne River (RM 24.5) since 2009. The main purpose of the weirs is to monitor CHNFR escapement, so the weirs are normally removed in January following the CHNFR spawning season, however, the weirs have occasionally been operated through June. During the last 16 years, the weir on the Stanislaus River has been operated from February through June during 10 of those years. Migrating adult salmon have been documented during that time period on the Stanislaus River in 9 of those 10 years as summarized below (Table 1).

Year	Number of Days Weir Operated February-June	Total Number of Salmon Observed	Number of Clipped Salmon Observed
2003	0	-	-
2004	0	-	-
2005	0	-	-
2006	145	22	6
2007	0	-	-
2008	87	13	0
2009	143	33	3
2010	0	-	-
2011	22	6	3
2012	151	115	10
2013	69	6	0

2014	46	1	1
2015	11	3	2
2016	16	0	0
2017	0	-	-
2018	4	2	0
2019	0	-	-

Table 1. Stanislaus River Weir Data, February-June, 2003-2019. (FishBio 2019)

The weir on the Tuolumne River has been operated during spring in eight of the last ten years. Adult salmon migration was documented at the weir between February and June in all eight years (Table 2).

Year	Number of Days Weir Operated February-June	Total Number of Salmon Observed	Number of Clipped Salmon Observed
2009	74	17	4
2010	0	-	-
2011	144	55	2
2012	113	107	5
2013	96	46	1
2014	57	5	0
2015	103	5	1
2016	0	-	-
2017	49	2	0
2018	2	3	2

Table 2. Tuolumne River Weir Data, February-June, 2009-2019 (TRTAC 2020)

4.2.7. Adult Stranding

Adult CHNSR migrating through freshwater require enough flow for passage and olfactory cues as well as adequate water quality and temperature (CDFG 1998). Attraction of adults into terminal waterways and migration barriers results in delays or stranding, ultimately affecting spawning success. Flood bypasses and drainage canals are known stranding areas for CHNSR as documented by CDFW fish salvage efforts (Beccio 2016; Gahan et al. 2016; CDFW 2017). Adult CHNSR fish kills due to stranding have been observed in the Sutter Bypass and on the Sacramento River at the Butte Slough Outfall Gates (BSOG; RM 139) because of poor passage conditions and attraction into the outfall gates, respectively (Garman 2018).

Adult CHNSR have been rescued from the Yolo Bypass during low Sacramento River flows (as measured at Freeport), suggesting tidal related flow fluctuation at the confluence of the Sacramento River and the Cache Slough complex creates strong attraction cues for migrating adults (CDFW 2017). Additionally, the Yolo Bypass has been identified to increase route timing or prevent access to holding and spawning habitats for entrained individuals. Even flows from the Yolo Bypass/Cache Slough Complex junction into the Sacramento River (near RM 14) as low as 1,000 cfs are suggested to attract adult Chinook salmon and sturgeon (*Acipenser spp.*) migrating to spawning reaches of the Sacramento River and associated tributaries (DWR 2015). The Yolo Bypass is bordered at the most northern extent by the Fremont Weir, which acts as a flood relief structure for the Sacramento River. When river stage exceeds the top of the weir, water spills over and inundates portions of the Yolo Bypass. This influences adult CHNSR migration by: 1) increasing attraction flows into the Yolo Bypass, 2) providing passage through the Yolo Bypass to

the Sacramento River above the confluence with the Feather River and Sutter Bypass/Butte Creek, and 3) stranding fish in the Yolo Bypass as flows recede. Presence of adult CHNSR has been confirmed within the Yolo Bypass throughout their migration window through operations at Wallace Weir and post-flood monitoring below the Fremont Weir (Beccio 2016; Gahan et al. 2016).

Flows around Delta water conveyance structures, such as the DCC, have also been demonstrated to delay or strand adult Chinook salmon attempting to return to natal streams. An acoustic telemetry study of CHNFR movement throughout the Delta highlighted route confusion when interacting with the DCC and associated flows. In this study, adult San Joaquin River CHNFR were implanted with an acoustic tag and tracked as they moved through the Delta. Individuals interacting with the DCC and associated flow complexity experienced increased travel time to reach the spawning reaches of their natal streams (McKibbin 2019).

4.2.8. Adult Holding and Spawning

Adult CHNSR hold over-summer in deep pools as they mature. Historical holding habitat for CHNSR adults included accessible streams above approximately 2,000 ft above sea level where water temperatures remained cool through summer months (CDFW 2019a). Due to agricultural diversions, dams, and habitat degradation, holding habitat is often limited currently to lower elevations where managed reservoir releases (e.g., Clear Creek, Feather River) or imported cold water (e.g., Butte Creek) are provided.

Preferred holding pools are at least 1 to 3.3 m (3 to 10 ft) deep with water velocities between 0.15 and 0.4 m/s (0.5 to 1.3 ft/s) (Marcotte 1984; Puckett and Hinton 1974). Adult CHNSR prefer to hold in deep pools with bedrock substrate and avoid cobble, gravel, sand, and especially silt substrate in pools (Sato and Moyle 1989). Target temperatures for adult holding include a 7-day average of the daily maximum (7DADM) below 15°C (59°F), with temperatures consistently greater than 20°C (68°F) considered lethal (USEPA 2003). However, temperature tolerance appears to differ among populations, and Central Valley CHNSR appear to be tolerant of higher temperatures than populations in the Pacific Northwest that informed the USEPA (2003) guidelines. Experienced CDFW biologists working in Butte Creek typically regard sustained average daily temperatures above 19.4°C (67°F) as the threshold above which disease pathogens become more virulent and pre-spawn mortality increases in holding pools (Ward 2004).

CHNSR holding habitats on Mill Creek are located between RM 18 and 48. On Deer Creek, CHNSR are found holding in 35 km of stream below Upper Deer Creek Falls (Killam et al. 2017). Holding habitats on Butte Creek extend a distance of over 13 RM from the Parrot-Phalen Dam to the Quartz Bowl Pool where a natural fish barrier prevents further upstream movement (Garman 2014). Holding habitats on the Feather River are limited in the low flow section to a 12 km stretch between the outlet of the Thermalito Afterbay (RM 59) to the fish barrier dam (RM 66) (PFMC 2019). In the Yuba River, CHNSR holding occurs in deep pools (up to 40 feet in depth) in the “Narrows” reach of the river just downstream of Englebright Dam and Yuba County Water Agencies’ Narrows 2 Powerhouse (YCWA 2014).

Pre-spawn mortality of holding CHNSR appears to occur annually in holding habitats (PFMC 2019; Garman 2014). Pre-spawn mortality is influenced by a wide range of factors including high water temperature, high population density (i.e., density dependent mortality), and low habitat availability. On the Feather River, pre-spawn mortalities are attributed to a lack of suitable habitat with high population

densities of holding and spawning adults, both CHNSR and CHNFR, in habitats adjacent to the hatchery (PFMC 2019). On Butte Creek, elevated temperatures and adult densities are major contributors to observed pre-spawn mortality (Garman 2014).

CHNSR spawning begins in mid-August and continues through mid-October, with females laying an average of approximately 4,200 eggs in gravel stream beds (CDFG 1998; Moyle 2002; Giovannetti and Brown 2008). On Butte Creek, spawning occurs mid to late-September through October. Peak spawning on Butte Creek is the last week in September or the first week in October, depending on annual variation in ambient air temperatures (Garman 2014). Observed timing of CHNSR spawning on Deer and Mill Creeks is mid-September through mid-October (Johnson and Merrick 2012). Harvey (1995, 1996, 1997) observed spawning occurring at higher elevations first in Deer Creek, which are the coolest reaches, with spawning progressing downstream over the spawning season. Similar CHNSR spawn timing has been observed on Clear and Battle Creeks and the Yuba River, where USFWS and Pacific States Marine Fisheries Commission conduct extensive monitoring of spawning location and timing. However, spawning on the Yuba River has been reported as early as September 1 (YCWA 2014). Collection for the FRFH CHNSR broodstock occurs mid-September through the end of September.

Natural spawn timing of CHNSR can overlap with CHNFR in tributaries where both are found using the same habitat. These areas of overlap include the Sacramento River mainstem, Deer Creek, Mill Creek, and the Feather River. CHNFR are found in Butte Creek, but their spawning reaches are located below those of CHNSR. Spawning of CHNSR and CHNFR occurring in the same habitat reaches can lead to density dependent mortality caused by redd superimposition. Density dependent mortality can decrease juvenile production and potentially lead to population level impacts (PFMC 2019).

Spawning and incubation habitat for CHNSR includes gravel bedded reaches within Sacramento River tributaries. Adults often spawn in gravel beds near the tail of holding pools, in water depths of 0.25 m (0.8 ft) or greater (Puckett and Hinton 1974) and water velocities between 0.3 and 1.3 m/s (0.98 to 4.3 ft/s) (McReynolds et al. 2006). Preferred spawning substrate is a mixture of gravel and cobble approximately 2.5 to 10.0 cm in diameter (Reclamation 2011) that contains minimal (i.e., <5%) fine sediment (Kondolf 2000; Raleigh et al. 1986). Optimal temperatures for spawning are less than 13°C (55°F) (USEPA 2003).

4.2.9. Redd Maintenance

4.2.9.1. Temperature Management

Water temperature greatly influences the duration of egg incubation and time of emergence in different river drainages, with emergence occurring after the yolk-sac is absorbed (Williams 2006). Approximately 900-1,000 thermal units are required for incubation of Chinook salmon eggs (1 thermal unit = 1°C above freezing x 24 hours) (Raleigh et al. 1986). Based on CHNSR redd surveys and RST data from Battle and Clear Creeks, 1,850 Duplicant Temperature Units (DTUs) are normally required for development, emergence, and capture in the RST (CDFW 2019a; Giovannetti and Brown 2008).

Water temperatures are warmer in Butte Creek than in Mill and Deer Creeks. Within Butte Creek, juvenile CHNSR first appear in late November, with juvenile emergence continuing through January (McReynolds et al. 2006). However, in Mill and Deer Creeks where most adults spawn at higher elevations, juveniles emerge from January through March, up to six months after the onset of spawning (Johnson and Merrick 2012).

4.2.9.2. Dewatering

Stable and continuous river flows are important to the early life history (egg incubation to emergence from the gravel) of salmonids. If redds are dewatered or exposed to warm, deoxygenated water, incubating eggs and/or larval fish may not survive. Dewatering can occur anytime a flow reduction occurs. On the upper Sacramento River, the transition from summer to winter flow regimes involves flow reductions from September to November as less water is needed for agricultural purposes (Revnak et al. 2017). Spawning CHNSR (mid-August through mid-October) are of particular concern because redds constructed in shallow areas are susceptible to dewatering under typical flow reduction actions by Reclamation that occur beginning in late August as agricultural water demands decrease (Revnak et al. 2017).

4.2.10. Juvenile Migration

Juvenile CHNSR utilize freshwater rearing habitat in natal tributaries, the mainstem Sacramento River and its flood bypass system, and the Delta. Juveniles express greater rearing plasticity compared to other Central Valley Chinook races characterized by large variation in the size, timing, and age at which they emigrate from their natal tributaries to the ocean. Juveniles can either emigrate to the ocean as fry, parr, or smolts the following spring after emerging as young-of-year (YOY), or over-summer and emigrate the following fall, winter, or spring as yearlings (CDFG 1998). YOY CHNSR typically emigrate soon after emergence as fry and rear for a few months in downstream habitats, such as the mainstem Sacramento River, accessible floodplains (e.g., Sutter or Yolo bypasses), or the Delta. YOY CHNSR may also rear in their natal habitat and out-migrate as parr or smolts.

Juvenile CHNSR may spend from three to fifteen months in freshwater habitat before emigrating to the ocean (Johnson and Merrick 2012). This diversity in emigration timing creates resiliency to catastrophic events and is crucial to preserve the integrity of the remaining CHNSR populations. In Butte Creek, between the Parrott-Phelan Diversion Dam and the Sutter Bypass West Borrow Weir 1 monitoring sites, Hill and Webber (1999) found YOY CHNSR residence times ranging from 67 to 113 days before salmon entered the Sacramento River near the confluence with the Feather River (RM 80).

4.2.11. Juvenile Floodplain Use

In the Central Valley, more than 95% of floodplain habitats have been leveed and drained, primarily for flood control or conversion to agriculture (Lund et al. 2010). Floodplains and other off channel habitats can provide refuge from high flows and sediment loads, reduce competition, increase prey availability and potentially reduce encounters with predators, all of which can improve rearing conditions and increase growth and survival rates (Jeffres et al. 2008; Moyle et al. 2007; Limm and Marchetti 2003; Sommer et al. 2001).

Emigration route selection and route availability are variable among populations of CHNSR. Juveniles exiting the spawning reaches of Butte Creek as YOY enter the Sutter Bypass and subsequently the Sacramento River, near the confluence with the Feather River, however, exit to the Sacramento River can also occur at the BSOG. When Butte Creek stage is higher than that of the Sacramento River, the gates allow Butte Creek water to flow into the Sacramento River. These high Butte Creek flows are likely to coincide with CHNSR presence near the BSOG, allowing salmon entry into the Sacramento River. Acoustic telemetry data of juvenile Butte Creek CHNSR tagged and released at the Parrott-Phelan

Diversion Dam demonstrates juvenile salmon entry into the Sacramento River through the BSOG, above Butte Creek's primary confluence with the Sacramento River (RM 80) (Garman 2020).

Juvenile CHNSR exiting Deer and Mill Creeks also have alternative routes available to them during emigration to the Delta. YOY CHNSR exit Deer and Mill Creeks beginning in November, with peak emigration in February and March (Johnson and Merrick 2012). Frequently during these months, increased flow associated with winter storm flows often overtop the Sacramento flood relief structures, allowing juvenile entry into the bypass system. Peak emigration for yearling CHNSR exiting natal streams occurs October through December (Johnson and Merrick 2012). During this period, the Sacramento River overtops flood relief weirs less frequently; however, if Sacramento River flood flows occur during the yearling emigration period, alternative route availability would be similar to those described above.

4.2.12. Juvenile Stranding

Juvenile CHNSR can become stranded as a result of dam operations, storm events, flood control structures, and other infrastructure that cause abrupt changes in flow (Beccio 2016; CDFW 2017). Sudden changes in flow or unnatural flow patterns may inhibit natural migration cues, causing fish to become trapped in isolated pools or channels that at higher flows were connected to the river (Revnak et al. 2017). Stranding can lead to direct mortality when these areas drain or dry up. Indirect mortality can result through increased susceptibility to predation from otters, raccoons, birds, etc. or water quality deterioration in shallow or stagnant stranding locations (Revnak et al. 2017).

CDFW conducted a juvenile stranding monitoring program on the upper Sacramento River from the summer of 2016 to the spring of 2017. Sixty-nine stranding sites were surveyed between Keswick Dam (the uppermost limit of anadromy on the Sacramento River) and Tehama Bridge (a total of 73 river miles). A total of 19,892 juvenile CHNSR were rescued and returned to the Sacramento River. Eleven adult CHNSR or CHNFR were observed dead in a stranding pool (Revnak et al. 2017). CDFW has also documented adult and juvenile CHNSR stranding in the Sacramento and Yolo bypasses following Sacramento River flooding events (Beccio 2016; CDFW 2017). Since 1958, an estimated 4,515 juvenile Chinook salmon, of all races and life stages, have been collected by CDFW staff downstream of the Fremont Weir within the Yolo Bypass. In the Tisdale Bypass, which feeds the Sutter Bypass, an estimated 440 juvenile Chinook salmon, of all races and life stages, have been collected downstream of the Tisdale Weir (Beccio 2016). These numbers do not include un-surveyed swales and pools within the bypass, as rescue efforts were limited to the spill aprons and close adjacent areas of the Fremont and Tisdale Weir (Beccio 2016). It is likely that significant numbers of stranded juveniles are predated upon prior to rescue and significantly more juveniles are stranded than have been identified in un-surveyed waters within the bypasses. Juveniles rearing within the bypasses can experience delayed Delta entry with an increase in their travel distance if they are not allowed to exit the bypasses on the receding hydrograph of the river. This delay may subject juveniles to unfavorable hydraulic conditions in the Delta. Current Sacramento River hydrology is flashy, with large swings in flow over short periods of time. Fish rearing during high flows and exiting as bypass inundation subsides can be exposed to decreased flows and survival (Perry 2010; Notch et al. 2020; Cordoleani et al. 2019). The delay in Delta entry can also lessen the benefit of protections by water operational triggers designed to decrease entertainment of emigrating salmonids into the interior Delta.

4.2.13. Juvenile Delta Entry

The timing of CHNSR juvenile entry into the Delta is highly variable. Williams (2006) suggested Delta entry timing can range from December to May, and that the timing and age at Delta entry appears to be influenced by the timing of winter high flow events. Johnson and Merrick (2012) found large numbers of yearling CHNSR entering the Sacramento River from Mill and Deer Creeks in October and November. CHNSR mark and recapture-based studies on Butte Creek suggest that rearing versus migratory behavior can be highly variable between individuals within the same brood year and across water years and that emigration cues can be both flow and temperature related. While a portion of the emigrating population may leave Butte Creek as fry, another portion of the population may decide to rear in Butte Creek for extended periods and not enter the Sacramento River until May or June. Some individuals were observed rearing for 80 days and those that exhibited this behavior tended to rapidly emigrate through the Delta (Hill and Webber 1999; Ward et al. 2004a, 2004b, and 2004c). For Mill, Deer, and Butte Creeks, juveniles appear to be entering the Sacramento River during periods when conditions are not always ideal for rearing or downstream migration.

CDFW's Knights Landing RST program and trawl and beach seine monitoring provide information on juvenile CHNSR movement through the lower Sacramento and into the Delta (Julienne 2016; Williams 2006). These monitoring programs show that the timing of entry into the Delta is highly variable, ranging from November to May. A higher proportion of juveniles have been observed entering the Delta earlier in the season as fry in wet years compared to dry years, and this variability is thought to be influenced by timing of winter high flow events (Williams 2006).

As discussed above in the Delta Entry section for CHNWR, CHNSR are subject to emigration delays, entrainment, impaired growth, and direct mortality while migrating through the Delta due to routing through the DCC gates and Georgiana Slough, and into Project facilities.

4.2.14. Juvenile Ocean Entry

The seaward migration of juvenile CHNSR from the lower Sacramento River and Delta into San Francisco Bay is monitored using trawl surveys at Chipps Island between April and June. This monitoring suggests that the various juvenile CHNSR life histories and rearing strategies culminate in average saltwater entry in the spring, with mean monthly catch at Chipps Island peaking in April or May (Brandes and McLain 2001; Williams 2006). Juveniles entering the Delta prior to this point are likely searching for places to rear and grow prior to saltwater entry.

4.2.15. San Joaquin River Restoration Program

CHNSR-size juveniles (determined using the Delta Model length-at-date criteria (Delta Model LAD criteria; USFWS 1997)) have been captured at Mossdale trawl on the San Joaquin River since 1988 (Murphey 2018). Some experts speculate these juveniles are not CHNSR, but rather the progeny of CHNFR with increased growth rates. Genetic analysis would be required to verify that these fish are CHNSR. Since the implementation of the SJRRP, CDFW has recovered CWT juvenile salmon marked as released from the SJRRP (FRFH fish released at Interim Salmon Conservation and Research Facility) during the CHNSR emigration time period. The majority of these fish were recovered in April, indicating San Joaquin River CHNSR juveniles migrating into the south Delta prior to May (CDFW 2020c). This coincides with CHNSR juvenile movement in the northern basin.

On April 9, 2019, the SJRRP recovered the first adult CHNSR since the program implementation. A total of 23 adult CHNSR were captured in April and May 2019 in the restoration program area. In the same year, 11 more adult salmon were recovered at various locations in the lower San Joaquin River in May and June (Sutphin et al. 2019). These data may indicate some success in the restoration program and the potential for a developing CHNSR population on the San Joaquin River in the future.

4.2.16. Stressors

4.2.16.1. Hatchery Influence

Historically, wherever CHNSR and CHNFR populations overlapped (as described above), they were temporally segregated and genetic integrity was maintained. However, because of difficulties associated with holding adults over summer in the hatchery, CHNSR fish were left in the river until spawning, which presumably led to mixing with CHNFR in the hatchery (Williams 2006).

FRFH CHNSR may affect diversity through: (1) introgression with CHNFR due to overlap in spawn timing; (2) straying of FRFH CHNSR into natural origin CHNSR spawning habitat; and (3) disproportionately high levels of returning spawners in comparison to natural-origin fish (NMFS 2016a).

4.2.16.2. Competition and Hybridization with Fall-Run Chinook Salmon

In the Candidate Species Status Report, CDFG (1998) referenced impacts from competition and hybridization as factors affecting the ability of CHNSR to survive and reproduce. Following the construction of dams, which blocked historical habitat in the Sacramento and San Joaquin River Basins, CHNSR began spawning in the same reaches where CHNFR historically spawned, increasing competition and hybridization between the runs.

Additionally, historical hatchery practices contributed to hybridization between CHNSR and CHNFR. Genetic analyses have demonstrated substantial introgression between the runs at the FRFH and in the Feather River (Hedgecock et al. 2001; Hedgecock 2002). The California Hatchery Science Review Group reviewed hatchery practices and recommended strategies to reduce competition and hybridization within anadromous fish hatcheries and between hatchery-origin and natural fish (CA HSRG 2012). DWR and CDFW have incorporated many of these recommendations for spawning and release protocols at the FRFH. DWR also plans to provide spatial separation within spawning grounds with the installation of a segregation weir in the low flow channel of the Feather River.

In an effort to better refine genetic assignments, NMFS Southwest Fisheries Science Center recently developed assays for new genetic markers specific to Central Valley Chinook salmon based on migration timing. These new markers are anticipated to help distinguish CHNSR in the Central Valley from those introgressed with Feather River CHNFR (Davis et al. 2017). These markers will provide a crucial tool for hatchery management, by increasing the resolution of monitoring of hatchery and natural origin CHNSR in the Feather River Basin and Delta.

4.2.16.3. Contaminants

Contamination can lead to either acute toxicity, resulting in death when concentrations are sufficiently elevated, or more typically, chronic or sublethal effects that reduce the physical health of the organism when concentrations are lower (NMFS 2016b). Despite improvements to water quality in the Sacramento River and Delta, water pollution remains a threat for the conservation and recovery of all runs of Chinook salmon and their habitat (Macneale 2010; Meador 2013), and many potentially harmful

chemicals and contaminants of emerging concern (pharmaceuticals) have yet to be addressed (NMFS 2016a).

4.2.16.4. Predation

The Candidate Species Status Report (CDFG 1998) states that predation may be a factor in the decline of CHNSR. Predators of juvenile Chinook salmon include avian species (e.g., cormorants, gulls, terns, mergansers, egrets, herons, osprey), native fish (e.g., pikeminnow, sculpin, steelhead) and introduced species (e.g., striped bass, catfish, shad, black bass) (CDFG 1998). Large marine mammals (e.g., harbor seals, sea lions, killer whales) are known to prey on adult salmon (CDFG 1998). Predation is a natural phenomenon that can be increased to unsustainable levels by human activities such as hard in-river structures (e.g., diversions, bridge abutments, docks, riprap banks), changes in water management that lead to warmer water temperatures, introduction of nonnative species (e.g., submerged aquatic vegetation, clams, non-native predators), and changes to habitat such as diking and dredging. While it is known that high rates of predation occur in certain “hot-spots,” studies have shown that predation rates do not scale with predator density (Michel et al. 2019; Abrams 1993; Zeug et al. 2019). It is unknown whether predation has a population level effect on CHNSR or whether removing predators would have an appreciable effect on juvenile salmon survival. There is not enough evidence to determine if predation has increased or decreased since listing of CHNSR, despite considerable research interest in the topic.

4.3. Importance of Life History Diversity for Chinook Salmon

California’s Central Valley contains the southernmost runs of native Chinook salmon in the world, and experiences some of the most extreme climatic variations in North America. As a result, Chinook salmon in the Central Valley exhibit exceptionally diverse life-history traits compared to other stocks, particularly with respect to adult immigration and juvenile emigration timing (Healey 1991; Sturrock et al. 2019b). This “portfolio effect” contributes to population sustainability and abundance by distributing risk throughout the run and reducing intra specific competition (Healey 1991; Greene et al. 2010; Carlson and Satterthwaite 2011; Sturrock et al. 2015). Additionally, genetic and life-history diversity is important for species and population viability because genetic and phenotypic diversity: 1) allow a species to use a wider array of environments, 2) protect species against short-term spatial and temporal changes in the environment, and 3) provide the raw material for surviving long-term environmental change (NMFS 2000a). Restoring and maintaining this diversity is critical, especially as climatic conditions become more unpredictable as a result of climate change in a spatially and temporally varying environment such as the Central Valley.

CHNSR juveniles can emigrate to the ocean as sub-yearlings, including fry, parr, and smolts, during the spring, or over-summer and emigrate the following fall, winter, or spring as yearlings (CDFG 1998). Juvenile life-history diversity is particularly variable within Deer and Mill Creek CHNSR populations because they spawn over a large elevational range (1,200 to 5,203 feet) which results in significant variation in the duration of egg incubation and timing of fry emergence in the watershed (Johnson and Merrick 2012). As a result, depending upon the elevation at which an adult female spawned, CHNSR juveniles from a given brood year may emigrate as sub-yearlings from January through June, or as yearlings the following fall, winter, and spring (Johnson and Merrick 2012). In the Central Valley, juvenile Chinook salmon sampled in various locations throughout the Sacramento-San Joaquin River systems are classified by race using the LAD criteria (Fisher 1992) based upon projected annual growth. Diverse

juvenile life history expression, slow growth rates, and variable emigration timing can result in Deer and Mill Creek CHNSR juveniles being misidentified. Specifically, fall emigrants (yearlings) often are incorrectly classified as CHNLFR or CHNWR, and a significant portion of YOY CHNSR are classified as CHNFR and CHNLFR (Johnson and Merrick 2012). The inability to correctly identify Mill Creek and Deer Creek CHNSR juveniles in the freshwater environment has significant management implications with respect to preserving life history diversity.

Sacramento River CHNWR also exhibit diverse juvenile life histories. CHNWR juveniles primarily express an ocean-type life history pattern, with juveniles leaving spawning areas in the upper Sacramento River and emigrating as fry in the late summer or early fall. RST monitoring by the USFWS at RBDD (RM 243) for the period of April 4, 2002 through September 30, 2013 documented that on average, juvenile CHNWR passage was composed of 80% fry and 20% pre-smolt/smolt size-class fish (Poytress et al. 2014). Emigration past RBDD begins in July and lasts into March the following year, with 75% of average annual passage occurring by mid-October with sporadic pulses of smolts through March (Poytress et al. 2014). RST monitoring on the lower mainstem Sacramento River at Knights Landing (RM 89.5) is used to inform entry of CHNWR juveniles into the tidal delta environment. CHNWR juveniles have been recorded at Knights Landing as early as August and as late as April, with most catches recorded between October and April (Jason Julienne personal communication 1/2020; CalFish 2019). del Rosario et al. (2013) noted that substantial variation in peak passage of CHNWR juveniles at Knights Landing was strongly associated with the first high flows of the migration season, with flows of at least 14,000 cfs at Wilkins Slough (RM 118) coinciding with the first day that at least 5% of the annual total catch of CHNWR was observed. Similarly, Poytress et al. (2014) describes the significance of first flush of the season based on the relationship between river discharge, turbidity, and fish passage and that the importance of the first storm event of the fall or winter period in triggering juvenile fish migrations cannot be overstated.

While spatial and temporal juvenile Chinook salmon life-history diversity in the Central Valley is revealed through RST monitoring, studies of otoliths recovered from adult Chinook salmon document that spawning populations of Central Valley Chinook salmon are composed of individuals reflecting diverse early life-history strategies (Cordoleani et al. 2018; Phillis et al. 2018; Sturrock et al. 2019b). Deer Creek and Mill Creek CHNSR otolith research conducted by Cordoleani et al. (2018) highlighted multiple juvenile rearing strategies contributing to adult Mill Creek and Deer Creek CHNSR populations, with the contribution of different strategies being different among years. These studies also documented diverse habitat utilization and non-natal rearing, adding to existing research highlighting the importance of maintaining a portfolio of juvenile life history strategies in Pacific salmon (Greene et al. 2010; Carlson and Satterthwaite 2011; Schroeder et al. 2015).

NMFS (2000a) emphasizes the importance of conserving the genetic and phenotypic diversity of salmonid populations by: 1) protecting key components of the environment to which they are adapted, including allowing natural process of disturbance and regeneration to occur and 2) preventing human-caused alterations which could reduce fitness by weakening the adaptive fit between a salmonid population and its environment or limit a population's ability to respond to natural selection. Juvenile salmon mortality during emigration to the ocean is considered a critical phase contributing to overall adult salmon population dynamics (Healey 1991; Williams 2006).

The hydrology of the major Central Valley rivers and Delta have been highly modified. Dam releases on the major rivers are now generally much lower than unimpaired conditions in the winter and spring and

higher in the summer and fall, and exports in the Delta remove up to 50% of the freshwater from the system during certain time periods (Cloern and Jassby 2012; Hutton et al. 2017a; SWRCB 2017). Modification of the natural hydrograph, including suppression of winter pulse flows, has resulted in contraction of migratory windows, reducing the variability in emigration timing, and suppressing full expression of juvenile Chinook salmon life histories. Additionally, the changes in timing and magnitude of flow combined with water diversions negatively impacts rearing habitat, connectivity, and ecosystem processes to which salmon have adapted (Lloyd et al. 2004; Lytle and Poff 2004; Flitcroft et al. 2019), hence native species may be poorly equipped to survive new flow regimes (Poff et al. 1997; Poff and Zimmerman 2010). The resulting reduction in life history diversity could significantly reduce the resiliency of the Sacramento River watershed's four Chinook salmon runs and increase the risk of a temporal mismatch with favorable ocean conditions (Satterthwaite et al. 2014).

Supporting life history diversity requires a broad migratory window that includes both early and late migrants, available rearing habitat throughout the migratory corridor, and sufficient flow to support migration, habitat connectivity, and ecosystem processes in freshwater habitats and in the Estuary (Bunn and Arthington 2002; Montagna et al. 2002; Greene et al. 2010; Poff and Zimmerman 2010; Carlson and Satterthwaite 2011; Schroeder et al. 2015; Goertler et al. 2018; Hall et al. 2018; Phillis et al. 2018; Flitcroft et al. 2019; Sturrock et al. 2019b).

5. Take and Impacts of the Taking on Winter-run and Spring-run Chinook Salmon Routing, Rearing, and Survival

5.1. Introduction

Juvenile Chinook salmon rearing and migration occurs downstream of natal Central Valley rivers and tributaries in the Tidal Estuary and bays (tidal Sacramento River downstream of the I Street Bridge in Sacramento, the Delta, and the Suisun, San Pablo and San Francisco Bays) (Windell et al. 2017). The use of the Delta and San Pablo and San Francisco Bays by juvenile CHNWR and CHNSR is highly variable among years and even between downstream migrant groups during a single year (Windell et al. 2017). Natural-origin CHNWR juveniles can migrate into the Delta as early as September (Schaffter 1980) and have been observed leaving the Delta at Chipps Island from January to April (Dekar et al. 2013), although some may reside into May (Windell et al. 2017). In years with large precipitation storms and subsequent flow events on the Sacramento River in the late fall, a bimodal pulse of downstream CHNWR migrants occurs (del Rosario et al. 2013; Windell et al. 2017). The initial pulse of CHNWR typically follows the first large storm in November or December, with a second pulse in the February through March period when those rearing upstream of the Delta are cued to migrate downstream and into the San Francisco Bay (Dekar et al. 2013; Israel et al. 2015; Windell et al. 2017). In years lacking early season precipitation events, the CHNWR pulse tends to be unimodal, with the majority of Bay-Delta entry occurring in the late winter and early spring months (Israel et al. 2015; Windell et al. 2017) For CHNSR, Williams (2006) suggested Delta entry timing can range from December to May, and that the timing and age at Delta entry appears to be influenced by the timing of winter high flow events. CDFW's Knights Landing RST program and trawl and beach seine monitoring show that the timing of entry of juvenile CHNSR into the Delta is highly variable, ranging from November to May (Julienne 2016). A higher proportion of CHNSR

juveniles have been observed entering the Delta earlier in the season as fry in wet years compared to dry years, and this variability is thought to be influenced by timing of winter high flow events (Williams 2006).

Juvenile salmon migration timing is influenced by habitat opportunity and capacity in the lower Sacramento River system, Delta, and bays as well as hydrology (Windell et al. 2017). Connectivity within the tidal wetland network affects migration route selection and timing for juvenile Chinook salmon (Windell et al. 2017). Artificial structures can delay migrants and result in a mismatch of environmental cues and migration-timing adaptations (Schaller et al. 2014; Windell et al. 2017). CHNWR follow flow cues to initiate migration downstream (e.g., past Knights Landing), with large migratory pulses occurring coincident with the first large storm event of the winter season (del Rosario et al. 2013; Windell et al. 2017). However, their residence period within the tidal system before moving to the bays (e.g., past Chipps Island) varies, with residence time within the Delta ranging from 41 to 117 days (del Rosario et al. 2013; Windell et al. 2017). Additional variation in migration timing may result from temporal variability in habitat opportunity (Windell et al. 2017). For example, when large floodplain areas are available in periods of high flow, such as when the Fremont Weir overtops and juvenile salmon can access floodplain areas in the Yolo Bypass, CHNWR residence time may increase (Windell et al. 2017). Delta residence times also depend on size when entering the Delta (del Rosario et al. 2013; Windell et al. 2017). However, delayed migration in the mainstem channels of the Delta has also been observed (Michel et al. 2012; Windell et al. 2017). Human modification of the Delta has resulted in a channel network that no longer operates across predictable gradients for native fish and provides unnatural cues and routes for migration (SFEI-ASC 2014; Windell et al. 2017).

In the interior Delta, longer travel times and lower survival have been documented (Brandes and McLain 2001; Newman and Brandes 2010; Perry et al. 2010; Windell et al. 2017). In one study, survival probabilities were negatively associated with water exports, suggesting that water exports affect migration by increasing the risk of entrainment, although the authors note that many more years of data would be needed to precisely estimate the export effect (Newman and Brandes 2010; Windell et al. 2017). In the Central Valley, there is evidence for diverse juvenile migratory phenotypes contributing to the adult population (Miller et al. 2010; Sturrock et al. 2015; Windell et al. 2017). However, studies also show that biocomplexity among adult returns has been severely reduced such that annual return rates have become highly correlated in recent years, thus reducing basin-wide population stability and leaving Central Valley salmon populations more vulnerable to extreme events (Carlson and Satterthwaite 2011; Windell et al. 2017). An important contributor to reduced biocomplexity of adult returns has been the homogenization of juvenile out-migration timing promoted by hatchery and other management practices (Lindley et al. 2009; Windell et al. 2017). Planned wetland restoration is expected to diversify rearing habitat in the Delta and increase variation in out-migrant timing and population stability (Windell et al. 2017).

Juvenile Chinook salmon survival rates during rearing and migration are influenced by a number of factors, including hydrology. Migration corridors and rearing habitats near water diversions increase the risk of entrainment-related mortality for juvenile Chinook salmon (Windell et al. 2017). Juvenile salmon entrained into the south Delta experience a diminished ability to navigate out towards the ocean due to confusing navigational cues from altered hydrology, changes in channel network configuration and water quality gradients, and impairments to sensory systems from contaminants (Windell et al. 2017). Juvenile salmon arriving in the southern end of the Delta are at risk of entrainment in the SWP and CVP

export facilities (Windell et al. 2017). Each of these pumping plants has a fish salvage facility to protect fish from entering the pumping intakes, and recent research suggests that once juvenile salmon enter the southern Delta, survival can be higher for fish captured in the CVP salvage facility (Tracy Fish Collection Facility) and rereleased more seaward (Buchanan et al. 2013; Windell et al. 2017). However, little information exists to support this hypothesis and data on post-release survival of salvaged fish is scarce. This suggestion that survival is higher through the salvage process also highlights the extremely poor survival rate of juveniles in the south Delta, which is hypothesized to result from poor rearing conditions (such as low refuge habitat and food availability) and high predation risk (Windell et al. 2017). The population level benefit (if any) of salvage is uncertain. Furthermore, only a subset of entrained fish is salvaged, and an even smaller subset of these fish survive the salvage process. Mortality rates prior to salvage can be high due to predation or poor water quality conditions, and handling can cause stress and injuries that reduces both short and long-term survival. Trucking juveniles from the salvage facilities in combination with Delta water operations likely contributes to significant adult straying and anthropogenic structures along adult migratory routes may increase stranding risk, which is substantial in stilling basins or deep areas of weirs that are full of water after floodwaters recede (Sommer et al. 2005; Windell et al. 2017). Stranding can also occur after flooding of large floodplain areas (e.g., the Yolo Bypass) and riparian areas as the hydrograph recedes (Windell et al. 2017; Nagrodski 2011). Elsewhere in the tidal river Delta, a myriad of water diversions exists for local agriculture, most of which are un-screened (Moyle and Israel 2005), and mortality from these diversions may be significant during some seasons (Windell et al. 2017).

Juvenile salmon growth in the tidal Estuary is influenced by water temperature, food availability, and inter- and intra-specific competition (Windell et al. 2017). Juvenile salmon metabolic rates are influenced chiefly by water temperature (Bradford and Geen 1992, Beakes et al. 2014; Windell et al. 2017). In the lower Sacramento River and Delta, water temperature varies with air temperature, flow, and habitat type (Wagner et al. 2011; Windell et al. 2017). Shallow tidal wetland and floodplain habitats are generally warmer than leveed river channels (Sommer et al. 2001; Windell et al. 2017). Warmer water temperatures and longer water residence times in these areas boost productivity and retention of zooplankton and aquatic insect prey (Schemel et al. 2003), and result in faster growth rates in juvenile salmonids compared to steep, armored river channels (Sommer et al. 2001, Jeffres et al. 2008; Windell et al. 2017). Juvenile salmon densities and intra-guild competitor densities influence food availability (Windell et al. 2017). As such, high densities of hatchery salmon can have a negative impact on natural juveniles, which has been shown to occur during years of poor ocean conditions (Levin et al. 2001; Windell et al. 2017).

5.2. Effects of South Delta Export Operations on Juvenile Salmon Rearing, Routing, and Through-Delta Survival

This section focuses on take of juvenile CHNWR and CHNSR and related impacts of the taking on rearing, routing, and through-Delta survival, due to Project effects on Delta hydrodynamics. These Project-related hydrodynamic changes may reduce the suitability of the Delta for supporting successful rearing and migration, including by routing and entrainment of fish into the interior Delta, increasing the susceptibility of fish to predation, and increasing their exposure to poor water quality conditions. Beginning in Section 6 – Minimization of Take and Impacts of the Taking on Winter-run Chinook Salmon and Spring-run Chinook Salmon Rearing, Routing, and Through-Delta Survival of this Effects Analysis we

discuss minimization of these effects as a result of implementation of Conditions of Approval included in the ITP.

Project effects to Delta hydrodynamics may impact juvenile salmonid migration timing and duration, behavior, and survival through the Delta. Key drivers of Delta hydrodynamics are freshwater inflow, SWP and CVP exports from the south Delta export facilities, operations of the DCC, and the presence or absence of the Head of Old River Barrier (HORB). These drivers interact with tidal influences over much of the interior and southern Delta. During day-to-day SWP and CVP operations, these drivers are often correlated with one another (e.g., exports tend to be higher at higher San Joaquin River inflows) and regulatory constraints on multiple drivers may simultaneously be in effect. The modeling of Alternative 2b versus Existing Conditions in the FEIR reflects those realities and, while those scenarios are appropriate for Project analyses, they have limited value for evaluating the isolated effects of one driver versus another.

The FEIR utilizes a single concept, velocity changes at distributary junctions, to evaluate the effects of Project exports on entrainment of fish into the interior Delta, and concludes based on a DSM2 analysis that Project export operations have little to no effect on velocity changes at distributary junctions; therefore, no impact on routing, rearing, and through-Delta survival of juvenile CHNWR and CHNSR. This single concept underlying the analysis does not account for the complex and diverse life history strategies of CHNWR and CHNSR nor does it allow for full evaluation of the true and total impact, direct and indirect of Project operations on CESA-listed salmonids.

The analyses used in the FEIR rely primarily on CWT smolts and acoustically tagged hatchery CHNLFR smolts, in addition to other methods to evaluate routing and through-Delta survival of CHNWR and CHNSR, and include:

- Delta Hydrodynamics (based on Zeug and Cavallo 2014 and SST 2017)
- Delta Passage Model
- Survival, Travel Time, and Routing Analysis (STARS analysis, based on Perry et al. 2018)
- San Joaquin River-Origin Spring-Run Chinook Salmon Structured Decision Model

All of these analyses utilize modeling from CalSim II, which incorporates the operations of both the SWP and CVP. Thus, Delta hydrodynamic impacts discussed here include the combined impacts of the SWP and CVP.

These analyses have some applicability for evaluation of routing of juvenile salmon into the interior Delta and through-Delta survival based on north Delta inflow for highly mobile emigrating CHNWR and CHNSR smolts which transit the Delta in approximately seven days, but these analyses are not as useful in evaluating Project effects on natural CHNWR and CHNSR fry, parr, and smolts which rear in the Delta and comprise the bulk of these populations. These effects have not been quantified previously in the FEIR, and to our knowledge cannot currently be quantified based on a lack of empirical data. Thus, the impact of Project operations on rearing, routing, and through-Delta survival of juvenile CHNWR and CHNSR is likely greater than that quantitatively estimated in the FEIR. As stated in SST (2017) with respect to both the SWP and CVP:

Water export operations contribute to salmonid mortality in the Delta via direct mortality at the facilities, but direct mortality does not account for the majority of the mortality experienced in the Delta; the mechanism and magnitude of indirect effects of water project operations on Delta mortality outside the facilities is uncertain.

The FEIR does not quantify the contribution of SWP and CVP operations to the total mortality of juvenile salmonids. As stated in SST (2017), many of the mechanisms through which changes in Delta hydrodynamics, and other factors related to SWP and SVP operations, may contribute to salmonid mortality (e.g., change in vulnerability to predation in Delta channels, change in migration routing, reduced fitness due to impacts to rearing habitat and food webs, and impacts to ecosystem processes in the Estuary) are uncertain.

As further stated in the SST (2017), estimates of direct mortality (e.g., mortality resulting from pre-screen losses and losses at louver and salvage facilities, which are directly related to water project export facilities) have been developed from CWT data by several authors and show, in general, that the magnitude of direct loss (e.g., percentage of a marked release group observed in fish salvage) is typically low for juvenile Chinook salmon (typically less than approximately 1%). However, such estimates do not include export-induced mortality prior to entering the facilities that is indirectly related to SWP and CVP operations (e.g., mortality resulting from water project changes in habitat). Estimates of direct facility mortality as a proportion of total migration mortality have been as high as 5.5% for CHNWR and 17.5% for Chinook salmon released in the San Joaquin River (Zeug et al. 2014; SST 2017).

It is unknown whether equivocal findings regarding the existence and nature of a relationship between SWP and CVP exports and through-Delta survival is due to the lack of a relationship, the concurrent and confounding influence of other variables, or the effect of low overall survival in recent years (SST 2017). Further analysis of available data, as well as additional investigations to test hypotheses regarding export effects on migration and survival of Sacramento River and San Joaquin River origin salmonids migrating through the Delta are needed to address these data gaps (SST 2017). Some of these data gaps will be filled through ITP requirements to support ongoing monitoring, implement new monitoring, and new science (Conditions of Approval 7.5.1, 7.5.2, and 7.5.3 as well as 8.6.6).

5.2.1. Rearing

A quantitative evaluation of the Project's effect on CHNWR and CHNSR in-Delta rearing has not been conducted due to a lack of empirical data. Currently, there is a need for additional monitoring and science to bolster our current understanding of natural juvenile CHNWR and CHNSR behavior, habitat utilization, feeding strategies, occupancy, residence time, use of tidal surfing/selective tidal stream transport, predation effects, long-term routing, and other aspects which would be necessary to populate life cycle models or other methods to enable quantitative evaluation.

Individual rearing fish entrained into the interior Delta are subject to tidal forcing and may move through the San Joaquin River into the channels of Old and Middle Rivers (OMR), as well as other channel junctions in the reach, rather than moving towards the western Delta. Juvenile CHNWR and CHNSR from the Sacramento River basin have been observed in salvage at the Skinner Fish Facility and Tracy Fish Facility in the south Delta (see Section 7.3.4 – Historical Loss of Juvenile Chinook Salmon at the Salvage Facilities below) verifying that juvenile CHNWR are present in the waterways leading to these facilities. Due to extensive tidal movement and the reverse flows in the two main channels (Old and Middle Rivers) leading to the export facilities due to Project exports, juvenile CHNWR may disperse into many of the waterways adjacent to the export facilities, including those waterways that contain the three south Delta agricultural barriers (Old River, Middle River, and Grant Line Canal).

While Bay-Delta waterways function as migratory corridors for CHNWR and CHNSR smolts, they provide holding and rearing habitat for each of these species as well. 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). During the period that juvenile CHNWR are moving through alternate routes, they utilize the Delta for rearing. del Rosario et al. (2013) found that CHNWR are present in the Delta for an extended period of time, with an apparent residence time ranging from 41 to 117 days, with longer apparent residence times for juveniles arriving earlier at Knights Landing. Studies by Sturrock et al. (2015) and Miller et al. (2010) show that for Central Valley CHNFR, sizeable fractions of the adult 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 smolt life stage. Miller et al. (2010) found that among the 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. Similar life history diversity strategies likely exist for CHNWR and CHNSR (Flitcroft et al. 2019) and need to be evaluated through a comprehensive long-term monitoring program to provide sufficient data for analysis of Project impacts on juvenile CHNWR and CHNSR rearing in the Delta.

Analyses that rely on parameters for migrating fish versus rearing fish to characterize Project impacts on CHNWR and CHNSR will likely underestimate take. Specifically, quantitative evaluations of routing and through-Delta survival are primarily based on CWT and acoustic tag data for large hatchery smolts which are highly migratory and exhibit Delta transit times averaging approximately seven days. Application of a seven-day transit time is not well suited for analyses involving rearing fish, which comprise the bulk of annual natural CHNWR and CHNSR as they spend extended periods of time in the Delta.

As stated in SST (2017), the broad conceptual model developed by the South Delta Salmonid Research Collaborative Effort predicts that SWP and CVP operations could affect juvenile salmon migration timing, migration rates and route selection, and locations of rearing and habitat use in the tributaries influenced by SWP and CVP operations such as the Feather, American, Sacramento, and Stanislaus Rivers and Delta. Operations have the potential to constrain life history diversity as a result of altering instream flows, export operations, and other habitat conditions by favoring one type of life history attribute over others (SST 2017). Over time, this can represent a selective pressure that reduces diversity within a population and population abundance (SST 2017). The cumulative effect of SWP and CVP operations on juvenile salmonid mortality in and beyond the Delta, in relation to other stressors, is a major gap in our knowledge (SST 2017).

As described in Sections 6.4, 6.6, 6.7, 6.8, and 6.9 in more detail below, Conditions of Approval 8.12, 8.18, 8.19, 8.20, 9.1.1, 9.1.2, 9.1.3, 9.1.3.1, 9.1.3.2, and 9.1.3.3 of the ITP minimize the effects of the Project on rearing of juvenile salmon into the south Delta and salvage facilities.

5.2.2. Routing

5.2.2.1. Delta Hydrodynamic Assessment and Junction Routing Analysis

5.2.2.1.1. Delta Hydrodynamic Assessment and Junction Routing Analysis – Winter-run Chinook Salmon

To assess potential hydrodynamic effects of Project operations on juvenile salmon routing, the FEIR used hourly DSM2 HYDRO outputs to identify Delta channels exhibiting velocity changes under Refined Alternative 2b and Existing Conditions scenarios. The analysis is stratified by water year type and by the three seasons when juvenile salmonids are present in the Delta (fall, winter, and spring). CalSim II modeling indicates that inflows to the Delta from the Sacramento and San Joaquin Rivers generally

would not be appreciably different under Refined Alternative 2b and Existing Conditions scenarios. In the Delta, the largest hydrodynamic differences between Refined Alternative 2b and Existing Conditions scenarios that may influence juvenile salmonids occurring in the south Delta result from changes to spring export rates and the HORB.

Between September and November, velocities in the interior Delta (between Highway 4 and north to the San Joaquin River mainstem) are generally similar between Refined Alternative 2b and Existing Conditions scenarios. The largest velocity changes are apparent near the HOR. Under Refined Alternative 2b, no barrier is in place at this location and, therefore more water is flowing into eastern Old and Middle Rivers, increasing velocities in these channels. Velocities in the mainstem San Joaquin River both upstream and downstream of the HOR exhibit few differences in critical, dry, below-normal, and above-normal water years. In wet water years, the absence of the HORB causes moderately increased velocities upstream and slightly decreased velocities downstream of the HOR under Refined Alternative 2b. Exports proposed for fall months (particularly November) lead to slight velocity changes in the south Delta near the export facilities. Flows in the south Delta are tidal (i.e., bidirectional), and velocity changes in this region reflect both slightly stronger negative velocities and slightly weaker positive velocities.

Between December and February, exports between Refined Alternative 2b and Existing Conditions scenarios are similar and the HORB is not installed. Velocities throughout the south and interior Delta are largely unchanged in winter months between the Refined Alternative 2b and the Existing Conditions scenarios.

Between March and May, velocities in the interior Delta (between Hwy 4 and north to the San Joaquin River mainstem) are generally similar between Refined Alternative 2b and Existing Conditions scenarios. The largest velocity changes are apparent near the HOR. Under Refined Alternative 2b, no barrier is in place at this location and, therefore, more water would flow into eastern Old and Middle rivers, increasing velocities in these channels. Velocities in the mainstem San Joaquin River both upstream and downstream of the HOR exhibit increasing differences with wetter water year types. These differences are due to the absence of the HORB under Refined Alternative 2b. The lack of HORB causes moderate to large increases in velocities upstream of the HOR, and slight to moderately decreased velocities downstream of HOR. These impacts occur because the presence of the HORB creates a hydraulic head that slows upstream velocities and this impact is stronger with higher San Joaquin River flows. Exports proposed for spring months (particularly April and May) lead to some velocity changes in the south Delta near the export intake facilities. Minimal impacts are apparent in critically dry years, but slight to moderate velocity differences occurred in the Old and Middle rivers immediately north of the export facilities during wetter water year types. Velocity changes associated with spring exports under Refined Alternative 2b do not appear to extend into the interior Delta. Flows in the south and interior Delta are tidal (i.e., bidirectional), and export-related velocity changes observed in these regions reflect both slightly stronger negative velocities and slightly weaker positive velocities.

Delta hydrodynamic impacts identified in the FEIR analysis include the combined impacts of the SWP and CVP. The FEIR states the SWP responsibility for Delta water operations during the September through May period evaluated above is approximately 20-60% depending on the month and water year type.

CWT and acoustic tag studies suggest relatively few juvenile Chinook salmon entering the Delta from the north will be exposed to velocity changes observed in the south Delta with Refined Alternative 2b (e.g., less than 1% of CWT fish were found in salvage; Zeug and Cavallo 2014). Fish passing through the DCC or Georgiana Slough and continuing to migrate westward in the mainstem San Joaquin River will experience no velocity changes likely to influence their survival or behavior. Fish that move southward enough in the Old and Middle River corridor to reach areas of altered velocities may be more likely to continue moving toward the export facilities and become vulnerable to entrainment. However, velocity changes that could occur in the spring and fall are not likely to affect CHNWR because most CHNWR are expected to have exited the Delta by April and May and are not generally present in the region in September and November.

5.2.2.1.2. Delta Hydrodynamic Assessment and Junction Routing Analysis – Spring-run Chinook Salmon

When considering changes in flow proportion impacts, it is important to consider when juvenile salmon of various races may be present in the Delta. Juvenile CHNSR are present in the Delta between November and early June with a peak in April. CWT and acoustic tag studies suggest few juvenile Chinook salmon entering the Delta from the Sacramento River would be exposed to velocity changes observed in the south Delta under Alternative 2b (e.g., Zeug and Cavallo 2014). Juvenile CHNSR entering the Delta from the Sacramento River and passing through the DCC or Georgiana Slough and continuing to migrate westward in the mainstem San Joaquin River would be expected to experience no velocity changes likely to influence their survival or behavior. Fish that move southward enough in the Old and Middle River corridor to reach areas of altered velocities may be more likely to continue moving toward the export facilities and become vulnerable to entrainment. Though the geographic footprint of velocity changes is relatively small, greater exports under Alternative 2b during April and May could affect a greater number of CHNSR juveniles than under the Existing Conditions scenario, with this season generally coinciding with the peak of juvenile CHNSR migration.

For CHNSR from the San Joaquin River basin, the absence of the HORB under the Proposed Project and Refined Alternative 2b causes relatively large differences in velocities in the mainstem San Joaquin River between approximately Mossdale and Stockton. Velocities upstream of the HOR are higher under Alternative 2b (without HORB) and have the potential to be beneficial to juvenile Chinook salmon and steelhead by increasing their migration rate. This increase in velocity occurs when HORB is not installed because the presence of the HORB creates hydraulic head that slows upstream velocities and the impact is stronger with higher San Joaquin River flows. However, velocities downstream of the HOR under Alternative 2b are reduced and may offset the potential benefit of increased velocities upstream of HOR. The absence of HORB under Alternative 2b will allow more San Joaquin River origin juvenile salmonids to pass through Old River and the Grant Line Canal and approach the export facilities. While this routing increases entrainment risk for these fish, available CWT and acoustic tag studies indicate survival in this region is very poor generally and not adversely influenced by export rates (SST 2017). Entrainment at the CVP has been observed to yield higher through-Delta survival (via trucking) than volitional migration through the Delta by other routes, even with positive Old and Middle River (OMR) conditions (Buchanan et al. 2018; SJRGA 2011, 2013). Though entrainment has the potential to increase during April and May due to increased exports under Alternative 2b in these months, through-Delta survival of juvenile CHNSR originating from the San Joaquin River basin may not be impaired by these

operations, relative to the Existing Conditions scenario (see also the analysis below based on the San Joaquin River-Origin Spring-run Chinook Salmon Structured Decision Model).

The FEIR's junction routing analysis for the HOR junction indicates the proportion of flow moving into the Old River route and toward the CVP and SWP export facilities and is relevant for juvenile CHNSR emigrating from the San Joaquin River basin. Thus, lower flow proportion values indicate decreased flow toward the export facilities. Flow proportion into the Old River varied by month and water year type. Differences between Alternative 2b and Existing Conditions scenarios were apparent in November, April, and May. For these months, flow proportion into the Old River route is higher under Alternative 2b in all water year types, but the differences were clearest and most substantial in below normal and drier years. In April and May of dry years, flow proportion into the Old River route was 40% greater under Alternative 2b than under the Existing Conditions scenario. Results for April and May in wet, above-normal, and below-normal water years were highly variable for the Existing Conditions scenario because placement of the HORB was variable under wetter conditions (the barrier was assumed not to be installed at Vernalis flow >5,000 cfs). This change in flow proportion indicates juvenile salmon approaching the Delta from the San Joaquin River basin during April and May are much more likely to enter the Old River route under Alternative 2b than under the Existing Conditions scenario.

Juvenile CHSNR originating from the Sacramento River basin would not encounter the HOR junction and would therefore not be affected by these differences. No juvenile CHNSR are expected to be emigrating from the San Joaquin River basin in November, so differences in this month do not have biological significance. All juvenile salmon emigrating from the San Joaquin River basin must pass through the HOR junction. Thus, Alternative 2b is expected to result in an increased proportion of juvenile salmon passing through the Old River route. However, recent acoustic tagging studies indicate no difference in survival for fish migrating through the Old River route relative to fish continuing through the San Joaquin River route (Buchanan et al. 2018). It is also important to note that although Alternative 2b does not include installation of the HORB, CHNSR juveniles may receive some ancillary protection during April and May from the risk assessment-based approach for OMR flow management included in Alternative 2b, and as required by Conditions of Approval in the ITP, that would be undertaken for other species.

Delta hydrodynamic impacts identified in the FEIR analysis include the combined impacts of the SWP and CVP. The FEIR states the SWP responsibility for Delta water operations during the November through June period evaluated above is approximately 20%-60% depending on the month and water year type.

5.2.2.1.3. Discussion of Delta Hydrodynamic Assessment and Junction Routing Analysis Conclusions

With respect to routing of CHNWR and CHNSR that originate in the Sacramento River drainage in relation to Project effects, the FEIR analysis concludes that although more salmon in the Old and Middle River corridor may be entrained under Alternative 2b than under Existing Conditions, entrainment from the Sacramento River into the interior Delta is similar between routing junctions due to similar distributary velocities. However, these results should be interpreted with caution because the FEIR analysis does not consider all variables affecting entrainment of juvenile salmonids into distributary junctions as these data are limited due to lack of current scientific information on the subject.

The FEIR relies on the Collaborative Adaptive Management Team's (CAMT) Salmonid Scoping Team (SST) 2017 report (SST 2017) to justify its use of velocity changes to evaluate routing behavior. As stated in the ITP Application:

A foundation for assessing far-field effects has been provided by work of the Collaborative Adaptive Management Team's (CAMT) Salmonid Scoping Team (SST 2017). The SST completed a thorough review of this subject and defined a driver-linkage-outcome (DLO) framework for specifying how water project operations (the "driver") can influence juvenile salmonid behavior (the "linkage") and potentially cause changes in survival or routing (the "outcome").

The SST concluded altered "Channel Velocity" and altered "Flow Direction" were the only two hydrodynamic mechanisms by which exports and river inflows could affect juvenile salmonids in the Delta.

However; Table 2-1 of SST (2017) provides the "Hydrodynamics DLO Components for Analysis" and notes that several potentially important outcomes, in addition to "Channel Velocity" and altered "Flow Direction", including percent positive flow, water temperature, salinity, residence time, and source/origin of water were not analyzed. Additionally, Table 2-2 of SST (2017) provides the "Behavior DLO Components for Analysis" and notes that the following potentially important factors were not analyzed:

- Drivers
 - Water quality (e.g. temperature, dissolved oxygen, salinity, turbidity, contaminants)
 - Hydraulic residence time
 - Small-scale hydrodynamics as affected by structures/bathymetry
- Linkages – Physiological and behavioral responses to hydrodynamic or water quality conditions, gradients, or variability such as:
 - Rearing
 - Active swimming
 - Energy expenditure
 - Selective tidal stream transport
- Outcomes
 - Timing of Delta entry
 - Delta residence time
 - Rearing location

SST (2017) also references Cavallo et al. (2015) which concluded that the proportion of flow entering a distributary junction was the best predictor of routing, accounting for 70% of observed variance in route selection. Similarly, the SST (2017) refers to results of fine-resolution acoustic and hydrodynamic monitoring in the Sacramento River at Georgiana Slough to demonstrate the ability to predict route selection of juvenile salmonids based on the location of the fish in the channel cross-section and the hydraulic streaklines showing the proportion of the river flow entering the slough (DWR 2012). Routing at a junction depends on instantaneous flow fields and velocities at the junction in three dimensional space, the spatial distribution of fish as they enter the region of the junction space, and the individual behavior of the fish to the environmental variables it encounters in this space. In the vast majority of instances, there is little or no data that can be provided with the available tools at hand, in a way that allows for evaluation and quantification of the specific hydrodynamics at a given junction. In light of the

absence of this information, the proportional routing of fish can be estimated based on longer-term hydrodynamic measures assuming a uniform arrival of fish at the junction throughout the averaging period. Other routing studies evaluate the concept of critical streakline, which is a more detailed evaluation of flow split described in Cavallo et al. (2015) that includes fish position. A critical streakline means that fish on one side of the streakline are more likely to move into distributaries (streams that branch off and flow away from a mainstem channel) or weirs on that same side of the channel (Perry et al. 2016; Stumpner 2018). While there are numerous factors that affect the channel position of the critical streakline at any channel junction, it is apparent that the higher the percentage of total flow that enter distributaries, the farther into the channel the critical streakline reaches.

Given the number of variables hypothesized to affect entrainment into distributaries leading to the interior Delta, including those not analyzed in SST (2017), the focus of the FEIR on Project effects to velocity changes at these junctions as determined by DSM2 modeling does not fully capture potential effects of Project operations on CHNWR or CHNSR. This is particularly highlighted by the SST (2017) finding that:

The Delta Simulation Model 2 (DSM2) may be useful for assessing how exports from the South Delta, river inflows, barriers, and tides can influence the magnitude, duration, and direction of water velocities and flows within channels, depending on its accuracy relative to validation for specific areas and time scales. However, 15-minute velocities and flows estimated from DSM2 have been found to vary substantially from measured conditions and timing related to tidal conditions (Appendix C, Pages C-14 through C-231) and were not found to be accurate for assessing fish fates and behaviors at specific times and locations which would require direct measurement of flows in the field, or the application of simulation models depending on the temporal and spatial resolution needed to support analyses of specific hypotheses or management questions.

The extensive work by Perry et al. (2018) parallels this concept, although in much greater detail for the Sacramento River adjacent to the DCC gates. Higher flows in the Sacramento River mute the tidal effect and less flow and fewer fish enter the DCC route when the gates are open. Hydrodynamic conditions downstream of the junction have more pronounced riverine characteristics when flows are high, and there is less tidal influence in the area of the junction.

SST (2017) further states:

Because the routing “decision” occurs at the time the fish reaches the junction, local flow conditions at the time of arrival (including tidal effects), rather than daily or longer-term average flows, affect the outcome. On the mainstem San Joaquin River, especially in the tidal reaches downstream of the Head of Old River, flow changes due to the tides are greater than flow changes due to export rates. One way which high San Joaquin River inflow may improve through-Delta survival is that it moves the region of tidal influence farther downstream and may lead to flow conditions at junctions that reduce routing into the interior Delta. Our conceptual model assumes that individual fish will enter the junction space over a discrete period of time (daily) and that daily net flows (tidally averaged in tidal regions) will influence the pattern of flow dispersal at the junction over the diurnal tidal cycle in which the fish is present in the junction space. Stronger downstream flows (more positive daily net flows) will move the tidally influenced

zone farther downstream, and the junction will have less water flowing into it, either by magnitude or duration.

SWP operations including both the storage of water in Lake Oroville, which reduces flow in the mainstem Sacramento River, and export operations, which increase the percentage of flow diverted from the Sacramento River into the interior Delta, are likely to increase routing and entrainment into the interior Delta. SST (2017) and the ITP Application both conclude that negative export effects increase with proximity to the export facilities. Specifically, SST (2017) utilized acoustic tag data from San Joaquin River release locations to evaluate south Delta effects and south Delta routing and concluded that survival is poor for fish near the export facilities. Although these routing results were more applicable to CHNFR and steelhead originating from the San Joaquin drainage, the conclusion is also applicable for Sacramento River basin origin CHNSR and CHNWR that become entrained in those areas of the south Delta.

As described in Sections 6.2, 6.3, 6.5, 6.7 and 6.9 in more detail below, Conditions of Approval 8.9.1, 8.9.2, 8.17, 8.20, 9.1.3, 9.1.3.1, 9.1.3.2, and 9.1.3.3 of the ITP minimize the effects of the Project on routing of juvenile salmon into the south Delta and salvage facilities.

5.2.3. Through-Delta Survival

5.2.3.1. Delta Passage Model

The FEIR's analysis of through-Delta survival for juvenile salmonids uses the Delta Passage Model (DPM), which integrates operational effects of the Existing Conditions and Alternative 2b scenarios that could influence through-Delta survival of migrating juvenile Chinook salmon smolts. Functions included in the DPM include reach-specific flow-survival and flow travel-time relationships, flow-routing relationships, and export survival relationship. The DPM integrates operational impacts of the Existing Conditions and Alternative 2b scenarios that could influence through-Delta survival of migrating juvenile Chinook salmon smolts, including Sacramento River CHNWR.

The results of the FEIR's DPM should be interpreted with caution. Specifically, the results should only be considered relevant, with caveats, for natural CHNWR and CHNSR that have reared upstream and are rapidly transiting through the Delta as smolts, as well as hatchery CHNWR and CHNSR smolts released upstream of the Delta. The DPM does not evaluate routing and through-Delta survival for rearing natural CHNWR and CHNSR populations that spend extended periods of time in the Delta. These individuals comprise the majority of these populations.

For CHNWR and CHNSR smolts rapidly transiting the Delta, survival estimates generated by the DPM are not intended to predict future outcomes. Instead, the DPM provides a simulation tool that compares the effects of different water management options on smolt migration survival, with accompanying estimates of uncertainty. The DPM was used to evaluate overall through-Delta survival for the Existing Conditions and Project scenarios. Again, the DPM is a tool to compare different scenarios and is not intended to predict actual through-Delta survival under current or future conditions. As with other methods found in the FEIR's analysis, it is possible that underlying relationships (e.g., flow-survival) that are used to inform the DPM will change in the future. There is an assumption of stationarity of these basic relationships to allow scenarios to be compared for the current analysis, recognizing that it may be necessary to re-examine the relationships as new information becomes available.

5.2.3.1.1. Delta Passage Model Results – Winter-Run Chinook Salmon

Across the 82-year simulation period, mean through-Delta survival was 0.2% greater for Alternative 2b (28.5%, 95% CI 15.7-44.2) relative to the Existing Conditions scenario (28.3%, 95% CI 15.9-44.5). Survival was greater under the Existing Conditions scenario for 24 of the 82 years and greater under Alternative 2b in 37 years. Differences in individual years were generally small (< 1%) with the largest difference occurring in 1975 when survival was 1.9% higher than under the Existing Conditions scenario. Confidence intervals for through-Delta survival overlapped between scenarios in all years.

For all scenarios, mean survival rates tracked water year type with the highest value in wet years and the lowest value in critical years. In each water year-type, mean survival was slightly higher under Alternative 2b, relative to the Existing Condition. However, 95% confidence intervals overlapped substantially between survival estimates. The largest difference between scenarios occurred in below-normal years when mean survival under Alternative 2b was 0.32% higher than the Existing Conditions scenario.

Through-Delta survival impacts as represented by the DPM include the combined impacts of the SWP and CVP. The FEIR states that the SWP responsibility for Delta water operations during the main winter-spring (~December through April) period of CHNWR entry into the Delta is approximately 20% to 60%.

5.2.3.1.2. Delta Passage Model Results – Spring-Run Chinook Salmon

Across the 82-year simulation period, mean through-Delta survival was 0.4% greater under the Existing Conditions scenario (26.4%, 95% CI 14.5-45.5) relative to Alternative 2b (26.0%, 95% CI 14.7-44.7). Survival was greater under the Existing Conditions scenario for 58 of the 82 years and greater under Alternative 2b in 16 years. Differences in individual years were generally small (< 1.5%) with the largest difference occurring in the 1975 model year when survival under the Existing Conditions scenario was 1.9% higher than under Alternative 2b. Confidence intervals for through-Delta survival overlapped between scenarios in all years.

For both scenarios, mean survival rates tracked water year type with the highest value in wet years and the lowest value in critical years. Mean through-Delta survival was greater for the Existing Conditions scenario relative to Alternative 2b in all but critical water year types. The 95% confidence intervals for survival estimates overlapped between scenarios in each water year type.

Through-Delta survival impacts as represented by the DPM include the combined impacts of the SWP and CVP. The FEIR states the SWP responsibility for Delta water operations during the spring (~March through May) period of CHNSR entry into the Delta is approximately 20% to 60%.

5.2.3.2. Survival, Travel Time, and Routing Analysis (STARS, Based on Perry et al. 2018)

The FEIR includes an analysis of through-Delta survival for juvenile salmonids using the STARS Model based on Perry et al. (2018), which 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. The results of STARS should be interpreted with caution. Specifically, the results should only be considered relevant, with caveats, for natural CHNWR and CHNSR that have reared upstream and are rapidly transiting through the Delta as smolts and hatchery CHNWR and CHNSR released upstream of the Delta. The DPM does not evaluate routing and through-Delta survival for natural CHNWR and CHNSR, nor Project-related effects to the behavior and life history diversity

displayed by the majority of these populations which spend extended periods in the Delta. Further, the statistical model of Perry et al. (2018) provides limited analysis of through-Delta survival as it considers the effects of Freeport flows and DCC operations but does not include south Delta exports. Thus, the modeling results presented herein are insensitive to any difference in exports between the scenarios being considered. Detailed methods and results for the STARS model are presented in Perry et al. (2019).

5.2.3.2.1. STARS Model Results – Winter-Run Chinook Salmon

Although the STARS analysis considered survival, travel time, and routing, the discussion herein focuses on differences in survival because the survival calculations integrate flow-survival relationships, travel time, and routing of fish into different parts of the Delta with varying survival.

The STARS model results suggest little difference in predicted through-Delta survival of CHNWR between Alternative 2b and Existing Conditions scenarios, except for juveniles migrating before December. Given that most individuals appear to migrate into the Delta with early winter flow pulses (del Rosario et al. 2013) that may coincide with closure of the DCC, this may limit the potential for some of the early emigrating juvenile CHNWR to find their way to the south Delta and potentially be entrained at the SWP export facility. Historically, a relatively low proportion of juvenile CHNWR are salvaged (Zeug and Cavallo 2014). Therefore, the differences between the Existing Conditions and Alternative 2b scenarios in emigration survival, as influenced by routing (entrainment into the interior Delta) and travel time, are not considered a substantial impact on the emigrating CHNWR population.

The analysis of through Delta survival, routing, and timing as represented by the STARS model reflect combined SWP and CVP operations. The FEIR states that the SWP responsibility for Delta water operations during November when differences in survival were most pronounced is approximately 50-60% depending on the water year type. Also noted previously, STARS is not capable of evaluating the indirect effect of the Project on rearing and survival which is likely many times greater than the effect of direct take via salvage and loss at the export facilities.

5.2.3.2.2. STARS Model Results – Spring-run Chinook Salmon

As described for CHNWR, the STARS model provides an assessment of potential Project effects on juvenile CHNSR emigrating from the Sacramento River through the Delta (Perry et al. 2019), albeit somewhat limited in considering only the effects of Freeport flows and DCC operations.

Run-specific analyses are not conducted using the STARS model. Rather, a daily analysis of juvenile Chinook salmon entry into the Delta was conducted from October through June, which encompasses the CHNSR migration period. However, the discussion of the STARS model results for CHNSR considered the months of November through May based on the time period when they could potentially rear and emigrate from Delta.

The analysis revealed that overall, there generally was little difference in predicted survival between Alternative 2b and Existing Conditions scenarios. Specifically, the STARS model results suggest little difference in predicted through-Delta survival of CHNSR between Alternative 2b and Existing Conditions scenarios in all months of the emigration period in all water year types, except for juveniles migrating before December. Although the STARS analysis showed decreases in Chinook Salmon survival under Alternative 2b associated with entrainment into the Delta during November in all water year types, the difference was attributed mainly to DCC operations. Further, these differences in survival during

November may not necessarily be applicable to emigrating CHNSR because it is likely that CHNSR emigrating out of the Sacramento River during November are yearling fish that may exhibit differences in susceptibility to routing into the Delta from the CHNLF used to develop the model. Therefore, the differences between Alternative 2b and existing conditions scenarios in emigration survival, as influenced by routing (entrainment into the interior Delta) and travel time, are not considered a substantial impact on the emigrating CHNSR population. Again, the STARS model evaluates Project-related effects due to changes in inflow at Freeport, but does not evaluate the effects of changes in exports between scenarios.

5.2.3.3. San Joaquin River-Origin Spring-run Chinook Salmon Structured Decision Model

The Delta Structured Decision Model was developed by the Central Valley Project Improvement Act Science Integration Team to evaluate the impact of different management decisions on the survival and routing of juvenile CHNFR. The model relies on survival-environment relationships and routing-environment relationships from acoustic studies conducted in the Sacramento and San Joaquin Rivers and at the SWP and CVP export facilities. Only results from the San Joaquin River sub model are reported by the Science Integration Team. The model and documentation have not been finalized and the code for the most recent version of the model that was used in the FEIR was accessed at <https://github.com/FlowWest/chinookRoutingApp>.

The FEIR estimated survival results from the structured decision model for San Joaquin-origin CHNSR by weighting the daily proportion of CHNSR captured in the Sacramento trawl and reported as annual estimates and as aggregations by water year type. Sacramento River CHNSR timing was used because the reintroduced CHNSR in the San Joaquin River has not existed long enough to generate a San Joaquin River-specific entry distribution.

Across the 82-year CalSim II modeling period, through-Delta survival was low (< 4%) for Alternative 2b and Existing Conditions modeling scenarios. Survival was higher under Alternative 2b relative to the Existing Condition for all years except one. Note this may be because the model is designed to increase survival as exports increase based on the assumption that survival is higher through the salvage facilities than through the Delta. Little information exists to support the hypothesis that salvage is higher through the salvage facilities, and data on post-release survival of salvaged fish is scarce. The population level benefit (if any) of salvage is uncertain. Furthermore, only a subset of entrained fish is salvaged, and an even smaller subset of these fish survive the salvage process. Mortality rates prior to salvage can be high due to predation or poor water quality conditions, and handling can cause stress and injuries that reduces both short and long-term survival. Although survival was higher under Alternative 2b in most years the magnitude of the difference between scenarios was variable. In all water year types survival was higher under Alternative 2b relative to the Existing Condition.

Through Delta survival of CHNSR under Alternative 2b tracked water year type with the highest values in wet and above-normal years and the lowest values in dry and critical years. Interquartile ranges of survival under the Existing Conditions and Alternative 2b overlapped only in critical years. However, in all water year types, interquartile ranges of survival were greater under Alternative 2b.

Through-Delta survival impacts as represented by the San Joaquin River Structured Decision Model include the combined impacts of the SWP and CVP. The FEIR states that the SWP responsibility for Delta

water operations during the spring (~March through May) period of CHNSR entry into the Delta is approximately 20% to 60%.

As described in Sections 6.2, 6.3, 6.5, 6.6, 6.7, 6.8, and 6.9 in more detail below, Conditions of Approval 8.9.1, 8.9.2, 8.17, 8.18, 8.19, 8.20, 9.1.1, 9.1.2, 9.1.3, 9.1.3.1, 9.1.3.2, and 9.1.3.3 of the ITP minimize the effects of the Project on through-Delta survival of juvenile salmon into the south Delta and salvage facilities.

5.3. South Delta Temporary Barriers Project

As described in the ITP Project Description, operation of three south Delta temporary barriers will continue according to existing terms and conditions (the construction and removal of the barriers is authorized under separate permits). The barriers are located at Old River near Tracy, Middle River near Victoria Canal, and Grant Line Canal near the Tracy Boulevard Bridge. The purpose of the barriers is to increase water levels, circulation patterns, and water quality in the south Delta for local agricultural diversions. The barriers will be operational no earlier than May 15 and through September 30, with complete removal no later than November 30. Flap gates will be tied open during operation of the temporary barriers. DWR does not propose to install the HORB. Historically the barrier was installed in some years during spring (April 15-May 30) and fall (September 15-November 30). During the spring, this barrier helped to maintain fish migration through the San Joaquin River by preventing fish from entering Old River.

Juvenile CHNWR have the potential to be present near the locations of the south Delta agricultural barriers during operation as juvenile CHNWR have been observed in salvage at both the Skinner Fish Facility and Tracy Fish Collection Facility (Tracy Fish Facility) during April and May (and June, however this has only occurred in one year (2003) since 1993). However, the risk of juvenile CHNWR impacts is substantially reduced because the flap gates on the barriers will be tied open while the barriers are in place, which will allow juveniles to move freely upstream and downstream of the barriers; minimizing juvenile Chinook salmon entrainment in Old River, Middle River, and/or the Grant Line Canal and associated reductions in survival or routing into the export facilities. The number of juvenile CHNWR potentially affected by the barriers during any given year is unknown as the number of juvenile CHNWR present in the interior Delta varies annually. This is evident by looking at historical loss data from water years 1993-2018, which shows juvenile CHNWR loss at the salvage facilities ranging from 9 to 1,552 fish in April and 5 to 78 fish in May. However, take of juvenile CHNWR associated with the barriers has the potential to occur. Because the Project does not include HORB installation, operations may facilitate the entrainment and routing (take) of additional CHNWR from the interior Delta into Old River and toward the barriers, ultimately leading to the export facilities.

The ITP Application acknowledges the potential effect the barriers may have on CHNSR, however it focuses on effects to San Joaquin River fish. Juvenile CHNSR from both the Sacramento and San Joaquin River Basin populations can be expected to be present near the barriers during operation. Based on historical salvage data, prior to the efforts to reestablish CHNSR into the San Joaquin River basin, juvenile CHNSR were observed at the fish salvage facilities from February (with some salvage in January of a few years) through June. Presence of juvenile CHNSR from the Sacramento River basin at the Grant Line Canal barrier is also possible given the effects of tides in Delta waterways which can push juvenile salmon upstream to the location of the barrier. CHNSR are present in the interior Delta for a longer period of time than CHNWR and thus experience more exposure to the barriers. Additionally, CHNSR are

present in much larger numbers in the interior Delta than CHNWR (see Section 7.3.4 – Historical Loss of Juvenile Chinook Salmon at the Salvage Facilities below). These factors indicate that the barriers may have more of an effect on juvenile CHNSR than CHNWR. However, as described above, juvenile Chinook salmon entrainment in Old River, Middle River, and/or the Grant Line Canal and associated reductions in survival or routing into the export facilities will be minimized because the flap gates on the barriers will be tied open while the barriers are installed.

DWR issued a report regarding the effects of the south Delta agricultural barriers on the survival of emigrating juvenile salmonids (DWR 2018). The report stated that the presence of the south Delta agricultural barriers will considerably reduce juvenile salmonid survival compared to open channels. Survival is lowest when the barriers are installed, and the flap gates are closed. Survival improved when the flap gates were tied open. Survival was also reduced during the construction of the barriers. Juvenile salmonids were typically preyed upon upstream of the barriers while delayed on their downstream migration. Predator density increased after the construction of the barriers, but most noticeably upstream of the barriers. The barriers increased the time that juvenile salmonids spent in the vicinity of the barriers, which likely increased their vulnerability to predators located upstream of the barriers. Juvenile salmonids encountering the barriers will move downstream through open culverts preferentially, but few fish were detected moving over the weir crest if the culverts were tied open. If the culverts were tidally operated, fish could only go through when the flood tide pushed them open. Under these conditions, more juvenile salmonids went over the weir crest but could only do so when flows overtopped the weir crest on flood tides or on ebb tides before the water elevations declined to the point where water depth was diminished over the crest. By increasing the time that juvenile salmonids spent in the vicinity of the barriers, the fish were also vulnerable to being exposed to elevated water temperatures as the season progressed.

5.4. Water Transfers

As described in the ITP Project Description, the SWP water transfer window will extend from July through November. Juvenile CHNWR are likely to be present in the waters of the Delta during the majority of the water transfer window. Juvenile CHNSR are likely to be present in the Delta as early as September, with their presence increasing during November, especially if early season storms create flow conditions in the Sacramento River basin to stimulate downstream movements. There is a low potential for adult CHNWR to be present in the Delta at the very beginning of their upstream migration (November) period. There is a slightly higher potential for CHNSR to be present in the Delta during the proposed water transfer window. Yearling CHNSR may be present in the Delta in October and November if upstream precipitation events in tributary watersheds stimulate downstream migration. Adult CHNSR may be present in the Delta during their upstream migration during early July.

For those fish present in the Delta during the water transfer window, there will be an increase in altered hydrodynamics in waters adjacent to the export facilities as a result of any additional exports to implement a water transfer. This may lead to increase in alterations in salmonid routing and the risk of entrainment into the interior Delta and export facilities. Increases in routing and entrainment will result in delayed emigration, increased exposure to predators, and decreased survival rates. These risks are more pronounced for juvenile fish than they are for adult fish (NMFS 2019).

If water transfers originate from reservoir releases, all life stages of CHNWR and CHNSR may be impacted by the transfer window. Particularly, water transfers during the fall months of October and

November may contribute to redd dewatering and juvenile stranding downstream of reservoirs, impacting spawning adults, redds, incubating eggs, newly emerged fry, and juveniles. If flow releases from reservoirs are ramped up to conduct a transfer, spawning adults and rearing juveniles may move to and occupy areas in the stream channel that were not previously inundated with water. Spawning adults may build redds and lay eggs in these areas. If flows are suddenly dropped or ramped down at too high of a rate, these redds with incubating eggs and/or emerging fry may become dewatered and be subjected to poor water quality conditions such as low dissolved oxygen levels and elevated water temperatures, and thence suffer mortality. Inundated areas during transfers may create pools, side channels, or other areas that may attract congregates of juveniles. If flows are suddenly dropped or ramped down too fast, these juveniles may not react quickly enough to swim out of these areas before they are disconnected from the active stream channel and thus become stranded where they may be subjected to poor water quality conditions (e.g., low dissolved oxygen, elevated water temperatures), increased predation, and thence suffer mortality.

5.5. Suisun Marsh Salinity Control Gates Operation

The SMSCG are located on Montezuma Slough about 2 miles downstream of the confluence of the Sacramento and San Joaquin Rivers. The objective of SMSCG operation is to decrease the salinity of the water in Montezuma Slough. In addition to the existing October through May operation to meet Suisun Marsh water quality standards, Permittee will operate the SMSCG for up to 60 days, not necessarily consecutive, between June and October of dry, below normal, and above normal water years to improve habitat conditions for the Delta Smelt Summer-Fall Action (as described in Conditions of Approval 9.3.1 and 9.1.3.2). If a dry year follows a below normal year Permittee will operate the gates for 30 days during this same time period. During the operation of the gates for the Delta Smelt Summer Fall Action between June and October, the gates will mostly likely be operated during the summer (July and August) when Delta smelt habitat needs are high.

Adult CHNWR and CHNSR are likely to be present during the SMSCG operational period of October through May. Their presence during operations between June to October is less likely as most adults have migrated to upstream tributaries by this time. Juvenile CHNWR are likely to be present during the SMSCG operational period from October through May, but not during the operational period between June and October. Juvenile CHNSR emigrate as both YOY and yearling, so they have the potential to be present during the October through May operational period and potentially in June.

Salmonid smolt predation by striped bass and pikeminnow could be exacerbated by operation of the SMSCG. These predatory fish are known to congregate in areas where prey species can be easily ambushed. Pikeminnow are not typically major predators of juvenile salmonids (Brown and Moyle 1981), but both pikeminnow and striped bass are opportunistic predators that will take advantage of localized, unnatural circumstances. The SMSCG provides an enhanced opportunity for predation because fish passage is reduced when the structure is operating. During operation of the gates from October through May, DWR proposes to limit the operation of the SMSCG to periods required for compliance with salinity control standards, and this operational frequency is expected to be 10-20 days per year. This limited operation of the SMSCG will not provide the stable environment which favors the establishment of a local predatory fish population and the facility is not expected to support conditions for an unusually large population of striped bass and pikeminnow, so predation impacts are minimal during these operations. As described above, adult and juvenile CHNWR and CHNSR presence is not

expected during July and August when the SMSCG would mostly likely be operated for the Delta Smelt Summer-Fall Action, thus predation and other impacts to salmon due to operation of the gates is not anticipated.

6. Minimization of Take and Impacts of the Taking on Winter-run and Spring-run Chinook Salmon Rearing, Routing, and Survival

This section describes how Conditions of Approval included in the ITP minimize take of CHNWR and CHNSR and impacts of the taking as a result of changes in routing, rearing, and through-Delta survival associated with the Project.

6.1. Condition of Approval 7.5.1 – Upstream Monitoring During Water Transfer Window

Permittee will develop and implement a program to monitor relevant flow rates prior to, during, and after all water transfers, and redd distribution, redd dewatering, and juvenile stranding during the Project water transfer window of July 1 through November 30 and notify CDFW no more than 24 hours after each redd dewatering or juvenile stranding event observed as part of the monitoring program. These measures will minimize the impacts water transfers have on all life stages of CHNWR and CHNSR when water transfers are conducted as reservoir releases by documenting whether stream flows downstream of reservoirs are sufficient to maintain redds and juvenile rearing and emigration.

6.2. Condition of Approval 8.9.1 – Construct and Operate a Salmonid Migratory Barrier at Georgiana Slough

Permittee will construct and operate a Georgiana Slough Migratory Barrier to reduce entrainment of juvenile CHNWR and CHNSR into Georgiana Slough during emigration in the Sacramento River. Entrainment into the interior Delta through Georgiana Slough may result in migration delays and further entrainment of juvenile CHNWR and CHNSR into the south Delta export facilities (Perry et al. 2010). A salmonid migratory barrier is expected to provide a higher probability of survival to Chipps Island for emigrating juvenile CHNWR and CHNSR that encounter the Sacramento River-Georgiana Slough junction and reduce entrainment of emigrating CHNWR and CHNSR into the interior and south Delta. Operation of the Georgiana Slough Migratory Barrier may increase juvenile salmon vulnerability to predation through creation of enhanced predatory fish habitat adjacent to the in-water barrier components. Adults that enter Georgiana Slough from the south may experience increased migration timing during upstream spawning migration, causing an increased risk of pre-spawn mortality. However, previous DWR pilot studies at Georgiana Slough noted adult salmonids were capable of navigating beneath the barrier (i.e., Bio-Acoustic Fish Fence with sound, light, and bubble deterrent), which only covers the top 50% of the water column (DWR 2012, 2014). Despite the potential for some increased juvenile vulnerability to predation and increased migration timing for adults, the operation of the barrier is expected overall to reduce Project impacts to CHNSR and CHNWR, and those benefits of the migratory barrier outweigh potential negative impacts.

Prior to construction and operation of the barrier, DWR will develop a CDFW-approved Georgiana Slough Migratory Barrier Operations Plan detailing the operational timing, components, and location of

the barrier, and associated criteria for operations. During operations, DWR will continue pilot investigations (e.g., real-time fish tracking) to evaluate and refine the barrier's efficiency of precluding juvenile CHNWR and CHNSR from entering Georgiana Slough. During the pilot investigations, DWR will evaluate upstream passage of adult CHNWR and CHNSR to ensure the barrier does not obstruct upstream migration. The plan and pilot investigations include CDFW involvement and approval to ensure the barrier provides benefits to CHNWR and CHNSR and will not be detrimental to the continued management and recovery of CHNWR and CHNSR.

6.3. Condition of Approval 8.9.2 – Evaluate the Benefits of Salmonid Guidance Structures at Sutter and Steamboat Sloughs

Juvenile Chinook salmon that are entrained into the interior Delta experience increased mortality and travel times compared to those that continue emigrating through the mainstem of the Sacramento River or those that route through Sutter and Steamboat Sloughs (Perry et al. 2010; Newman and Brandes 2010). Sutter and Steamboat Sloughs are important migratory paths for juvenile CHNWR and CHNSR, as either route reduces the risk of juveniles being entrained into the interior Delta (Perry et al. 2010). Floating fish guidance structures near the junction between the Sacramento River and Sutter and Steamboat Sloughs are expected to provide a higher probability of survival for emigrating juvenile CHNWR and CHNSR by increasing the proportion of juveniles that enter Sutter and Steamboat Sloughs and minimizing the proportion of juveniles that migrate into the interior and south Delta. This Condition of Approval will require further evaluation of potential benefits of migratory barriers as Sutter and Steamboat Sloughs, to inform future decisions.

6.4. Condition of Approval 8.12 – Barker Slough Pumping Plant Longfin and Delta Smelt Protection

Reducing the maximum seven-day averaged diversion rate at the BSPP to less than 60 cfs, between January 15 and June 30 in dry and critical water years will have a beneficial impact on food web dynamics in the greater Yolo Bypass region by reducing the amount of prey items removed from the system through exports. Rearing CHNWR and CHNSR in the Yolo Bypass rely on these food sources for healthy development and maturation.

6.5. Condition of Approval 8.17 – Export Curtailments for Spring Outflow

DWR will reduce exports from April 1 to May 31 each year to achieve the SWP proportional share (Condition of Approval 8.10) of export reductions established by the ratio of Vernalis flow (cfs) to combined CVP and SWP exports, scaled by water year type, to provide incidental spring outflow. Juvenile CHNWR and CHNSR emigration and rearing in the Delta occurs during this time period. The increased outflow may result in reduced routing and entrainment into the interior Delta and salvage facilities, increased quality and quantity of rearing habitat due to increased water availability, and reduced impacts to ecosystem function in the Delta, including food production. This will provide for increased through-Delta survival of emigrating juvenile CHNWR and CHNSR.

6.6. Condition of Approval 8.18 - Potential to Redeploy up to 150 TAF for Delta Outflow and Condition of Approval 8.19 – Additional 100 TAF for Delta Outflow

With CDFW approval, DWR may increase exports between April 1 and May 31 of all water years above what would otherwise be allowed by operating to Condition of Approval 8.17 to curtail exports and enhance Delta outflow. In return, the increase in the volume of water exported, up to 150 TAF, will be available as Delta outflow beginning March of the next water year, unless the next year is critical (Spring Outflow Block). DWR will also provide 100 TAF in wet and above normal water years to enhance Delta outflow (Additional 100 TAF block of water). Both the Additional 100 TAF and the Spring Outflow blocks of water will be dedicated to Delta outflow through one or several means (including Term 91 conditions, dedication under Section 1707 of the California Water Code, or another agreement) and provided through water purchases or through SWP water (i.e., Oroville Reservoir releases). If the water is provided through Oroville Reservoir releases, these actions will provide enhanced stream habitat (e.g., potentially cooler temperatures and inundated area) in the Feather River for emigrating juvenile and spawning adult CHNSR depending on the time of release. In the spring, reservoir releases will benefit juveniles by providing a freshet of cooler water for rearing and emigration. In the summer, reservoir releases will benefit holding and spawning adults by increasing suitable spawning area with cooler water temperature, increased depth, and increased flow. However, drawdown of water releases will need to be monitored to prevent redd dewatering if releases continue through the CHNSR spawning season (i.e., mid-August through mid-October). If the water is provided through water purchases, this action may provide similar benefits to CHNWR and CHNSR juvenile and adults in the form of increased instream flow depending on the location of the water purchase.

6.7. Condition of Approval 8.20 – Delta Outflow Operations Plan and Report

Each year, DWR will develop and operate to a CDFW-approved Delta Outflow Operations Plan that will describe the amount of water available to supplement Delta outflow associated with the Additional 100 TAF and Spring Outflow Block. The plan will include the timing and volume of water available on a daily basis between March 1 and October 31 and the operational actions (i.e., export curtailments, Oroville Reservoir releases, and water purchases) that will be taken to ensure blocks are available. The requirements in this plan will ensure that the blocks are planned and accounted for at least 5 days prior to the start date of the plan. The plan also includes CDFW involvement and approval to ensure each block of water will not be detrimental to the continued management and recovery of CHNWR and CHNSR.

Each year, DWR will develop a CDFW-approved Delta Outflow Operations Report that will describe implementation of that year's Delta Outflow Operations Plan. The plan will include daily information pertaining to Delta outflow, exports at Banks Pumping Plant and C.W. Bill Jones Pumping Plant (Jones Pumping Plant), OMR index, San Joaquin inflow, Freeport flow, daily controlling factors and allowable Banks Pumping Plant exports, and documentation of the volume and timing of the blocks of water provided that year. The requirement of this report will ensure the blocks are allocated and documented prior to December 1 and before the next plan is required. The report also includes CDFW involvement

and approval to ensure each block of water provided benefits to the continued management and recovery of CHNWR and CHNSR.

6.8. Conditions of Approval 9.1.1 and 9.1.2 – Habitat Restoration for Delta Smelt and Longfin Smelt

As described in Conditions of Approval 9.1.1 and 9.1.2 of the ITP, Permittee shall restore and conserve 8,000 acres of tidal wetland habitat as compensatory mitigation for DS, 800 acres of mesohaline habitat as compensatory mitigation for LFS, and 396.3 acres of tidal wetland habitat as additional compensatory mitigation for both smelt species. CHNWR and CHNSR must pass through the Delta during their emigration to the Pacific Ocean. Although rearing and migration through the Delta represents a short period of their overall lifecycle, a large proportion of juvenile CHNWR and CHNSR are expected to be exposed to the proposed tidal habitat and mesohaline habitat restoration in the Delta. The habitat restoration is expected to benefit juvenile CHNWR and CHNSR rearing in several aspects, including increased food availability and quality, and refuge habitat from predators. These benefits can be manifested by higher growth rates in fish utilizing these habitats and increased survival through the Delta.

6.9. Conditions of Approval 9.1.3, 9.1.3.1, 9.1.3.2 and 9.1.3.3 – Delta Smelt Summer-Fall Action

The Delta Smelt Summer-Fall Action will improve DS food supply and habitat, thereby contributing to the recruitment, growth, and survival of DS. The action includes requirements to maintain a monthly average 2 ppt isohaline at 80 km (X2) from the Golden Gate Bridge in above normal and wet water years during September and October. The action also includes a requirement to operate the SMSCG for up to 60 days, not necessarily consecutive, between June and October of dry, below normal, and above normal water years. If a dry year follows a below normal year Permittee will operate the gates for 30 days during this same time period. Operation of the SMSCG is anticipated to require supplemental reservoir releases or export curtailments to maintain compliance with salinity standards. If the action is achieved through export reductions and/or releases from Oroville Reservoir, emigrating juvenile CHNWR and CHNSR may experience some benefit. Specifically, reduced exports may result in reduced routing and entrainment of juvenile CHNWR and CHNSR from the Sacramento and San Joaquin Rivers into the interior Delta, CFF, and the export facilities. Reservoir releases may provide an increase in stream flows, thereby enhancing stream habitat in the Feather River for spawning CHNSR adults and incubating redds, as well as any emigrating juvenile CHNSR. Depending on the magnitude of the release, juvenile CHNWR and CHNSR in Feather River tributaries and the Sacramento River may also experience increased stream flows as they emigrate to the Delta.

7. Take and Impacts of the Taking - Entrainment of Winter-run and Spring-run Chinook Salmon

7.1. Introduction – Entrainment of Covered Species

Operation of the Project will result in take in the form of entrainment for all Covered Species. Entrainment is the incidental removal of species in the water diverted by the Project from the Estuary

(Castillo et al. 2012). Entrainment as a result of Project operations draws in and/or attracts fish and other organisms into water diversion intakes or areas with reduced habitat quality, ultimately resulting in migratory delays, reduced fitness, or mortality. In the Delta, entrainment occurs primarily at the SWP facilities (including CCF and the Skinner Fish Facility) and the CVP facilities (Tracy Fish Facility), as well as other smaller water diversion intakes. In addition, altered hydrodynamics cause fish to become entrained into terminal areas such as the Yolo Bypass and the south Delta. All life stages of all Covered Species occurring in the Project Area are susceptible to entrainment. Entrainment of other organisms such as primary and secondary producers (which provide food for Covered Species) is largely unaccounted for and the magnitude of the potential impact to Covered Species is not well understood.

At the SWP export facilities, fish enter CCF through water diversion from Old River. CCF is located near the town of Byron in the south Delta and consists of a ~2,500 acre artificially flooded embayment that serves as a storage reservoir for the SWP (Clark et al. 2009). During high tide cycles, when the water elevation in Old River exceeds that of the CCF, up to five radial gates, located on the southeast corner of CCF, open to divert water from the Delta into CCF. Daily operations of the radial gates depend on scheduled water exports, tides, and storage availability with CCF. The Banks Pumping Plant pumps water diverted from CCF via the intake channel near the SFF into the California Aqueduct. Fish entering the CCF must travel approximately 3.4 km to reach the Skinner Fish Facility. The Skinner Fish Facility was designed to protect fish > 20 mm from entrainment into the Banks Pumping Plant by diverting them into holding tanks where they can be salvaged and returned to the Delta. Water is drawn to the Skinner Fish Facility from CCF via the intake canal and past a floating trash boom. The trash boom is designed to intercept floating debris and guide it to an onshore trash conveyor. Water and fish then flow through a trash rack, equipped with an automated cleaner. Openings into the trash rack exclude fish wider than 51 mm from entering the Skinner Fish Facility (CDFG 1981). Fish that move through the trash rack enter a series of louvers arranged in a V pattern and are behaviorally guided to holding tanks where they remain until sacrificed (if sampled clipped fish) or released back into the Delta (all unclipped fish).

At the CVP export facilities, water is drawn into the Tracy Fish Facility from the Old River. The Tracy Fish Facility was designed to protect fish > 20 mm from entrainment into the Delta-Mendota Intake by diverting them into holding tanks where they can be salvaged and returned to the Delta. Upon entry to the Tracy Fish Facility, fish encounter a floating trash deflector boom, much like the trash boom located at the entrance to the Skinner Fish Facility. Water and fish then flow through a trash rack with openings averaging 57 mm (2.25 inches) and equipped with an automated cleaner (Reyes et al. 2018). Fish that move through the trash rack enter the primary channel followed by a series of louvers that behaviorally guide fish into the salvage holding tanks for processing.

Salvage describes the process of catching and collecting a portion of the entrained fish and transporting them to release locations outside of the interior Delta. It is hypothesized that salvage increases survival of individual fish, when compared to migrating through the Delta, thereby lessening the population level impact of entrainment. However, little information exists to support this hypothesis and data on post-release survival of salvaged fish is scarce. The population level benefit (if any) of salvage is uncertain. Furthermore, only a subset of entrained fish is salvaged, and an even smaller subset of these fish survive the salvage process. Mortality rates prior to salvage can be high due to predation or poor water quality conditions, and handling can cause stress and injuries that reduces both short and long-term survival.

Handling and transporting adult and juvenile salmonids increase stress-related impairment and mortality (Cook 2015; Cook 2018a; Cook 2018b; Raquel 1989; Teffer et al. 2017). Handling can lead to air exposure and hypoxia from crowding, which can cause swimming impairment in salmonids post-release (Donaldson et al. 2011; Hinch et al. 2019). This impairment makes juvenile and adults highly vulnerable to predation. Handling can also cause direct injuries and the removal of the protective epidermal mucus, which increases an individual's susceptibility to fungal and bacterial infections (Dash et al. 2018; Reverter et al. 2018). Adult Chinook salmon that survive handling and transport and continue on to the spawning reaches of their natal streams can have decreased spawning fitness and fecundity due to the energy expenditure and stress related with capture, handling, and release (Wilson et al. 2014). Handling and transport stress induced mortality is difficult to document in juvenile Chinook salmon, as these fish are typically unable to be monitored post-release. Raquel (1989) examined the effects of handling and trucking of fish collected at the Skinner Fish Facility. Low levels of immediate mortality of juvenile Chinook salmon were observed with over 98% survival during the study period. It was noted, however, low levels of immediate mortality were biased low because they do not account for undocumented mortality following release. A study in the mid-1970s examined the mortality of juvenile Chinook salmon attributed to handling and trucking from the CVP's Tracy Fish Facility (Raquel 1989). The study found 57% of juvenile Chinook salmon captured and transported died shortly after release. Additionally, as described in Keefer and Caudill (2014), collection and transportation can cause interrupted olfactory imprinting of juvenile salmon during migration and lead to increased adult straying rates.

Since operations began, the SWP has coordinated operations with the CVP to maintain Delta water quality and a formal coordination agreement has been in place since 1986 to ensure each project retains its portion of the shared water for export and bears its share of the obligation to protect beneficial uses (DWR and Reclamation 1995, Arthur et al. 1996). Some facilities were developed for joint use, such as San Luis Reservoir, O'Neill Forebay, and more than 100 miles of the California Aqueduct and related pumping facilities (DWR and Reclamation 1995). Such coordination is increasingly necessary over time to achieve multiple, mandatory water quality objectives (e.g., D-1641) while optimizing water supply south of the Delta (Arthur et al. 1996). Water exports from the south Delta SWP and CVP facilities create hydrodynamic conditions that result in fish entrainment into the south Delta and subsequently the export facilities (Brown et al. 1996, Kimmerer 2008, Grimaldo 2009). Using adult DS as an example, a recent analysis of salvage identified hydrodynamics (total exports, OMR flow), water quality (turbidity), and population abundance as the most important factors influencing salvage (Grimaldo et al. 2017). More specifically, SWP exports, Yolo Bypass flows, and DS abundance best explained adult DS salvage at the SWP across the entrainment season, whereas species abundance, OMR flows, and turbidity best explained adult salvage through the entire entrainment season at the CVP (Grimaldo et al. 2017). Similarly, the SST (2017) documented higher numbers of juvenile Chinook salmon are salvaged during times when OMR is more negative. Reductions in the average daily OMR will reduce entrainment of CHNWR and CHNSR into the interior Delta and increase their survival by reducing their emigration time through the Delta (Perry et al. 2016) (also see Section 7.3.1 below). Because salvage at both the SWP and CVP fish facilities were found to be determined either directly by SWP exports or by local hydrodynamic conditions strongly influenced by SWP exports (OMR flow), entrainment risk of Covered Species attributable to SWP is best assessed by evaluating patterns of Covered Species salvage at both the SWP and CVP fish facilities as combined salvage. Currently, combined salvage from both the SWP and CVP fish facilities provides the only means to effectively extrapolate the effects of south Delta SWP export operations on entrainment of fishes into the central and south Delta (Smith 2019).

7.2. Entrainment of Adult Winter-run and Spring-run Chinook Salmon

7.2.1. Entrainment of Adult Chinook Salmon into Clifton Court Forebay

7.2.1.1. Introduction

Adult Chinook salmon have historically been salvaged at the Skinner Fish Facility. Using the Delta Model LAD criteria (USFWS 1997), Chinook salmon greater than 300 mm FL are classified at the facilities as “unknown adults” with no run designation or genetic sample collected. Currently there are no targeted studies that evaluate adult Chinook salmon presence in CCF so there is no way to adequately quantify adult take within CCF. However, historical entrainment of adult Chinook salmon into CCF has been documented during DWR predator removal studies and observations at the entrance to the Skinner Fish Facility (Wunderlich 2015 and 2018a; NMFS 2019; CDFW 2020b). The purpose of the following analysis was to evaluate take of adult Chinook salmon through entrainment into CCF.

7.2.1.2. Methods and Results

To better understand adult entrainment at the export facilities, CDFW evaluated bycatch data from the CCF Predation Studies (CFPS; Wunderlich 2015, 2017), the CCF Predator Reduction Electrofishing Studies (PRES; Wilder et al. 2018), and the CCF Predator Fish Relocation Study (PFRS; CDFW 2020b). DWR conducted CFPS studies from 2013 through 2016 to evaluate juvenile salmonid survival and monitor for piscivorous fish and birds around CCF. In 2016, DWR began the PRES studies at the request of NMFS to implement interim measures to remove predators from CCF to reduce pre-screen loss of juvenile salmon. Under the PRES studies, DWR electrofished and relocated predators from CCF to Bethany Reservoir (the afterbay for the Banks Pumping Plant and conveyance facility for the California Aqueduct) from 2016 through 2018. Beginning in 2019, DWR started the PFRS study to relocate predators from CCF using commercial fishing techniques to capture predators.

During the 2013 CFPS, DWR conducted creel surveys in CCF between April 26, 2013 and December 31, 2013. For 1,101 anglers interviewed, one adult Chinook salmon was reported caught in October (Wunderlich 2015). October does not directly overlap with adult CHNWR or CHNSR presence in the Delta; therefore, it is assumed this adult was a CHNFR. During the 2015 CFPS, DWR conducted creel surveys in CCF between January 5, 2015 and December 29, 2015. For 1,247 anglers interviewed, one adult Chinook salmon was reported caught in November (Wunderlich 2017), consistent with CHNWR presence in the Delta (Moyle 2002; Yoshiyama et al. 1998; Myers et al. 1998).

Adult Chinook salmon are susceptible to electrofishing and can be stunned as part of the PRES studies conducted between 2016 and 2018. During the 2018 study season, Wilder et al. (2018) reported 55 Chinook salmon observed moving into the vicinity of the electrofishing boat in response to the electric field (Table 3). DWR’s report does not indicate individual size class, but states that individuals ranged from three inches to adult size and were observed from January through May. NMFS (2019) reports a total loss of 152 Chinook salmon during the three PRES studies, but the size class of these fish and spatial time scale in which they were observed is unclear. However, studies conducted between January and May overlap with presence of adult CHNWR (November through July) and CHNSR (January through

September) in the Delta (NMFS 2019; Johnson et al. 2011; Moyle 2002; Yoshiyama et al. 1998; Myers et al. 1998).

Month	Number of Chinook Salmon
January	6
February	13
March	7
April	22
May	7
Total	55

Table 3. Chinook salmon encountered by month in CCF during the 2018 PRES study season. Data taken from Wilder et al. (2018).

Commercial fishing practices employed under PFRS are not able to selectively fish for nonnative predators in CCF; therefore, Chinook salmon are likely to be entrapped or caught as bycatch. During the 2019 PFRS, twelve adult Chinook salmon were caught in CCF, including two which were assumed to be CHNSR and CHNWR based on presence and time of year (not genetically confirmed) (Table 4) (CDFW 2020b).

Date	Gear Method	Species	Origin	FL (mm)	Life Stage
5/9/2019	Kodiak Trawl	CHNSR	Hatchery	NA	Adult
10/10/2019	Fyke Trap	CHNFR	Natural	614	Adult
11/5/2019	Beach Seine	CHNFR	Hatchery	660	Adult
11/5/2019	Beach Seine	CHNFR	Natural	755	Adult
11/8/2019	Beach Seine	CHNFR	Natural	NA	Adult
11/12/2019	Beach Seine	CHNFR	Natural	752	Adult
11/12/2019	Beach Seine	CHNFR	Natural	670	Adult
11/14/2019	Beach Seine	CHNFR	Natural	807	Adult
11/14/2019	Beach Seine	CHNFR	Natural	790	Adult
11/15/2019	Beach Seine	CHNFR	Hatchery	762	Adult
11/21/2019	Beach Seine	CHNFR	Natural	805	Adult
12/20/2019	Fyke Trap	CHNWR	Hatchery	598	Adult

Table 4. Adult Chinook salmon bycatch data from May 2019 through December 2019 during the 2019 PFRS (CDFW 2020b). CHNSR highlighted in green and CHNWR highlighted in blue.

In addition to predation studies in CCF, the 2017 Delta Operations for Salmonids and Sturgeon (DOSS) technical advisory team annual report included documented observations of adult Chinook salmon (greater than 300 mm FL) at the entrance to the Skinner Fish Facility (DOSS 2017). These fish were observed from November through May, coinciding with adult CHNWR (November through July) and CHNSR (January through September) presence in the Delta (NMFS 2019; Johnson et al. 2011; Moyle 2002; Yoshiyama et al. 1998; Myers et al. 1998). DOSS (2017) attributed the increase in adult Chinook salmon entering the Skinner Fish Facility to two factors. In 2017, facility workers observed year-round occupancy of sea lions near the entrance to the Skinner Fish Facility. They noted the sea lions appeared to be working as a team with elephant seals to chase adult salmon into the direction of the trash rack for feeding. During the annual dive inspection in March, divers noted several locations where the openings between the vertical members of the trash rack were wider than two inches. It is not clear if this

damage was caused by marine mammal coordinated hunting, but it is assumed that this contributed to the damage.

7.2.1.3. Discussion

Targeted studies to evaluate entrainment of adult Chinook salmon into CCF have not been conducted in the past. During more recent predator reduction studies, adult Chinook salmon presence has been documented and is expected to continue to be documented as DWR implements the Enhanced Predatory Fish Removal and Relocation Study. This study is a combination of the most effective predator removal techniques from previous predator reduction efforts in CCF. The intent of the study is to maximize the removal of predators in CCF to reduce pre-screen loss of juvenile listed species. It should be noted that these studies are not targeted for adult Chinook salmon and may not overlap with their timing in the Delta. Therefore, fish collected are not necessarily representative of the abundance that may be present during adult salmon upstream migration through the Delta.

In its 2009 BiOp, NMFS indicated that there are direct impacts on adult Chinook salmon from entrainment into CCF, but assumed adults move freely into and out of CCF when hydraulic conditions at the radial gates permit (NMFS 2009). Maximum hourly water velocities through the radial gates can exceed 20 ft/s (Clark et al. 2009), which is double the burst speed of adult salmonids (CDFG 2010). As the radial gates are opened, water flow and water velocities are typically quite strong depending on the difference in water surface elevation between Old River and CCF. This makes egress from CCF difficult until the flow and velocities diminish as the water surface elevations begin to equalize. Any adult Chinook salmon attempting to exit the CCF would need to swim through the radial gates when inflow velocities were sufficiently low to permit their upstream movement, and before the radial gates are closed at the end of the tidal cycle. It is possible for Chinook salmon to remain resident within CCF for extended periods of time before conditions are suitable for their exit. This residence time results in delays in upstream spawning and can lead to stranding if fish are unable to exit through the radial gates. False attraction into CCF reduces the number of potential spawners, and thereby spawning success, due to delayed migration or pre-spawn mortality.

The presence of adult Chinook salmon at the entrance of the Skinner Fish Facility in 2017 is characteristic of natural social interactions among salmon. Berdahl et al. (2017) demonstrated that salmon use social interactions to synchronize entry into spawning grounds. Johnson et al. (2016) also showed that adult salmon caught in the ocean are more often from the same genetic group, suggesting that adults rely on collective navigation when migrating to spawning grounds. Attraction flows through the radial gates increase the likelihood of large groups of salmon migrating together into CCF exposing them to poor water quality conditions and pre-spawn mortality.

7.2.2. Salvage of Adult Chinook Salmon

7.2.2.1. Introduction

Adult Chinook salmon have historically been salvaged at the Skinner Fish Facility and Tracy Fish Facility. Using the Delta Model LAD criteria (USFWS 1997), Chinook salmon greater than 300 mm FL are classified at the facilities as “unknown adults” with no run designation or genetic sample collected.

The purpose of the following analysis, conducted by CDFW for this Effects Analysis, is to quantify existing take of adult Chinook salmon at the SWP and CVP export facilities using historical salvage data that

include adult Chinook salmon (>300 mm FL). This analysis provides greater understanding of SWP impacts to adult CHNWR and CHNSR.

7.2.2.2. Methods

To quantify adult salvage at the export facilities, adult salvage (total count) data and expanded salvage data at the SWP and CVP export facilities between water years 1993 and 2018 were summarized for all Chinook salmon greater than 300 mm FL. Data were separated based on presence of adipose fin to distinguish between natural and hatchery Chinook salmon at the export facilities.

Adult salvage data for the SWP and CVP export facilities were collected from the CDFW Bay-Delta Region salvage database (CDFW 2019c). Expanded salvage data were calculated to estimate total salvage during SWP operations. The database included specimen information pertaining to fork length and presence of an adipose fin.

Loss was not calculated for adult salmon as the loss equation (CDFW 2018) (see Section 7.3.1 – Entrainment of Juvenile Winter-run and Spring-run Chinook Salmon, Introduction for more detail about the loss equation), is used by both DWR and Reclamation to specifically estimate entrainment of juvenile salmonids into the SWP and CVP facilities. The loss equation was not designed or intended for estimating loss of adult salmonids.

7.2.2.3. Results

Between water years 1993 and 2018, 118 adult Chinook salmon were observed at the export facilities, with a greater proportion observed at the SWP (66%) than the CVP (33%) (Figure 1). Expanded salvage for adult Chinook salmon totaled 466 (Figure 2). The entrainment period for adult Chinook salmon extended from September through May, which overlaps with adult CHNWR and CHNSR presence in the Delta.

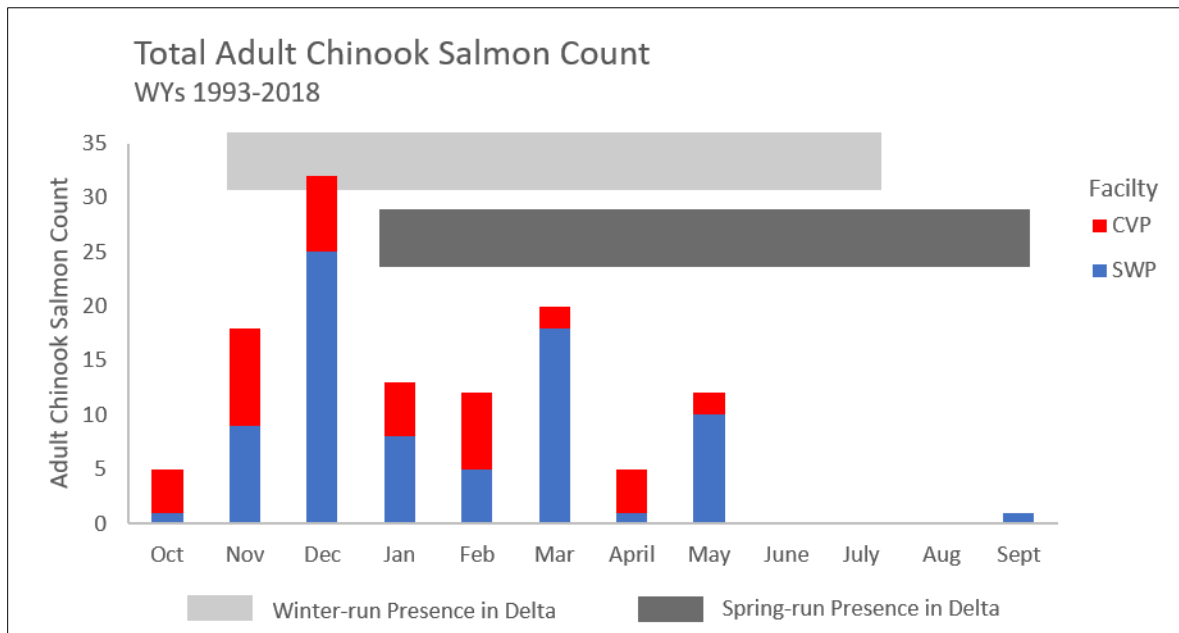


Figure 1. Total count of clipped and unclipped adult Chinook salmon observed at the SWP and CVP export facilities for water years 1993 through 2018. Monthly data are overlaid with adult CHNWR and CHNSR presence in the Delta (NMFS 2014, 2019; Johnson et al. 2011; Yoshiyama et al. 1998; Moyle 2002; Myers et al. 1998).

Of the 118 total adult Chinook salmon observed (expanded salvage of 466) at the export facilities, 45 were observed (expanded salvage of 103) in water year 2017 between November 3, 2016 and May 14, 2017.¹

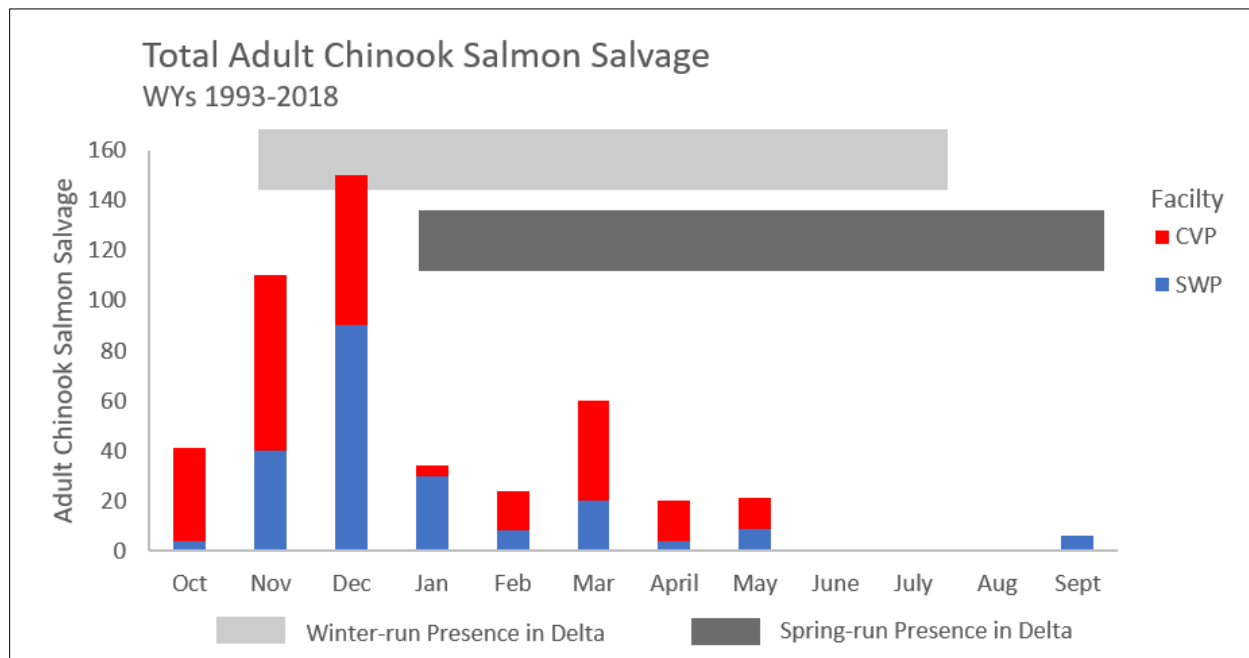


Figure 2. Total expanded salvage of clipped and unclipped salvaged adult Chinook salmon at the SWP and CVP export facilities for water years 1993 through 2018 by month. Monthly data are overlaid with adult CHNWR and CHNSR presence in the Delta (NMFS 2014, 2019; Johnson et al. 2011; Yoshiyama et al. 1998; Moyle 2002; Myers et al. 1998).

Further analysis indicates that 89% of the observed (84% of expanded salvaged) adult Chinook salmon were unclipped, implying these fish were natural origin (Figures 3 & 4).

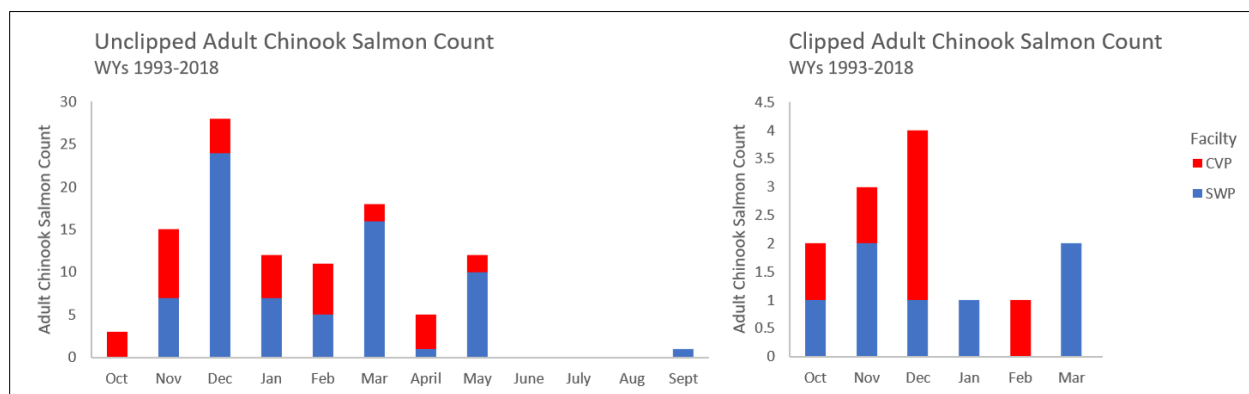


Figure 3. Total count of salvaged adult Chinook salmon separated by presence of adipose fin at the SWP and CVP export facilities for water years 1993 through 2018.

¹ Underwater divers identified several locations where the openings between the vertical members of the trash rack of the Skinner Fish Facility were wider than two inches (DOSS 2017). Repairs were made to the trash rack in March 2017, with reduced salvage in water year 2018 (total count of 2, expanded salvage of 5).

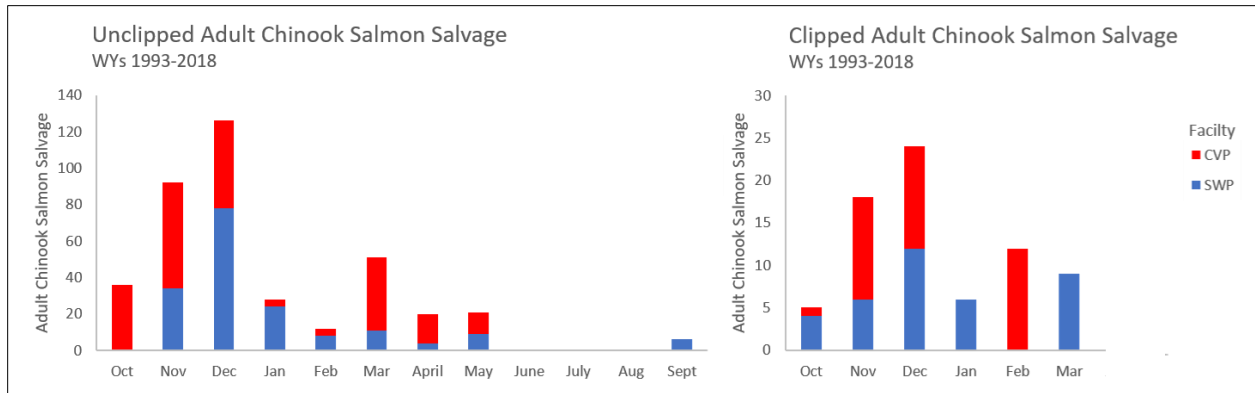


Figure 4. Expanded salvage of adult Chinook salmon separated by presence of adipose fin at the SWP and CVP export facilities for water years 1993 through 2018.

7.2.2.4. Discussion

Although the trash racks at the Skinner Fish Facility and Tracy Fish Facility were designed to exclude adult Chinook salmon, adults have been detected in the salvage process at both facilities. Genetic samples are not taken to confirm the presence of adult CHNWR or CHNSR; however, timing of historical salvage suggests that both CHNWR and CHNSR are likely to be entrained into the export facilities. The majority of adults salvaged historically were unclipped. Attraction flows from both facilities increase the likelihood of fish straying into the facilities at times when adults are relying on collective navigation from other salmon to find spawning grounds (Johnson et al. 2016). Natural unclipped salmon have olfactory imprinting that enables migration to natal spawning grounds while hatchery-origin fish are less likely to acquire olfactory cues due to hatchery practices (e.g., water treatment, trucking production releases; Sturrock et al. 2019a). Presence of unclipped adults in salvage indicates that immigrating adults may experience increased straying in the Delta, likely as a result of Project related alterations in hydrology, as seen in other systems including the Knights Landing Ridge Cut during the North Delta Flow Action Study (DWR 2019a). The loss of spawning adults due to straying could decrease the genetic diversity of these populations as well as decrease juvenile production.

The loss equation (CDFW 2018 and Attachment 6 to the ITP) does not account for historical adult loss at either facility. Each component of the loss equation was developed based on performance evaluation studies for juvenile salmonids, which behave and respond differently than adult salmonids. For example, pre-screen loss may not be measurable for adults because they may not experience mortality from predators like juveniles but may experience pre-spawn mortality due to stranding stress. Expanded salvage may also underestimate the abundance of adult Chinook salmon present.

In its current form, the loss equation states that fish greater than 100 mm FL experience zero loss during handling and transport (CDFW 2018 and Attachment 6 to the ITP). This does not address impacts from handling and transport during the salvage process, which is known to increase stress related impairment and mortality in adult salmonids (Cook et al. 2015; Cook et al. 2018a and 2018b; Raquel 1989; Teffer et al. 2017). Adult Chinook salmon that survive handling and transport and continue on to the spawning reaches of their natal streams can have decreased spawning fitness and fecundity due to the energy expenditure and stress related with capture, handling, and release (Wilson et al. 2014).

Cook et al. (2018b) documented both short- and long-term impacts to coho salmon in the form of external and physiological injuries caused by netting and handling. In this study, the authors

demonstrated that dermal injuries and changes in blood chemistry predicted delayed mortality, while reflex impairments, as a result of prolonged anoxia, resulted in an inability to escape predation and decreased survival shortly after release. Teffer et al. (2017) found similar results for sockeye salmon on the Fraser River, which experienced high rates of mortality between 5 and 12 days following net entanglement and handling. Additionally, in this study, pre-spawn mortality of handled salmon was linked to higher occurrences of the pathogens *F. psychrophilum* and *C. shasta* in examined carcasses, suggesting that the prevalence of these diseases is likely due to the suppressed immune system response fish experience during the stress of capture and handling.

7.3. Entrainment of Juvenile Winter-run and Spring-run Chinook Salmon

7.3.1. Introduction

Export effects in the south Delta are expected to reduce the probability that juvenile salmonids in the south Delta will successfully migrate out past Chipps Island, through either entrainment or mortality in the export facilities, or changes to migration rates or routes that increase residence time of juvenile salmonids in the south Delta and thus increase exposure time to agents of mortality such as predators, contaminants, and impaired water quality parameters (such as dissolved oxygen or water temperature) (NMFS 2019). Net OMR flows provide a surrogate indicator for how exports at the south Delta pumping facilities influence hydrodynamics in the south Delta. The Project's export's effects on OMR flows varies as a result of multiple factors including inflow, tides, and the amount of water being exported. The largest effect of exports on Delta hydrology is seen in Old River (SST 2017). Higher numbers of juvenile Chinook salmon are salvaged during periods of a more negative OMR value (SST 2017). Kimmerer (2008) also found that salvage of hatchery Chinook salmon from the Sacramento River increased with increasing export levels.

Based on particle tracking model (PTM) simulation of particles injected at the confluence of the Mokelumne River and the San Joaquin River, the risk of particle entrainment nearly doubles from 10% to 20% as net OMR flows increases southward from -2,500 cfs to -3,500 cfs, and quadruples to 40 percent at -5,000 cfs (NMFS 2009). At flows more negative than -5,000 cfs, the risk of entrainment increases at an even greater rate, reaching approximately 90% at -7,000 cfs. Even if salmonids do not behave exactly as neutrally buoyant particles, the risk of entrainment increases considerably with increasing exports, as represented by net OMR flows (NMFS 2009). Thus, the risk of entrainment into the south Delta channels is increased when OMR flows become more negative (NMFS 2009).

Beginning in Section 8 – Minimization of Take and Impacts of the Taking on Winter-run and Spring-run Chinook Salmon Entrainment of this Effects Analysis, we discuss minimization of Project entrainment effects as a result of implementation of Conditions of Approval included in the ITP.

7.3.2. Effects of South Delta Export Operations on Winter-run Chinook Salmon

CHNWR that are exposed to the export facilities in the waterways immediately adjacent to the facility intakes and individuals that do not migrate through the salvage facilities are expected to have reduced migratory success. An increased negative flow in the region immediately adjacent to the intakes to CCF and the CVP would increase the probability of fish being unable to reverse course and successfully exit the Delta, although the magnitude of this effect is currently unknown due to a lack of data regarding

fine-scale, reach-specific fish movement behavior and survival in those reaches under increased export conditions. Increased pumping has far-field migratory impacts as well, particularly in the Old and Middle River corridors which would negatively affect CHNWR in those corridors. Fish that are present in the Old River or Middle River corridors and their tributaries downstream of the south Delta export facilities would experience increased net flows towards the export facilities. Increased exports would obscure more of the ebbing tide signal that would normally cue fish to move out of those corridors and back into the main migratory corridor of the San Joaquin River before moving southwards into waters that are more heavily influenced by the effects of reverse flows due to exports (NMFS 2019).

7.3.3. Effects of South Delta Export Operations on Spring-run Chinook Salmon

CHNSR that are exposed to the pumping plants in the waterways immediately adjacent to the facility intakes are expected to have reduced migratory success. A more negative flow environment in the region immediately adjacent to the intakes of CCF would decrease the probability of fish being able to alter course and successfully exit the Delta, although the magnitude of this effect is currently unknown due to a lack of data regarding fine scale fish movement behavior and survival in those reaches under export conditions. This is particularly important for CHNSR that originate in the San Joaquin River basin and enter the Old River channel. These fish would migrate downstream in either the Old River, Middle River, or Grant Line/ Fabian – Bell channels. All three channels have considerable exposure to the effects of exports. The Old River and Grant Line/ Fabian-Bell channels pass directly in front of or in very close proximity to the intakes for the CVP and SWP, and a large proportion of fish moving through these channels are expected to be entrained into the fish salvage facilities where high levels of mortality are expected. The Middle River channel joins with the man-made Victoria Canal/ North Canal, a large dredged channel directly leading to the export facilities, and net flows move towards the export facility intakes under most conditions (NMFS 2019).

Increased exports have negative far-field migratory impacts as well, particularly in the Old and Middle River corridors which would impact CHNSR in those corridors. Fish that are present in the Old River or Middle River corridors and their tributaries downstream of the south Delta export facilities would experience increased net flows towards the export facilities. Increased exports would mute the ebbing tide signal to cue fish to move out of those corridors and back into the main migratory corridor of the San Joaquin River rather than moving farther southwards into waters that are more heavily influenced by the effects of reverse flows due to exports. This would affect both juvenile CHNSR originating in the Sacramento River basin as well as those CHNSR originating in the San Joaquin River basin and migrating downstream within the main stem channel of the San Joaquin River from upstream locations (NMFS 2019).

7.3.4. Historical Loss of Juvenile Chinook Salmon at the Salvage Facilities

“Loss” is a term used to refer to the estimated number of fish that experience mortality within the fish collection facilities as they go through the salvage process, and is estimated based on the number of salvaged fish (fish observed within the fish collection facilities at the export facilities) and a number of components related to facility efficiency and handling. Loss is estimated for each run of Chinook salmon that are observed at the salvage facilities. Salmon are identified as natural or hatchery origin based on

the presence or absence of an adipose fin (“unclipped” versus “clipped”). The race of unclipped fish is determined by the Delta Model LAD criteria (USFWS 1997), with the exception of genetic analysis for natural CHNWR, which was conducted from 2016 through 2019. CWTs in all clipped fish are read to determine race.

The salvage process at the SWP starts with fish entrainment into CCF, and proceeds with fish moving across the CCF until they enter the Skinner Fish Facility where they are collected in holding tanks. A screened subsample of fish that reach the salvage tanks are collected every two hours and the total fish salvage per sampling period is calculated by expanding the number of fish salvaged by the fraction of time that diversions were sampled. Fish loss for that period of time is calculated based on the standard loss equations (CDFW 2018 and Attachment 6 to the ITP). Daily salvage and loss are the cumulative sum for those metrics for all of the sampling periods that occurred in that day (NMFS 2019). After this stage, fish are transferred to tanker trucks and driven to release sites in the western Delta and released back into the Sacramento or San Joaquin Rivers. At the CVP, the fish salvage process starts with fish encountering the trash rack on Old River in front of the primary channel, and then progressing through the salvage process until the salvaged fish are ultimately released at the release sites, similar to the process at the Skinner Fish Facility (NMFS 2019). Data collected on juvenile Chinook salmon at both the Skinner Fish Facility and the Tracy Fish Facility during the salvage process are combined at the end of each day. The data is then used by both DWR and Reclamation to determine the total daily loss of each run of juvenile Chinook salmon. Combined loss of juvenile Chinook salmon can help to describe the total entrainment and loss that is occurring in the south Delta due to export operations at SWP and CVP pumping facilities.

Each step in the salvage process is associated with a different rate of mortality. CCF has a high mortality rate of juvenile Chinook salmon due to predation by fish and birds (Clark et al. 2009). The loss in CCF is termed “pre-screen loss” and the loss equation assumes this loss rate is 75% at SWP while CVP is assumed to have only a 15% pre-screen loss rate (CDFW 2018 and Attachment 6 to the ITP). Juvenile Chinook salmon also experience mortality at the louvers that screen them from entering Banks Pumping Plant at SWP or Jones Pumping Plant at CVP. The loss is termed “screening (louver) efficiency” and it is dependent upon the size of the fish as well as the water velocity through the louver (CDFW 2018 and Attachment 6 to the ITP). Fish that are salvaged at the Skinner Fish Facility and the Tracy Fish Facility may also experience loss during the handling, transport and release process. The loss equation assumes that fish that are 100 mm and smaller experience a 2% mortality rate, and fish that are 101 mm and larger experience a mortality rate of 0% during this part of the process (CDFW 2018 and Attachment 6 to the ITP).

The mortality rates that have been used in the loss equation have not been updated since 2003, and there have been more recent studies that show higher rates of loss, for example Wunderlich (2015) reported a pre-screen loss of 81.14% at SWP. Additionally, the loss equation does not consider the condition and survival of fish post-release. The salvage process, including handling, transport, and release can result in increased stress, dermal injury, increased risk for disease contraction, disorientation when released, predation during transport at release sites, and delayed mortality. Trucking juveniles from the salvage facilities in combination with Delta water operations likely contributes to significant adult straying. It is also important to note that the calculated loss at the facilities does not fully represent take of listed species under the CESA. “Take” is defined by Fish and Game Code section 86 as hunt, pursue, catch, capture, or kill, or attempt to hunt, pursue, catch, capture, or kill. Take of juvenile Chinook salmon occurs in the form of “capture” or “kill” when they are entrained into the salvage

facilities. Specifically, CDFW considers juvenile Chinook salmon taken when they enter through the radial gates at CCF, regardless of whether they survive the salvage and release process.

7.3.4.1. Historical Loss of Winter-run Chinook Salmon

Entrainment primarily affects emigrating salmonids during their juvenile and smolt life history stages although adult salmonids have been documented in salvage at both the SWP and CVP export facilities. CHNWR salvage data collected at SWP and CVP is available on the online database from 1993 through the publication of this document in March 2020 (CDFW 2019c). The Delta Model LAD criteria (USFWS 1997) is used to identify juvenile CHNWR at the south Delta salvage facilities. Starting in 2016, a rapid genetics protocol was implemented to properly identify CHNWR from the other runs of Chinook salmon.² This protocol was not carried forward in the 2019 NMFS BiOp and is not included in the ITP. To quantify historical loss of juvenile CHNWR, for purposes of this Effects Analysis, CDFW gathered data from the CDFW Bay-Delta Region salvage database (CDFW 2019c) and calculated loss using the loss equation (CDFW 2018 and Attachment 6 to the ITP).

Figure 5 shows the annual historical loss of juvenile LAD natural and hatchery CHNWR from water years 1993 to 2018. Annual loss of juvenile CHNWR decreased in 1997 (646 fish), then gradually increased and peaked in 2003 and 2004 (29,651 fish and 27,171 fish, respectively), followed by a sharp decline in 2005 (5,385 fish). After 2005, loss was somewhat steady until declining again rather drastically during the drought, ranging to a low of 330 in 2015. Recently, loss numbers have continued to be relatively low (1,064 fish in 2018) (Figure 5). This pattern of decline since 2005 is similar to the pattern of CHNWR adult escapement (CDFW 2019b), which indicates adult spawning success and egg-to-fry and juvenile survival may be a contributing factor. This decrease in CHNWR is likely caused by a combination of factors with a major contributor most likely being drought years as egg-to-fry survival to the RBDD was 5.6% in 2014 and 4.2% in 2015. The 2009 NMFS BiOp minimized entrainment and loss of CHNWR by restricting OMR flows to be more positive when a daily loss density trigger was exceeded (RPA Action IV.2.3). This action could also account for some of the decrease observed from 2009 to 2018.

Historically, juvenile CHNWR have been observed in the salvage facilities from December through June (Figures 6-12), with most of the salvage and loss occurring from December through April. However, the loss typically peaks from January through March. Migrating juvenile CHNWR typically finish exiting the Delta in late May (del Rosario et al. 2013), and therefore salvage and loss of juvenile CHNWR in May and June is generally very low. Loss of juvenile CHNWR in May only occurred in 10 of the 26 years, while loss of juvenile CHNWR during June only occurred in one year (2003). With decreasing numbers of CHNWR (as described in Section 4.1 – Life History of Winter-run Chinook Salmon), minimization measures are needed to reduce the entrainment and loss of juvenile salmonids that occurs at the salvage facilities.

² The rapid genetics protocol was required by an amendment to the 2009 NMFS Biological Opinion RPA Action IV.2.3 (OMR Management).

Juvenile Winter-Run Chinook Salmon Annual Loss

Water Years 1993 to 2018

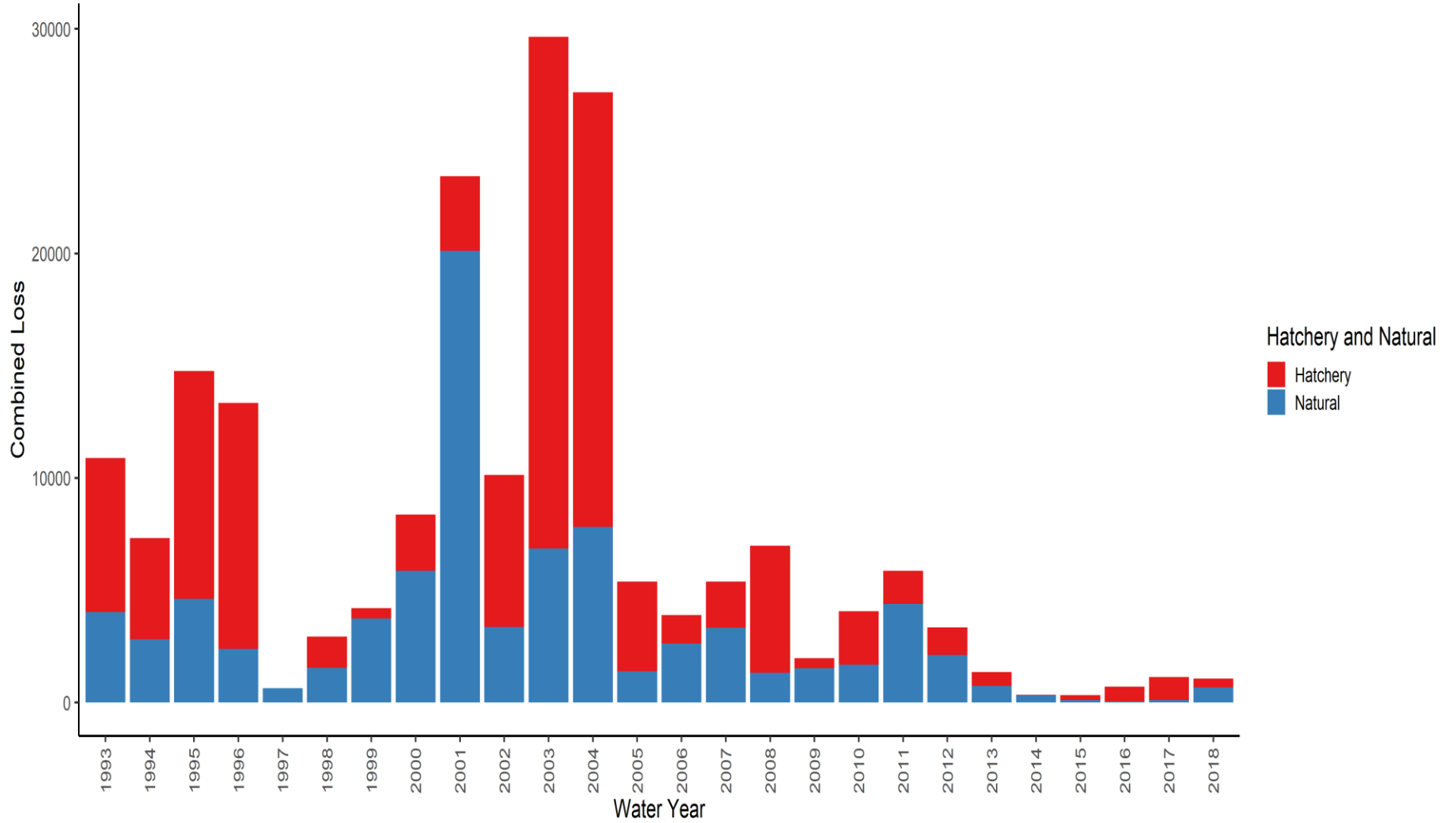


Figure 5: Juvenile CHNWR Annual Loss, Water Year 1993-2018. Combined annual loss at SWP and CVP of juvenile LAD natural and hatchery CHNWR from water years 1993 to 2018. "Annual" refers to water year (October through September).

Juvenile Winter-Run Chinook Salmon Monthly Loss

December, Water Years 1993-2018

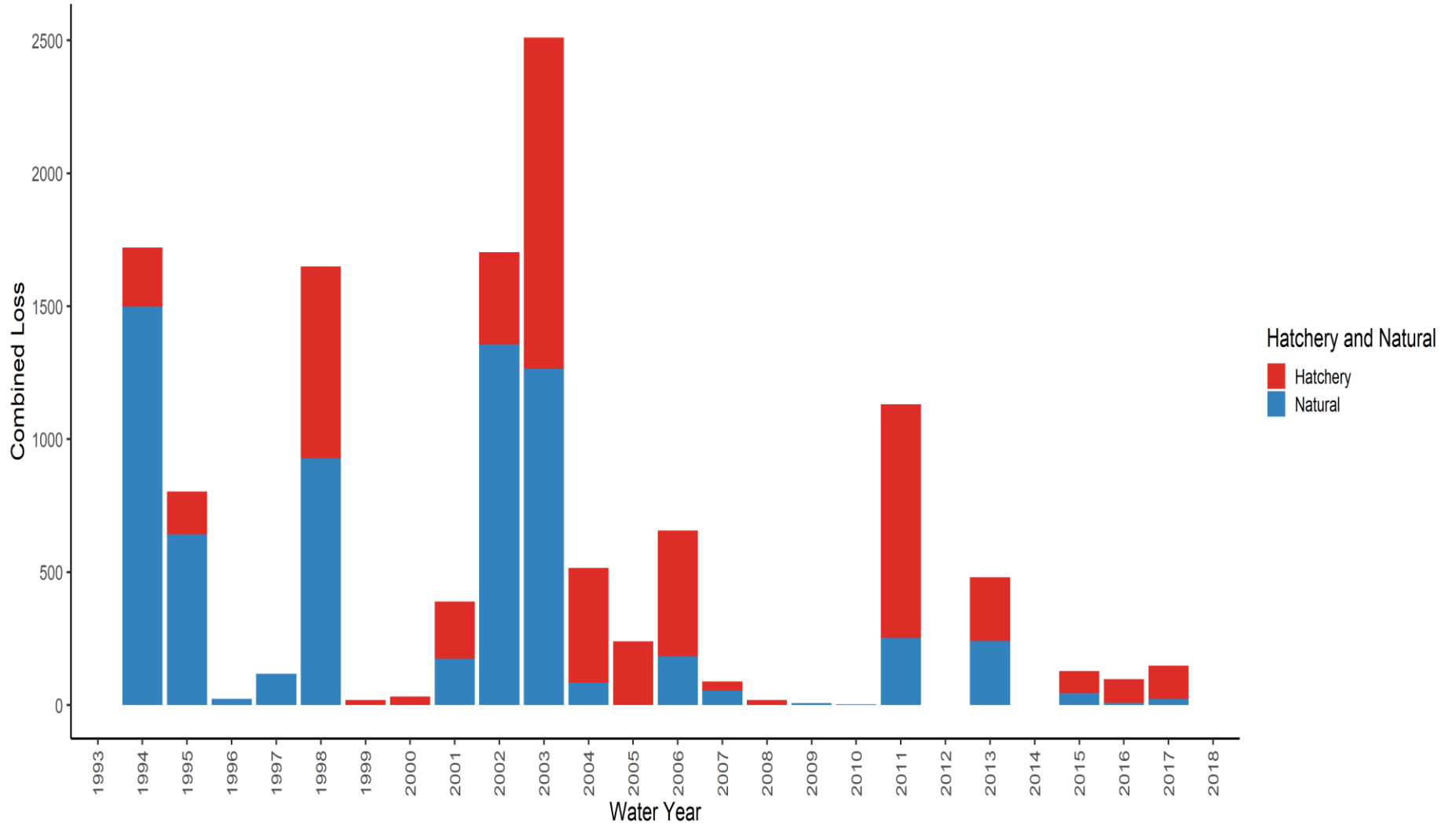


Figure 6: Juvenile CHNWR Monthly Loss, December Water Year 1993-2018. Combined loss of juvenile LAD natural and hatchery CHNWR for December from water years 1993 to 2018 at SWP and CVP.

Juvenile Winter-Run Chinook Salmon Monthly Loss
 January, Water Years 1993-2018

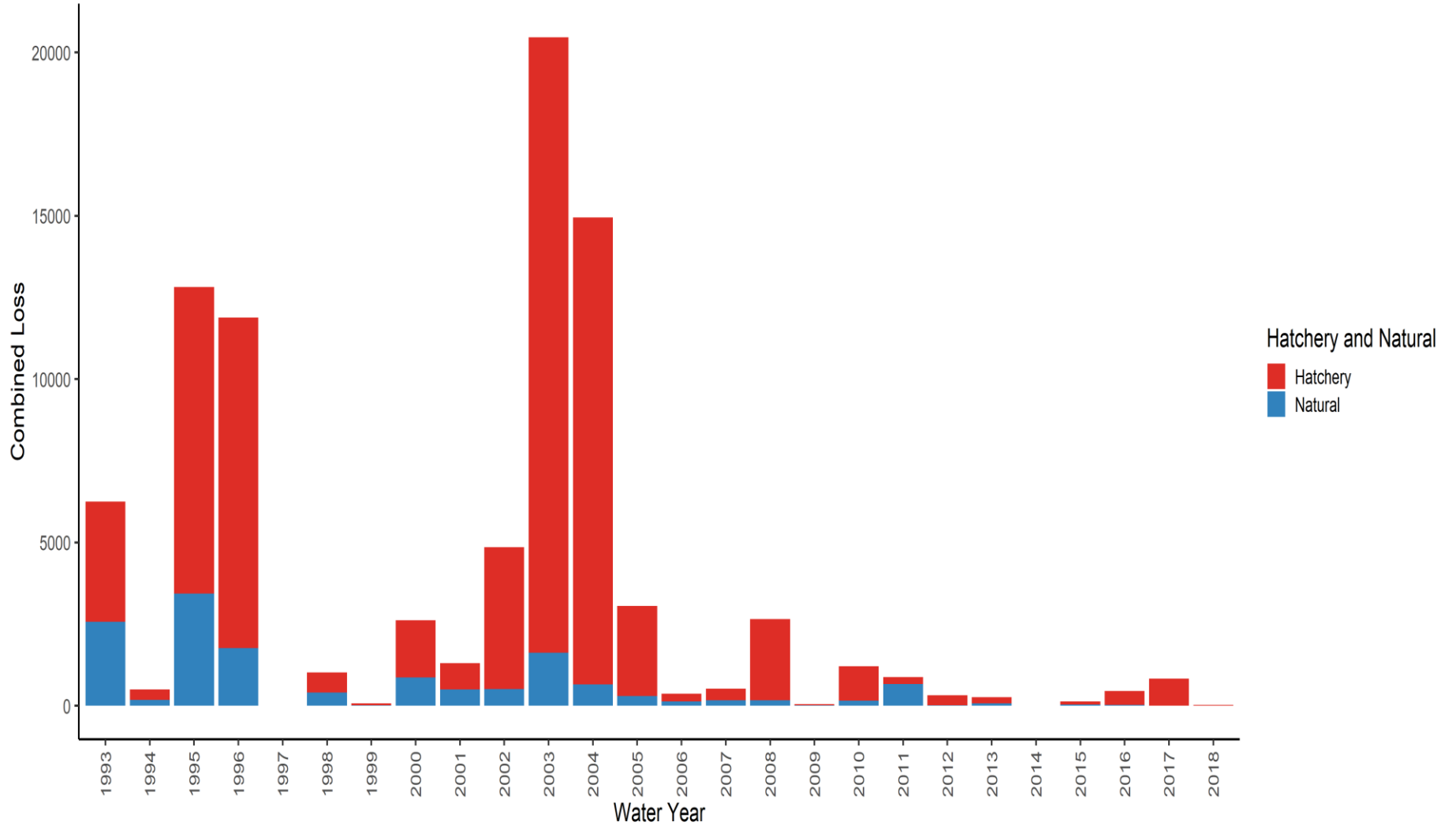


Figure 7: Juvenile CHNWR Monthly Loss, January Water Year 1993-2018. Combined loss of juvenile natural and hatchery CHNWR for January from water years 1993 to 2018 at SWP and CVP.

Juvenile Winter-Run Chinook Salmon Monthly Loss

February, Water Years 1993-2018

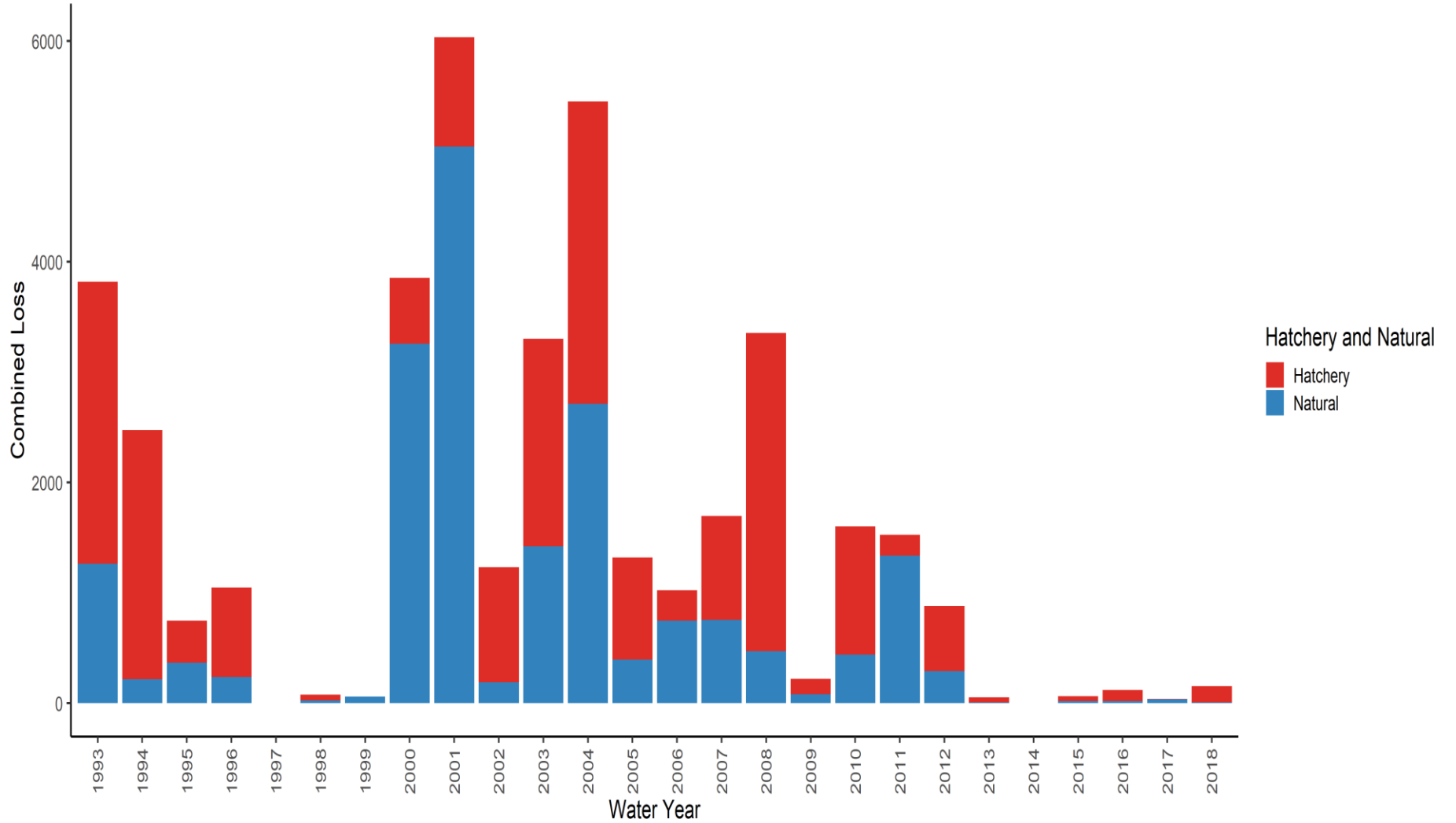


Figure 8: Juvenile CHNWR Monthly Loss, February Water Year 1993-2018. Combined loss of juvenile LAD natural and hatchery CHNWR for February from water years 1993 to 2018 at SWP and CVP.

Juvenile Winter-Run Chinook Salmon Monthly Loss

March, Water Years 1993-2018

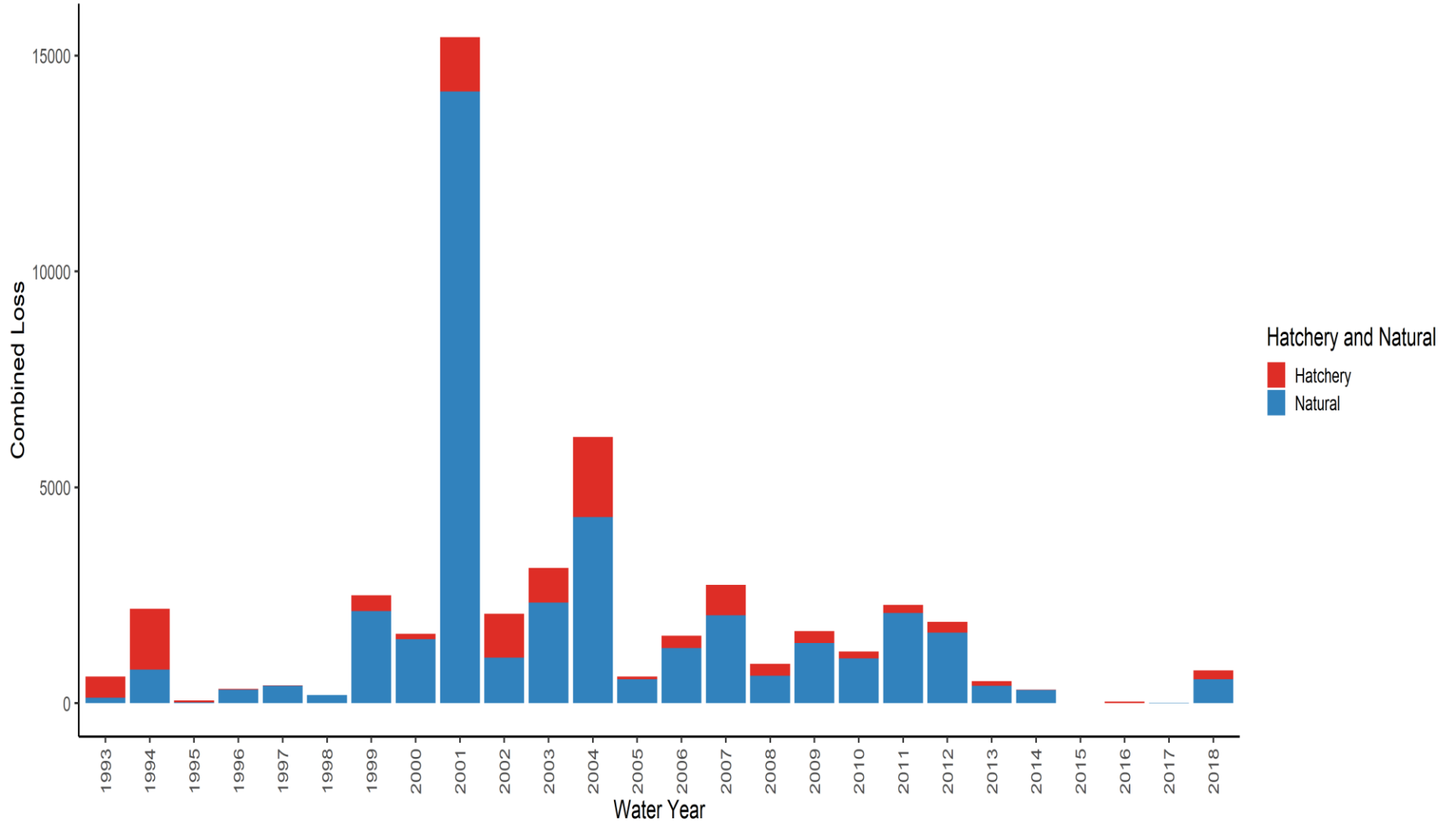


Figure 9: Juvenile CHNWR Loss, March Water Year 1993-2018. Combined loss of juvenile LAD natural and hatchery CHNWR for March from water years 1993 to 2018 at SWP and CVP.

Juvenile Winter-Run Chinook Salmon Monthly Loss

April, Water Years 1993-2018

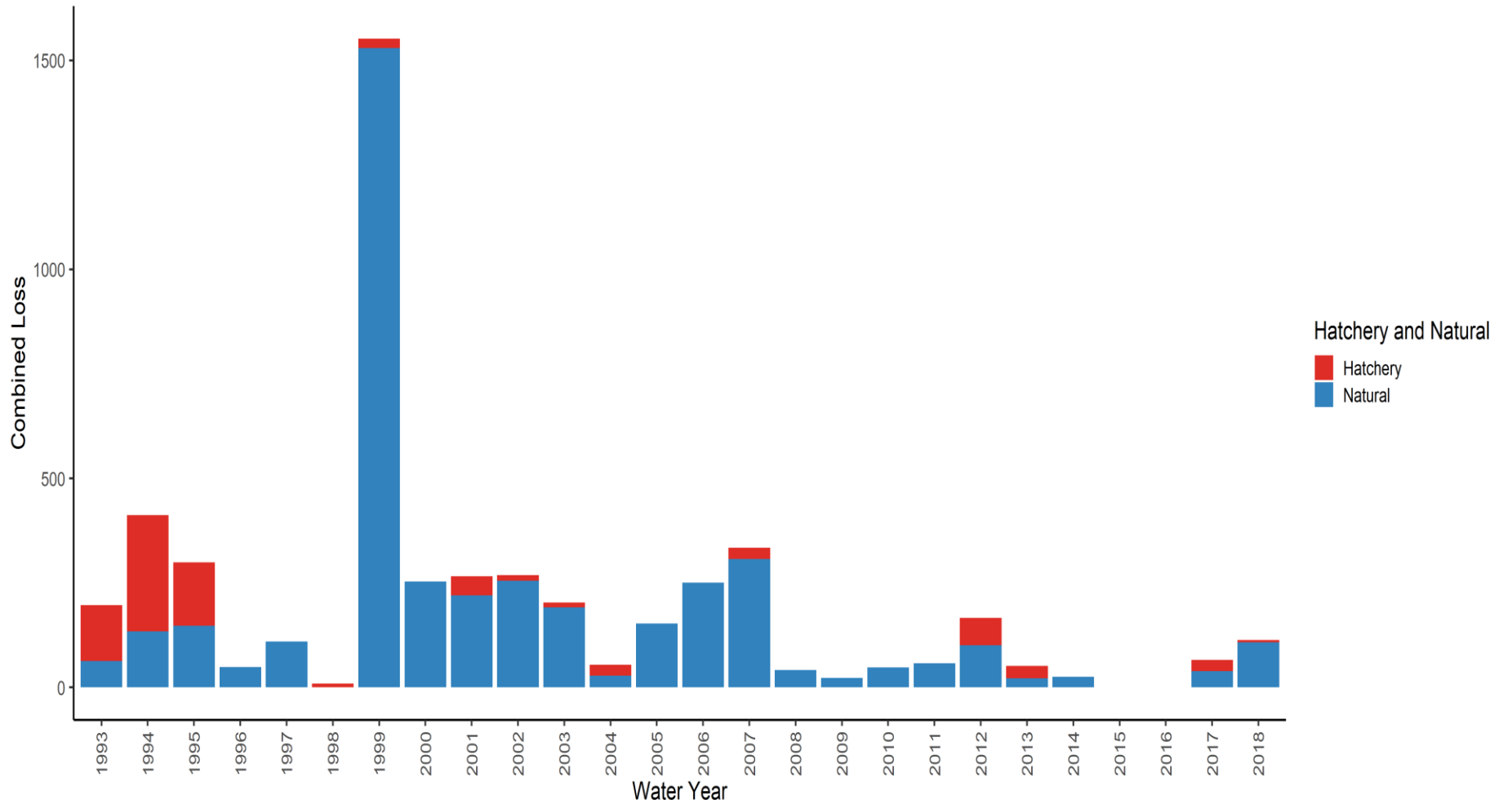


Figure 10: Juvenile CHNWR Monthly Loss, April Water Year 1993-2018. Combined loss of juvenile LAD natural and hatchery CHNWR for April from water years 1993 to 2018 at SWP and CVP.

Juvenile Winter-Run Chinook Salmon Monthly Loss

May, Water Years 1993-2018

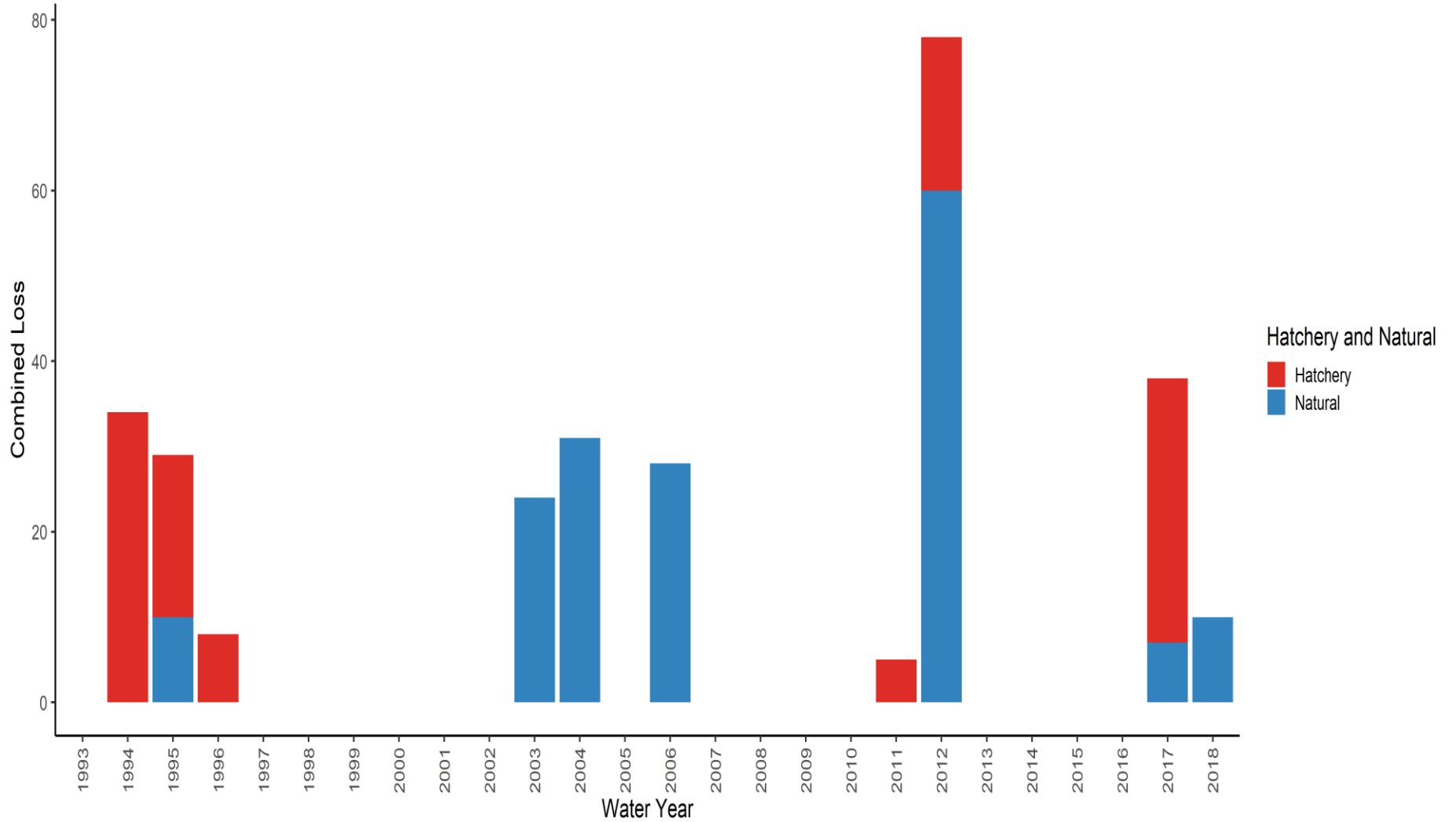


Figure 11: Juvenile CHNWR Monthly Loss, May Water Year 1993-2018. Combined loss of juvenile LAD natural and hatchery CHNWR for May from water years 1993 to 2018 at SWP and CVP.

Juvenile Winter-Run Chinook Salmon Monthly Loss

June, Water Years 1993-2018

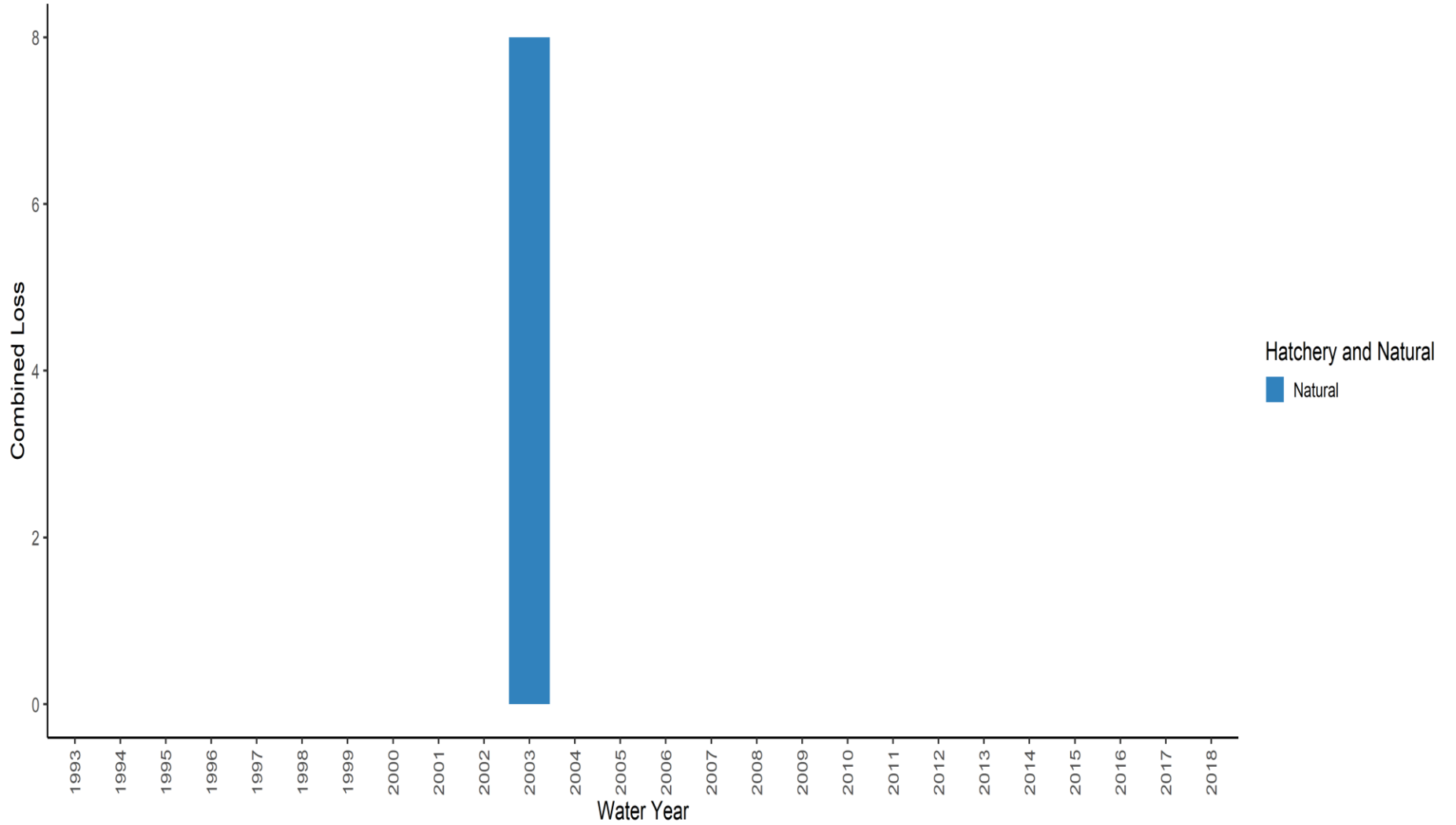


Figure 12: Juvenile CHNWR Monthly Loss, June Water Year 1993-2018. Combined loss of juvenile LAD natural and hatchery CHNWR for June from water years 1993 to 2018 at SWP and CVP.

7.3.4.2. Historical Loss of Spring-run Chinook Salmon

Entrainment primarily affects emigrating salmonids during their juvenile and smolt life history stages although adult salmonids have been documented in salvage at both the SWP and CVP export facilities. CHNWR salvage data collected at SWP and CVP is available on the online database from 1993 through the publication of this document in March 2020 (CDFW 2019c). The Delta Model LAD criteria (USFWS 1997) is used to identify juvenile CHNSR at the south Delta salvage facilities. To quantify historical loss of juvenile CHNSR, for the purposes of this Effects Analysis, CDFW gathered from the CDFW Bay-Delta Region salvage database (CDFW 2019) and calculated loss using the loss equation (CDFW 2018 and Attachment 6 to the ITP).

Figure 13 shows the annual historical loss of juvenile LAD natural and hatchery CHNSR from water years 1993 to 2018. Annual loss of juvenile CHNSR peaked in 1999 (128,238 fish), followed by a sharp decline in 2001 (41,430 fish), which continued on a declining trend with very low numbers experienced during drought years 2012-2016 (2,714 fish in 2012, 2,545 fish in 2013, 384 fish in 2014, 84 fish in 2015, and 884 fish in 2016). Peaks experienced in 2011 and 2017 (53,361 fish and 73,869 fish, respectively) can likely be attributed to both being extreme, uncharacteristic wet water years. Loss has increased in 2018 relative to the drought years but is still low relative to historic observations (20,097 fish). Low numbers of adult CHNSR and poor quality in-stream rearing conditions in tributaries during drought years may be a contributing factor to the low numbers of CHNSR observed in salvage (see Section 4.2 – Life History of Spring-run Chinook Salmon).

Historically, juvenile CHNSR have typically been observed in the salvage facilities from January through June (Figures 15-20), with peak salvage and loss occurring from March through May. Salvage and loss of juvenile CHNSR observed outside of these months is rare, however salvage and loss of juvenile CHNSR was observed once in October in 1998 (Figure 14) and once in September in 2000 (Figure 21). Loss in January is typically very low and was only observed in 4 of the 26 years. In addition to the end of the OMR Management season, June is the last month that salvage and loss occurs for CHNSR. Loss in June is normally low, however there were three years in this time-period when loss surpassed 5,000 fish (1995, 2011, and 2017). Zero loss of CHNSR occurred during the months of November and December from 1993-2018, so figures are not included for these months.

It is important to note that loss of CHNSR at the salvage facilities was calculated based on the Delta Model LAD criteria (USFWS 1997). This method of identification has been proven to be less accurate for juvenile CHNSR compared to other runs of juvenile Chinook salmon due to the diverse life history strategies of juvenile CHNSR, the environmental conditions juvenile CHNSR experience during emigration, and the quality and quantity of available rearing habitat juvenile CHNSR encounter prior to Delta entry. Harvey and Stroble (2013), found that 95% of the CHNSR sized fish were genetically CHNFR. Therefore, the loss of CHNSR at the salvage facilities could potentially be lower than what is represented in Figures 13-21. However, many YOY CHNSR are misidentified as CHNFR using the LAD criteria, so these fish are not being included with CHNSR salvage numbers (see Section 8.16 – Daily Spring-run Chinook Salmon Hatchery Surrogate Loss Threshold below). With decreasing numbers of CHNSR (as described in Section 4.2 – Life History of Spring-run Chinook Salmon above), minimization measures are needed to help reduce the entrainment and loss of juvenile salmonids that occurs at the Banks Pumping Plant and the Skinner Fish Facility.

Juvenile Spring-Run Chinook Salmon Annual Loss

Water Years 1993 to 2018

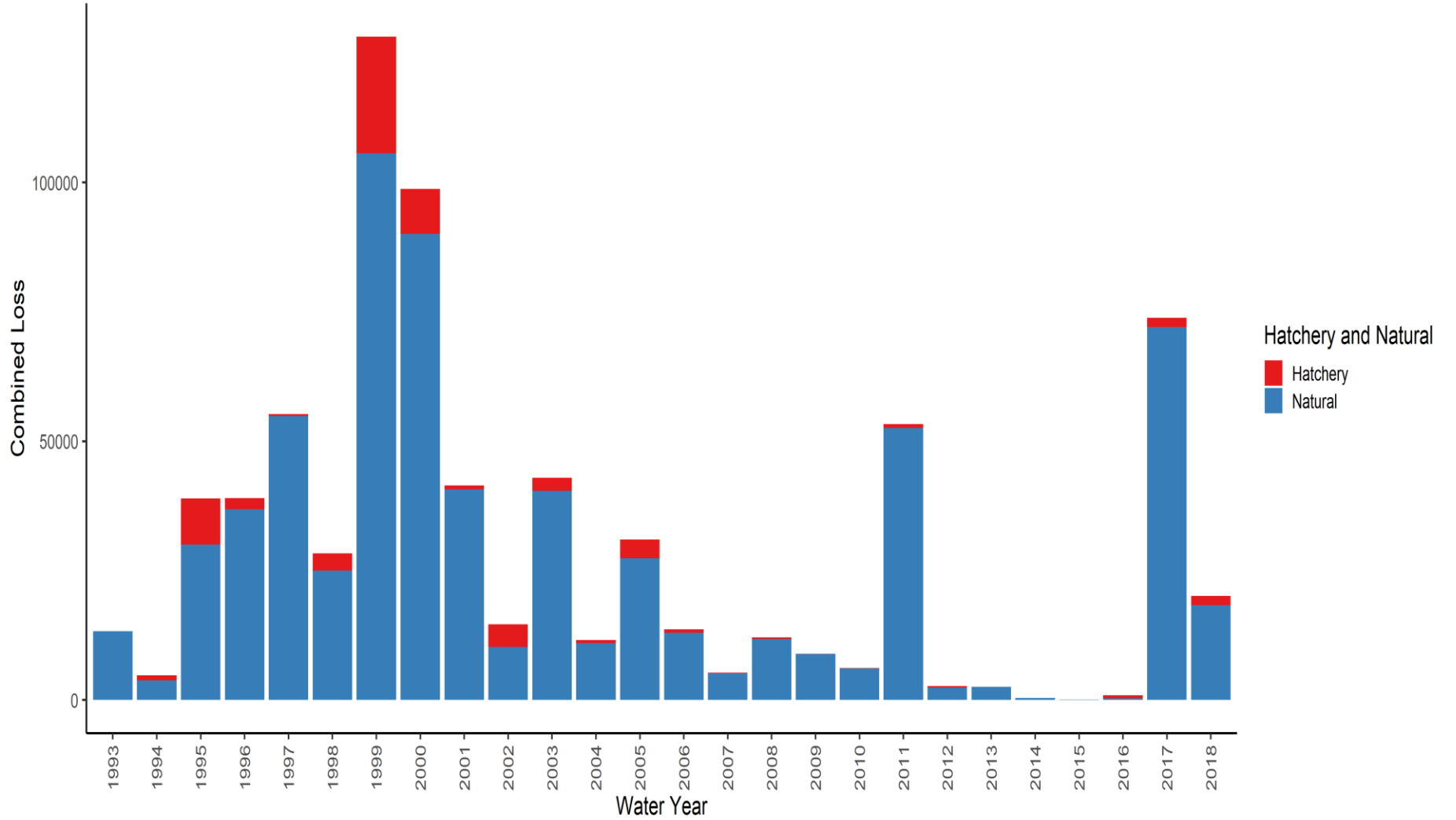


Figure 13: Juvenile CHNSR Annual Loss, Water Year 1993-2018. Combined annual loss at SWP and CVP of juvenile LAD natural and hatchery CHNSR from water years 1993 to 2018. "Annual" refers to the water year (October through September).

Juvenile Spring-Run Chinook Salmon Monthly Loss
October, Water Years 1993-2018

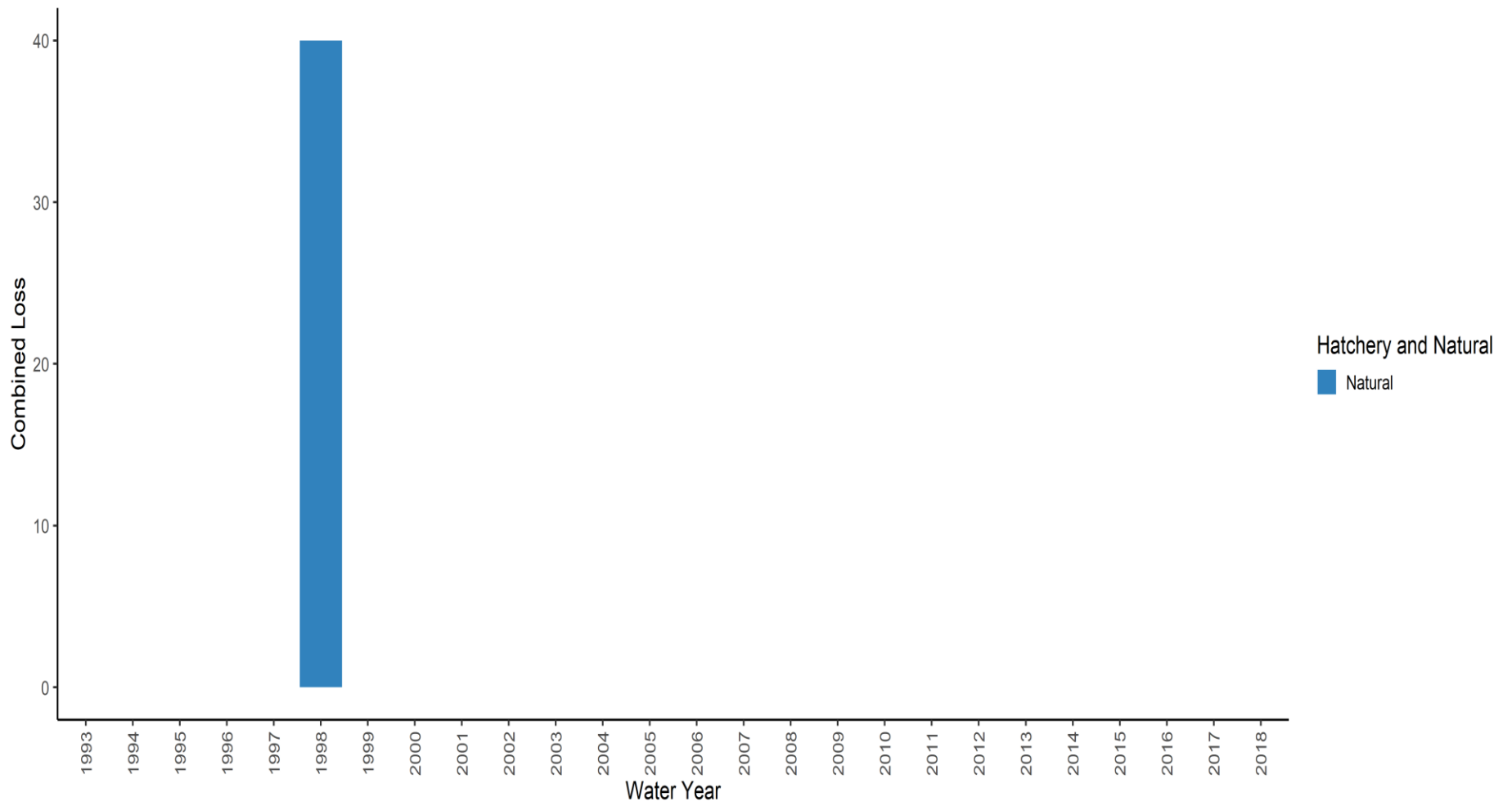


Figure 14: Juvenile CHNSR Monthly Loss, October Water Year 1993-2018. Combined loss of juvenile LAD natural and hatchery CHNSR for October from water years 1993 to 2018 at SWP and CVP.

Juvenile Spring-Run Chinook Salmon Monthly Loss

January, Water Years 1993-2018

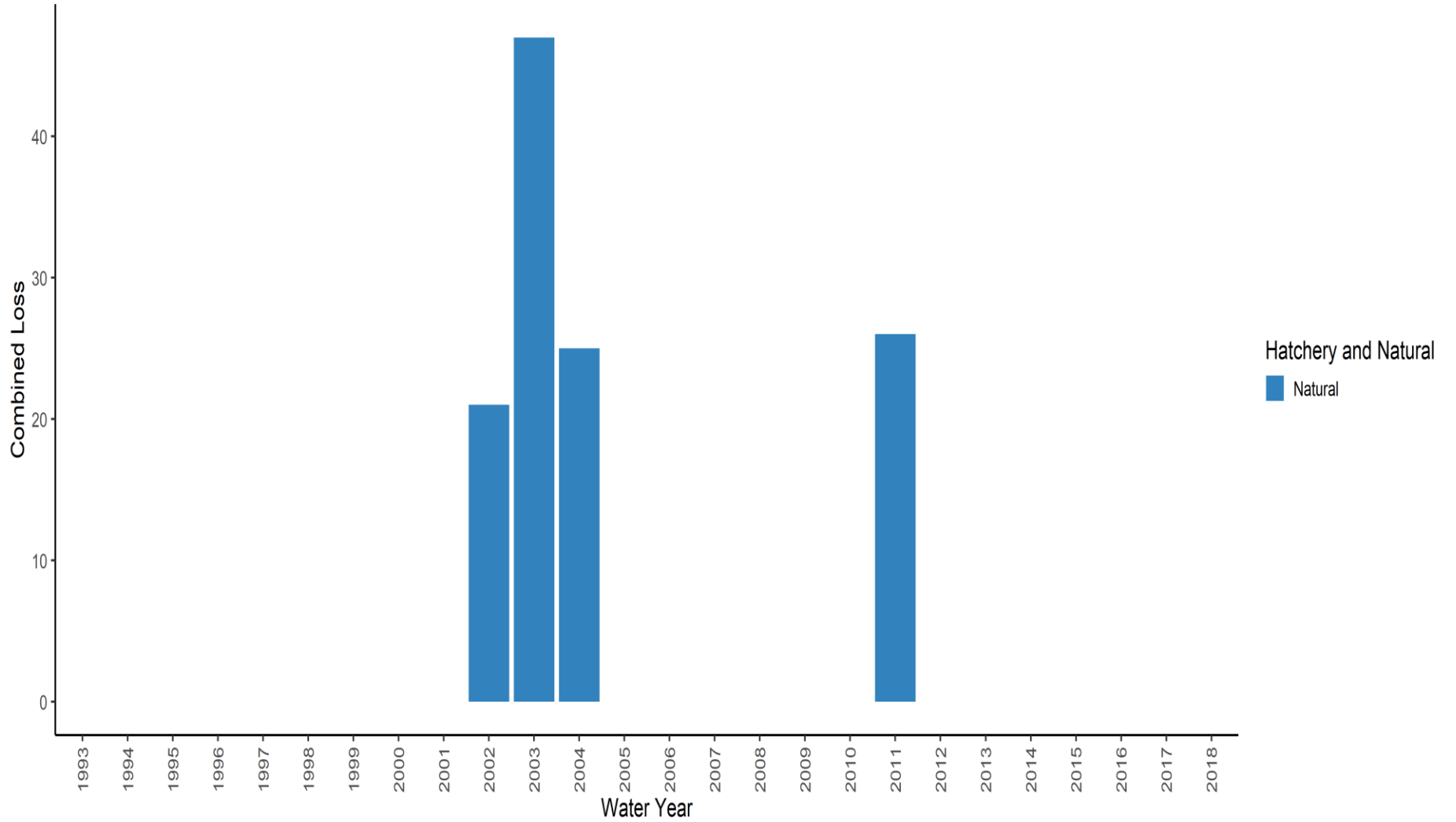


Figure 15: Juvenile CHNSR Monthly Loss, January Water Year 1993-2018. Combined loss of juvenile LAD natural and hatchery CHNSR for January from water years 1993 to 2018 at SWP and CVP.

Juvenile Spring-Run Chinook Salmon Monthly Loss

February, Water Years 1993-2018

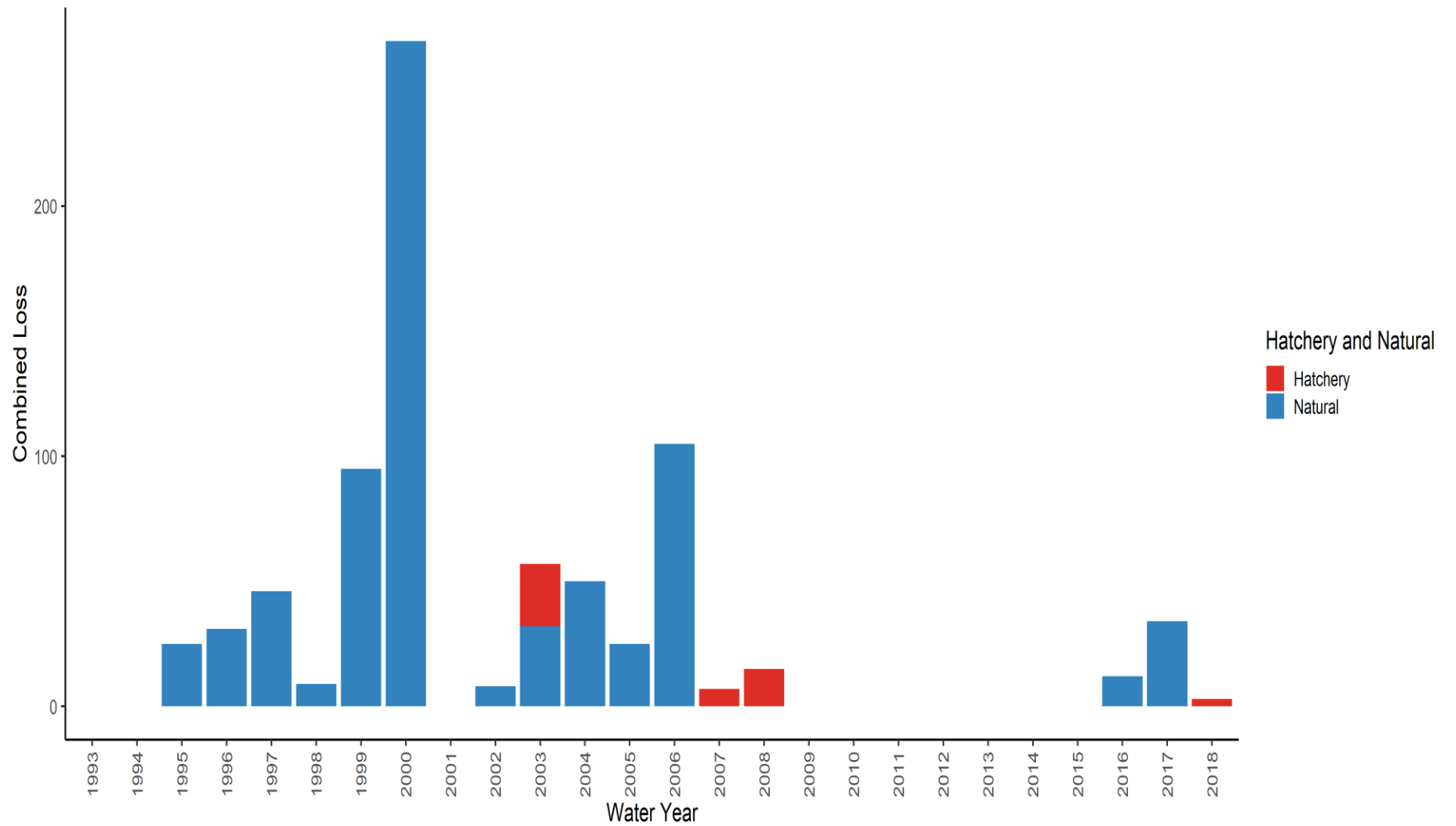


Figure 16: Juvenile CHNSR Monthly Loss, February Water Year 1993-2018. Combined loss of juvenile LAD natural and hatchery CHNSR for February from water years 1993 to 2018 at SWP and CVP.

Juvenile Spring-Run Chinook Salmon Monthly Loss

March, Water Years 1993-2018

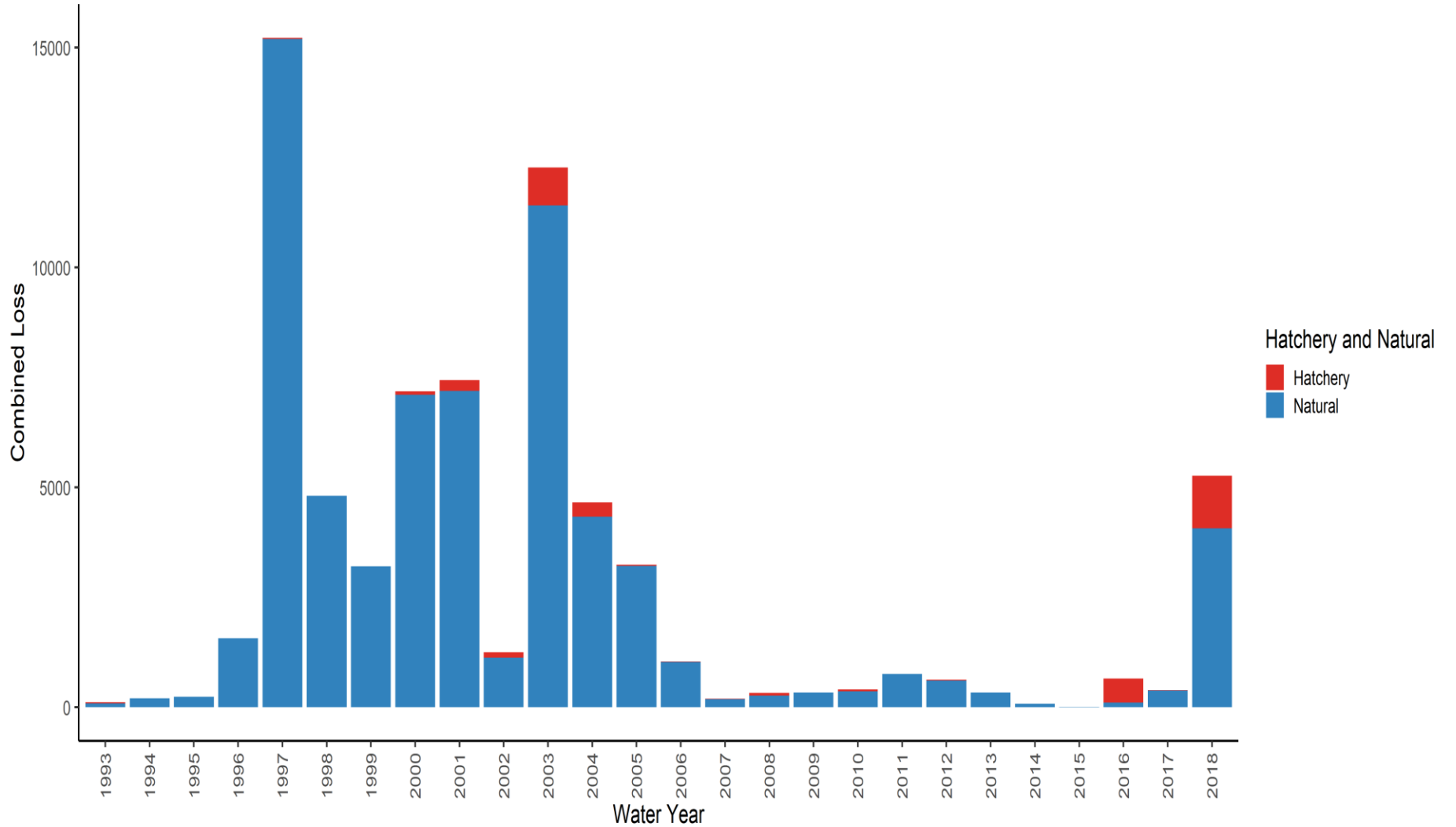


Figure 17: Juvenile CHNSR Monthly Loss, March Water Year 1993-2018. Combined loss of juvenile LAD natural and hatchery CHNSR for March from water years 1993 to 2018 at SWP and CVP.

Juvenile Spring-Run Chinook Salmon Monthly Loss

April, Water Years 1993-2018

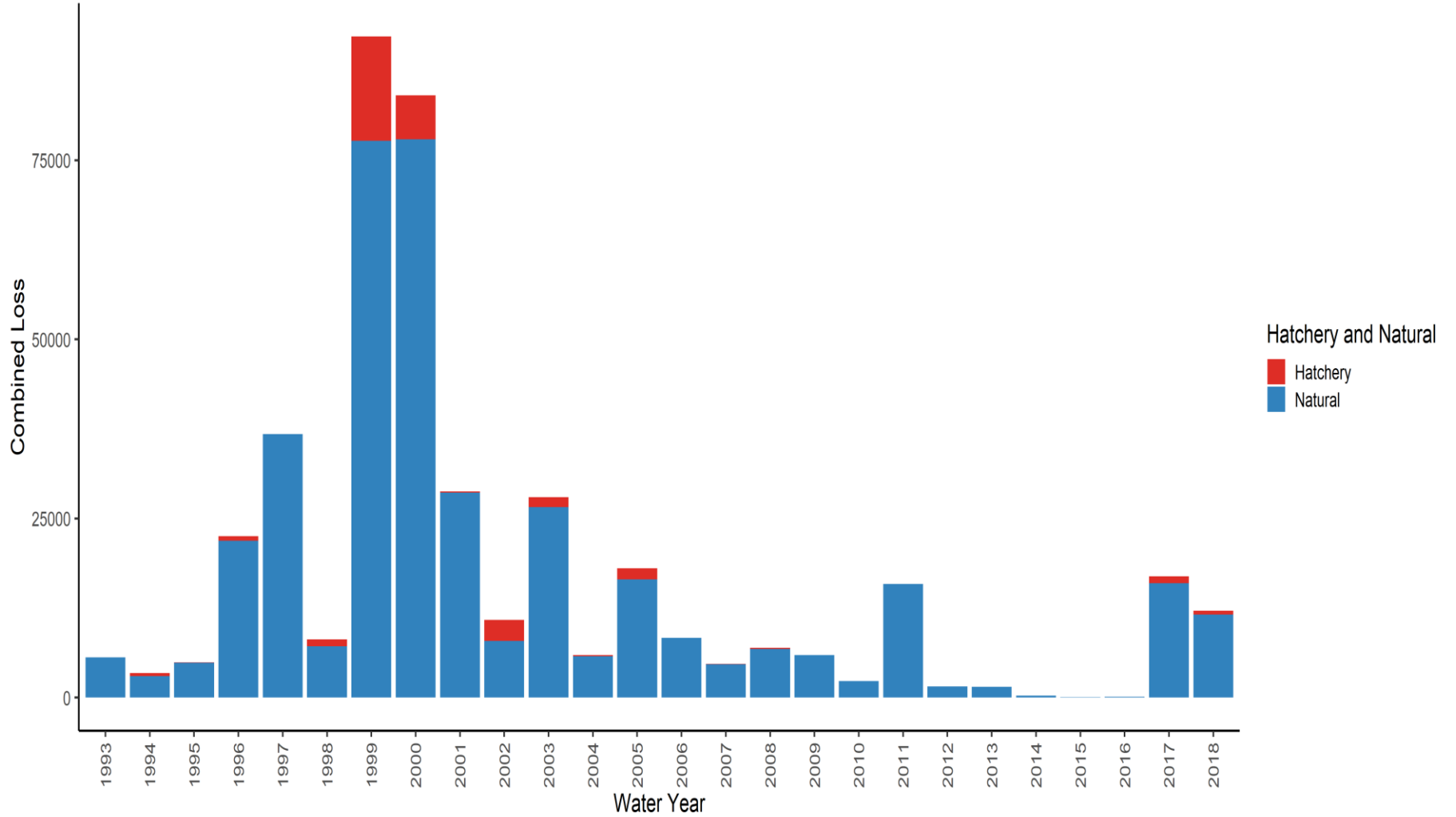


Figure 18: Juvenile CHNSR Monthly Loss, April Water Year 1993-2018. Combined loss of juvenile LAD natural and hatchery CHNSR for April from water years 1993 to 2018 at SWP and CVP.

Juvenile Spring-Run Chinook Salmon Monthly Loss

May, Water Years 1993-2018

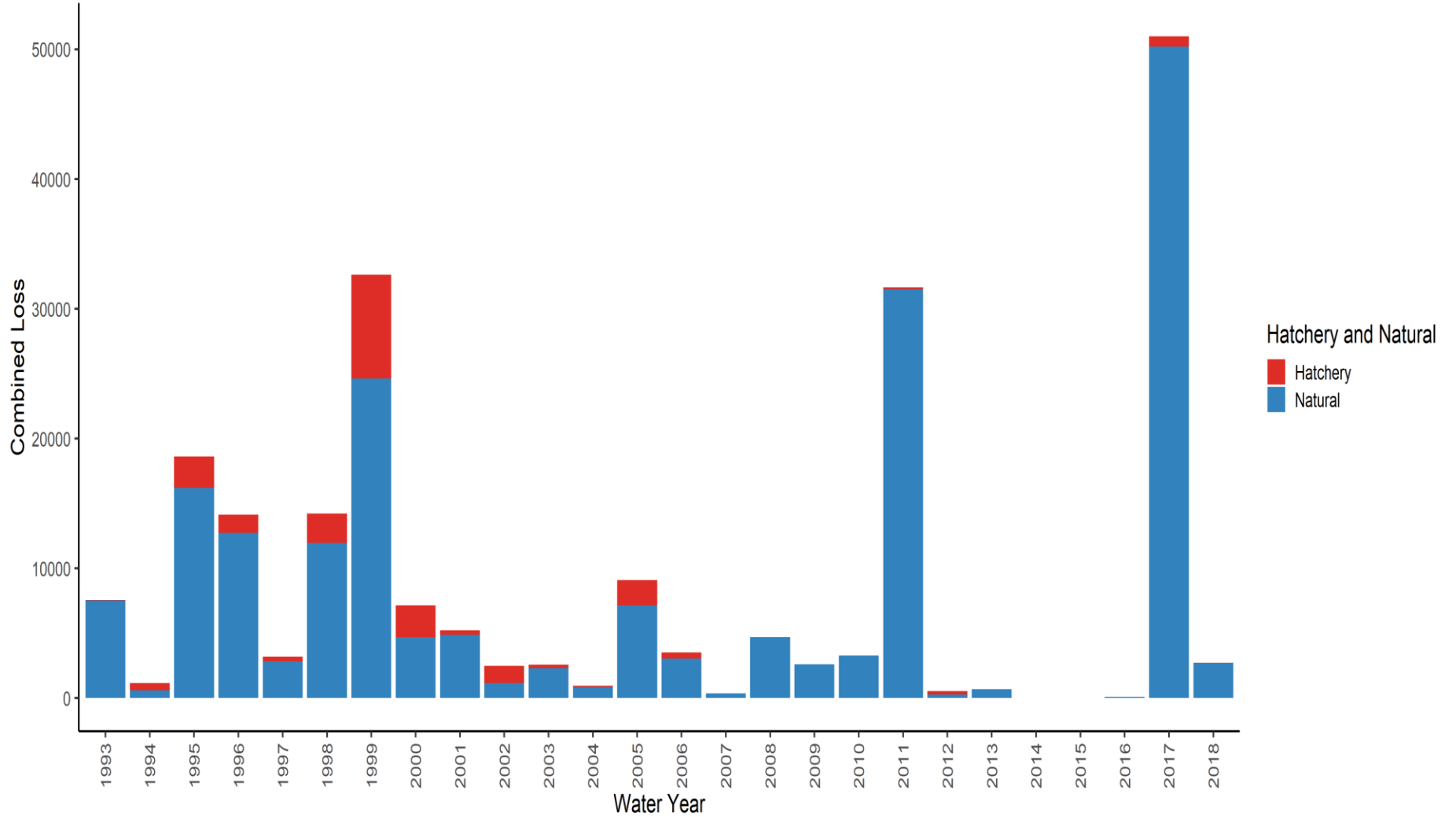


Figure 19: Juvenile CHNSR Monthly Loss, May Water Year 1993-2018. Combined loss of juvenile LAD natural and hatchery CHNSR for May from water years 1993 to 2018 at SWP and CVP.

Juvenile Spring-Run Chinook Salmon Monthly Loss

June, Water Years 1993-2018

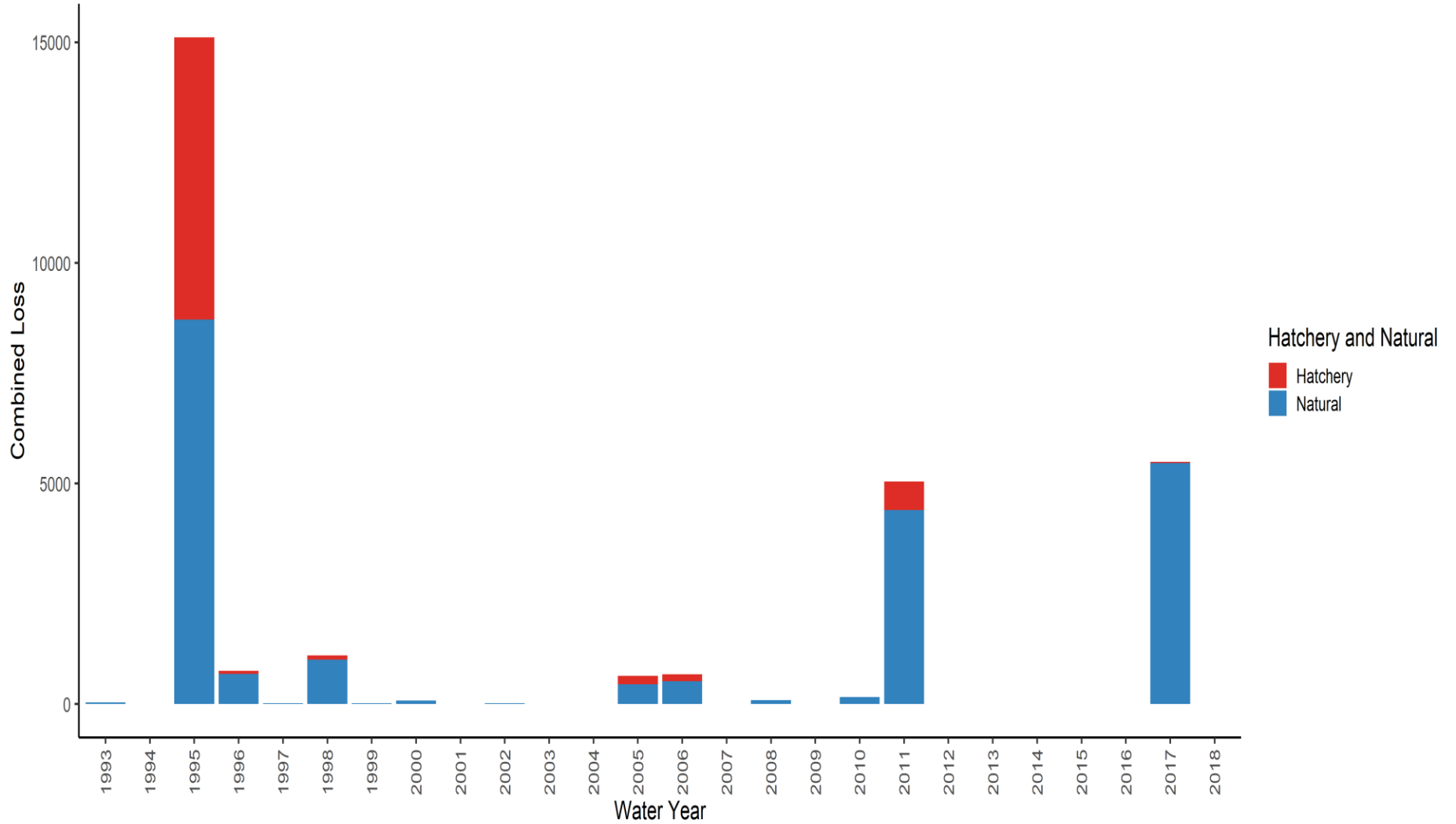


Figure 20: Juvenile CHNSR Monthly Loss, June Water Year 1993-2018. Combined loss of juvenile LAD natural and hatchery CHNSR for June from water years 1993 to 2018 at SWP and CVP.

Juvenile Spring-Run Chinook Salmon Monthly Loss September, Water Years 1993-2018

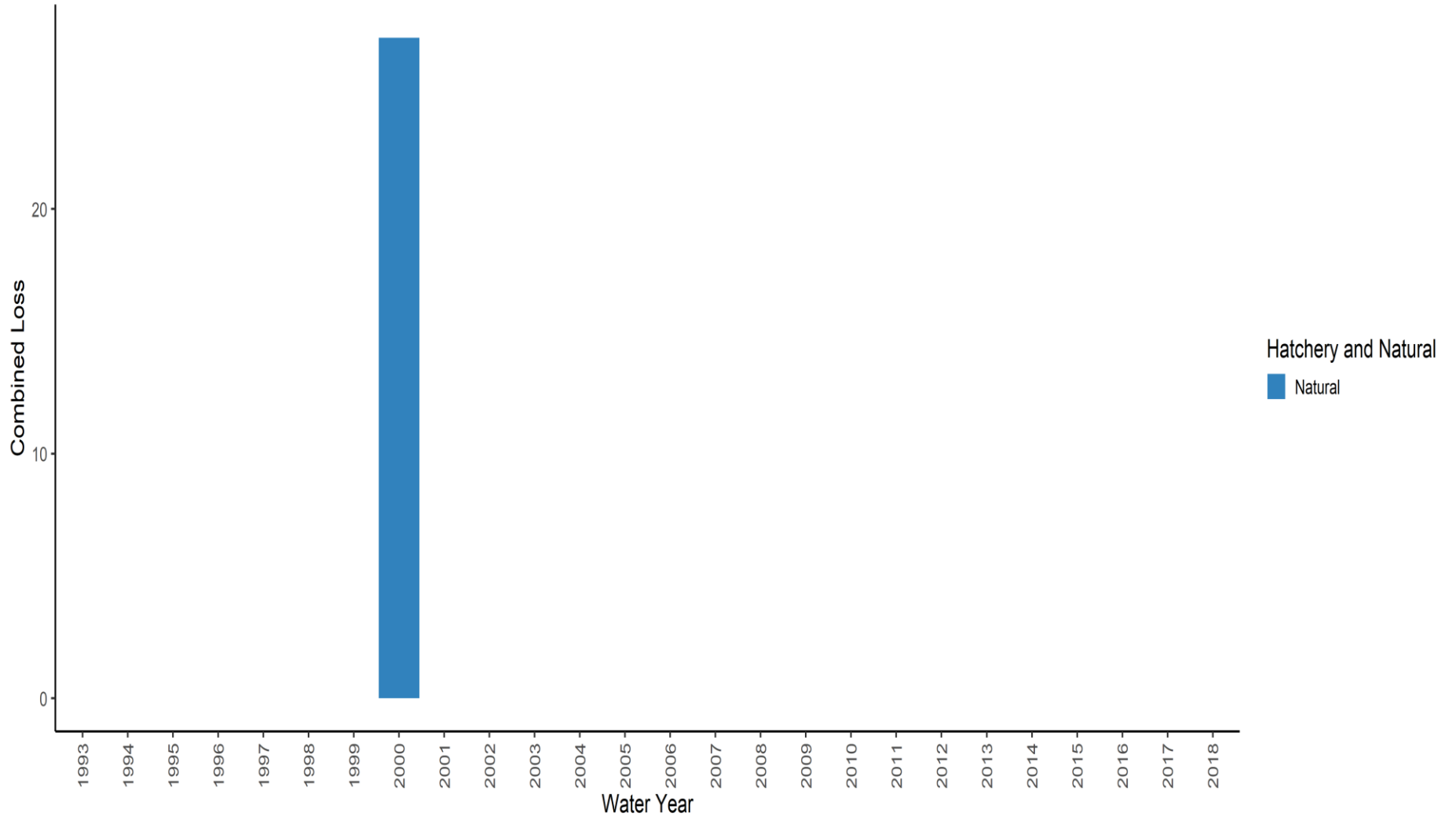


Figure 21: Juvenile CHNSR Monthly Loss, September Water Year 1993-2018. Combined loss of juvenile LAD natural and hatchery CHNSR for September from water years 1993 to 2018 at SWP and CVP.

7.3.5. Salvage Density Method Analysis

7.3.5.1. Introduction

The FEIR includes estimated entrainment loss generated from the Salvage-Density Method for CHNWR and CHNSR. This method evaluates the differences in entrainment loss at the SWP export facility between Existing Conditions and Alternative 2b. The FEIR states that the estimated entrainment loss should not be construed as accurate predictions of future entrainment loss but should rather be used to provide a coarse assessment of potential differences between the two scenarios. The method relies on CalSim II modeled differences in SWP exports, including changes to spring export curtailments for Delta outflow under the Alternative 2b³. The CalSim II model does not include real-time adjustments to operations including entrainment protections for larval and juvenile DS and LFS that may alter real-time operations. CalSim II is a monthly model and is not currently capable of incorporating biological data or modeling changes in operations at a finer timescale. However, the CalSim II model does include OMR flow restrictions of no more negative than -3,500 cfs in March and April based on an assumption that the single-year loss thresholds for natural CHNWR and/or natural Central Valley steelhead will trigger reduced exports to achieve an average OMR flow no more negative than -3,500 cfs during these months in wet, above normal, below normal, and dry water year types. Based on analyses in the 2019 NMFS BiOp of the performance of the thresholds during 2010-2018, an OMR reduction to -3,500 would have only triggered 4 out of 9 years in March (2011, 2012, 2013, and 2018) and 2 out of 9 years in April (2011 and 2018)⁴. Thus, the modeling assumption that OMR would be reduced to -3,500 throughout March and April of every year may not be accurate. Due to the uncertainty in future OMR restrictions between March and May, it is unclear if the estimated exports and OMR flows described in the FEIR accurately depict operations, including the potential increase in spring exports, under the Alternative 2b during this time frame. Therefore, it is possible that the number of fish entrained in the SWP and CVP as a result of operations under the Alternative 2b scenario may be underestimated.

7.3.5.2 Methods

The FEIR states that the Salvage-Density Method was updated from the version used in the 2019 NMFS BiOp (ICF International 2016) to include historical loss from water years 1994 through 2018 and to incorporate DWR's CalSim II modeling for Alternative 2b. The following describes the methods for the version of the Salvage-Density Method included in the FEIR.

7.3.5.2.1. Preprocessing of Input Data

Historical monthly export and salvage data for water years 1994 through 2018 were obtained from CDFW Bay-Delta Region salvage database (CDFW 2019c). Both unclipped and clipped fish were included

³ Under the Alternative 2b scenario, SWP will curtail exports from April 1 through May 31 each year to contribute the SWP share of the long-term average contribution of incidental spring outflow achieved under the USFWS 2008 and NMFS 2009 BiOps. However, the 2019 NMFS and USFWS BiOps do not require CVP to curtail spring exports to enhance Delta outflow. As a result, OMR during April and May is expected to be more negative under Project operations than under the Existing Conditions scenario.

⁴ The natural CHNWR single-year loss threshold would have triggered OMR reductions to -2,500 cfs on March 11 in 2011 and March 21 in 2012. The natural CHNWR single-year loss threshold would have been exceeded in both 2011 and 2012 on March 20 and March 31, respectively, thus possibly triggering further OMR reductions for the rest of the OMR Management period.

in the analyses because together they represent the impact to the species as listed under CESA. Salvage data for CHNWR and CHNSR represent expanded salvage data, which are extrapolated estimates of the total number of fish salvaged based on a subsample that was identified, counted, and measured. Salvage data were extrapolated into total entrainment losses to reflect prescreen loss, louver efficiency, and losses during transport to the release site. Although Appendix D of the ITP Application cites DWR and CDFG (1986) for the loss equation, it is assumed that loss was calculated using CDFW (2018d) as this is the most recent version of the loss equation used by the salvage facilities.

In its analysis, the FEIR acknowledged that expanded salvage and loss estimates have inherent statistical error associated with expansion of samples but accounted for this statistical error in the Salvage-Density Method. The method does not account for spatial distribution of fish populations, which may differ between the Existing Conditions and Alternative 2b and assumes a linear relationship between entrainment and exports. A linear relationship is assumed due to the lack of information characterizing changes in salvage with changes to exports. This choice is supported by Kimmerer (2008), which showed a linear relationship between hatchery Chinook salmon salvage and total south Delta exports up to 250-275 m/s (~8,800-9,700 cfs).

The CDFW Bay-Delta Region salvage database (<ftp://ftp.wildlife.ca.gov/salvage/>) identifies runs based on the Delta Model LAD criteria (USFWS 1997). The Delta Model LAD criteria (USFWS 1997) allows for overlap between runs, which creates uncertainty in the identification of the run. This is especially true for CHNSR and CHNFR, with CHNFR often misidentified as CHNSR based on the model (Harvey and Stroble 2013). Harvey and Stroble (2013) reported that 98% of the CHNSR-sized fish they analyzed were not genetic CHNSR (95% genetic CHNFR, 1% genetic CHNWR, and 2% genetic CHNFR). In its 2019 BiOp, NMFS corrected for the run-assignment error in the Salvage-Density Method analysis by multiplying the projected CHNSR loss by 0.02 and reported loss as “adjusted loss.” However, the FEIR does not indicate if it corrected for run-assignment error, so we assume it did not.

7.3.5.2.2. Winter-Run Chinook Salmon Normalization to Population Size

In the FEIR, DWR normalized the CHNWR loss data by the juvenile productive estimate (JPE) to account for the abundance of the population. This is due to the assumption that a relatively high number of fish are entrained at the export facilities in years of relatively high population abundance. Loss was normalized by multiplying the monthly loss by a factor to account for the relative size of the population in that year compared to the population size over the years from which loss data were available. The factor was the average JPE in the years from which loss data were available (1994-2018) divided by the JPE appropriate to the year of loss.

7.3.5.2.3. Estimated Entrainment Loss Calculation

For CHNWR and CHNSR, DWR calculated the monthly loss densities (fish per thousand acre-foot [TAF]) as the total monthly loss divided by the total volume of water exported in that month.

The estimated entrainment loss for each month under the two scenarios was calculated as the loss density for a given month and water year multiplied by the CalSim II modeled export volume for the same month for all the water years of that water year type. For example, there were eight wet water years in the data used to calculate loss densities (1994-2018) and there were 26 wet years in the CalSim II modeling (1922-2003). Using the month of January as an example, there were eight unique wet year January loss densities calculated. Each of these was then multiplied by each of the 26 wet year January

export volumes modeled by CalSim II. This results in a sample size of 130 to calculate the mean for January estimated entrainment in a wet water year.

CDFW calculated the percent change in the estimated entrainment loss for Existing Conditions and the Alternative 2b by taking the difference between the estimates and dividing it by the estimated loss for Existing Conditions.

7.3.5.3. Results

7.3.5.3.1. Winter-run Chinook Salmon

DWR’s results for the Salvage-Density Method showed, based on CalSim II modeled SWP exports, annual loss of CHNWR at the SWP export facility would be 1% (wet and critical water years) to 7% (dry water years) lower under the Alternative 2b than Existing Conditions (Table 5). Decreased loss in March occurs in all water year types, with decreases ranging from 4% (critical water years) to 25% (below normal water years; Tables 6-10). Increased loss in April occurs in wet, above normal, and below normal water year types. Decreased loss occurs in April of dry and critical water year types. Increased loss in May occurs in wet and below normal water year types, with no change in May loss for above normal, dry, and critical water year types.

Totals	Wet	Above Normal	Below Normal	Dry	Critical
Existing Conditions	5,381	8,184	4,031	3,958	1,809
Alternative 2b	5,301	7,815	3,814	3,667	1,790
Change	-1%	-5%	-5%	-7%	-1%

Table 5. Estimated entrainment loss of CHNWR at the SWP export facility averaged by water year type based on the Salvage-Density Method. Results were taken from Table 5.3-15f of the Alternative 2b analysis in the FEIR with percent change calculated by CDFW.

Totals	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept
Existing Conditions	0	0	377	2,397	624	1,846	126	11	0	0	0	0
Alternative 2b	0	0	376	2,452	633	1,589	235	16	0	0	0	0
Change	-	-	-0.3%	2%	1%	-14%	87%	45%	-	-	-	-

Table 6. Estimated entrainment loss of CHNWR at the SWP export facility averaged by month for wet water years based on the Salvage-Density Method. Results were taken from Table 5.3-15a of the Alternative 2b analysis in the FEIR with percent change calculated by CDFW.

Totals	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept
Existing Conditions	0	0	760	4,613	1,710	1,076	25	0	0	0	0	0

Alternative 2b	0	0	707	4,651	1,599	825	32	0	0	0	0	0
Change	-	-	-7%	1%	-6%	-23%	28%	-	-	-	-	-

Table 7. Estimated entrainment CHNWR at the SWP export facility averaged by month for above normal water years based on the Salvage-Density Method. Results were taken from Table 5.3-15b of Alternative 2b analysis in the FEIR with percent change calculated by CDFW.

Totals	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept
Existing Conditions	0	0	68	1,272	1,209	1,447	0	0	0	0	0	0
Alternative 2b	0	0	69	1,372	1,248	1,086	26	12	0	0	0	0
Change	-	-	1%	8%	3%	-25%	-	-	-	-	-	-

Table 8. Estimated entrainment loss of CHNWR at the SWP export facility averaged by month for below normal water years based on the Salvage-Density Method. Results were taken from Table 5.3-15c of the Alternative 2b analysis in the FEIR with percent change calculated by CDFW. Note the percent change for April and May is undefined ("-") due to error caused by dividing by a zero.

Totals	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept
Existing Conditions	0	0	354	531	990	2,039	44	0	0	0	0	0
Alternative 2b	0	0	381	576	1,017	1,652	41	0	0	0	0	0
Change	-	-	8%	8%	3%	-19%	-7%	-	-	-	-	-

Table 9. Estimated entrainment loss of CHNWR at the SWP export facility averaged by month for dry water years based on the Salvage-Density Method. Results were taken from Table 5.3-15d of the Alternative 2b analysis in the FEIR with percent change calculated by CDFW.

Totals	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept
Existing Conditions	0	0	243	386	697	436	39	7	0	0	0	0
Alternative 2b	0	0	235	417	683	418	31	7	0	0	0	0
Change	-	-	-3%	8%	-2%	-4%	-21%	0%	-	-	-	-

Table 10. Estimated entrainment loss of CHNWR at the SWP export facility averaged by month for critical water years based on the Salvage-Density Method. Results were taken from Table 5.3-15e of the Alternative 2b analysis in the FEIR with percent change calculated by CDFW.

7.3.5.3.2. Spring-run Chinook Salmon

DWR's results for the Salvage-Density Method showed, based on CalSim II modeled SWP exports, annual loss of CHNSR at SWP export facility would be 56% (wet water years) higher to 14% (critical water years)

lower under the Alternative 2b than Existing Conditions (Table 11). Decreased loss in March occurs in all water year types, with decreases ranging from 4% (critical water years) to 25% (below normal water years; Tables 12-16). Increased loss in April and May occurs in wet, above normal, and below normal water years types. Decreased loss occurs in April and May of dry and critical water year types.

Totals	Wet	Above Normal	Below Normal	Dry	Critical
Existing Conditions	26,798	19,221	3,679	6,449	2,521
Alternative 2b	41,747	22,865	3,730	5,909	2,174
Change	56%	19%	1%	-8%	-14%

Table 11. Estimated entrainment loss of CHNSR at the SWP export facility averaged by water year type based on the Salvage-Density Method. Results were taken from Table 5.3-16f of the Alternative 2b analysis in the FEIR with percent change calculated by CDFW.

Totals	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept
Existing Conditions	3	0	0	2	55	2,911	12,166	9,447	2,214	0	0	0
Alternative 2b	3	0	0	2	56	2,506	22,698	14,286	2,195	0	0	0
Change	0%	-	-	0%	2%	-14%	87%	51%	-1%	-	-	-

Table 12. Estimated entrainment loss of CHNSR at the SWP export facility averaged by month for wet water years based on the Salvage-Density Method. Results were taken from Table 5.3-16a of the Alternative 2b analysis in the FEIR with percent change calculated by CDFW.

Totals	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept
Existing Conditions	0	0	0	8	50	4,114	12,066	2,838	136	0	0	10
Alternative 2b	0	0	0	8	47	3,156	15,611	3,899	134	0	0	10
Change	-	-	-	0%	-6%	-23%	29%	37%	-1%	-	-	0%

Table 13. Estimated entrainment loss of CHNSR at the SWP export facility averaged by month for above normal water years based on the Salvage-Density Method. Results were taken from Table 5.3-16b of the Alternative 2b analysis in the FEIR with percent change calculated by CDFW.

Totals	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept
Existing Conditions	0	0	0	2	6	1,178	1,598	879	16	0	0	0
Alternative 2b	0	0	0	2	6	884	1,934	888	16	0	0	0
Change	-	-	-	0%	0%	-25%	21%	1%	0%	-	-	-

Table 14. Estimated entrainment loss of CHNSR at the SWP export facility averaged by month for below normal water years based on the Salvage-Density Method. Results were taken from Table 5.3-16c of the Alternative 2b analysis in the FEIR with percent change calculated by CDFW.

Totals	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept
Existing Conditions	0	0	0	0	0	789	4,007	1,654	0	0	0	0
Alternative 2b	0	0	0	0	0	639	3,697	1,573	0	0	0	0
Change	-	-	-	-	-	-19%	-8%	-5%	-	-	-	-

Table 15. Estimated entrainment loss of CHNSR at the SWP export facility averaged by month for dry water years based on the Salvage-Density Method. Results were taken from Table 5.3-16d of the Alternative 2b analysis in the FEIR with percent change calculated by CDFW.

Totals	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept
Existing Conditions	0	0	0	0	2	69	1,495	942	14	0	0	0
Alternative 2b	0	0	0	0	1	66	1,175	920	12	0	0	0
Change	-	-	-	-	-50%	-4%	-21%	-2%	-14%	-	-	-

Table 16. Estimated entrainment loss of CHNSR at the SWP export facility averaged by month for critical water years based on the Salvage-Density Method. Results were taken from Table 5.3-16e of the Alternative 2b analysis in the FEIR with percent change calculated by CDFW.

7.3.5.4. Discussion

7.3.5.4.1. Winter-run Chinook Salmon

The Salvage-Density Method provides an entrainment index that reflects export pumping weighted by the seasonal pattern of CHNWR abundance in the Delta, as reflected by historical loss data. The majority of historical loss for CHNWR occurs before April where there is little difference in the estimated entrainment loss, except in March, between Existing Conditions and the Alternative 2b. Modeling shows a decrease in entrainment loss in March of all water years under the Alternative 2b. Changes in estimated entrainment loss in March reflect CalSim II modeled OMR restrictions of -3,500 cfs during the month of March for all water years. As mentioned previously, OMR restrictions in March and April based on the single-year loss threshold are not reflective of actual historical loss, which would have only triggered OMR restrictions in 4 out of 9 years in March and 2 out of 9 years in April (between water

years 2010-2018). Therefore, it is likely that the estimated entrainment loss in March and April under the Alternative 2b underestimates future loss under this scenario.

In addition to the OMR restriction of -3,500 cfs, CalSim II modeling for April also includes spring export curtailments to achieve the SWP portion of historic Delta outflow under the 2008/2009 BiOps, consistent with Condition of Approval 8.17. Under the 2019 NMFS and USFWS BiOps, the CVP will not curtail exports during April and May to contribute to Delta outflow; therefore, OMR flows will become more negative than under Existing Conditions. More negative OMR flows increase the net flows towards the CVP and SWP export facilities. This is reflected in the estimated entrainment loss in April, which indicates an increase in loss for wet, above normal, and below normal water years under the Alternative 2b. Estimated entrainment loss in May shows an increase in loss in wet and below normal years. Increased loss in April and May impacts the tail end of the emigrating CHNWR population which can lead to a reduction in life history diversity, an impact that is unmeasurable in the short-term but likely significant over the long-term (Sturrock et al. 2019b).

Increases in the estimated entrainment loss and the potential for more negative OMR flows increases the probability of additional take of CHNWR under the Alternative 2b. Specifically, entrainment of salmon into the SWP export facilities and subsequent salvage, handling, transport, and release causes stress, dermal injury, and increased risk for disease contraction and exposure to predators, thereby decreasing survival and fitness, and ultimately reducing migratory success. More negative OMR flows near CCF and the CVP increases the probability of emigrating salmon being unable to maintain route and exit the Delta. Additionally, negative OMR flows affect the ebbing tide signal that would normally cue fish to move out of the Old and Middle River corridor and back into the main migratory corridor of the San Joaquin River. Fish moving through the Old and Middle River corridor will experience an increase in net flows toward the export facilities, which can lead to faster transit times for juvenile entering the facilities.

The estimated entrainment loss was lowest in critical years, which may reflect overall watershed survival differences between water year types. During wetter water years, more juveniles enter the Delta and are exposed to export operations (Newman and Brandes 2010; Brandes and McLain 2001). Lower salvage in drier years does not necessarily mean that OMR flow or export restrictions are providing better protections to the population. Often OMR flows are more negative in drier years even under export restrictions (to preserve water quality per D-1641) because of reduced Delta inflow. Instead, lower salvage in dry years is likely related to potentially lower population abundance due to poor conditions in the rivers (NMFS 2019).

7.3.5.4.2. Spring-run Chinook Salmon

The Salvage-Density Method provides an entrainment index that combines export pumping weighted by the seasonal pattern of CHNSR abundance in the Delta, as reflected by historical loss data. The majority of historical loss for CHNSR occurs between April and May. Modeling shows increases in the estimated entrainment loss in April and May of wet, above normal, and below normal water year types under the Alternative 2b. Modeling also shows decreases in estimated entrainment loss in April and May of dry and critical water year types.

CalSim II modeling for April includes both an OMR restriction of -3,500 cfs (in all water year types) as well as spring export curtailments to enhance Delta outflow from April 1- May 31 (in all water year types except critical), consistent with Condition of Approval 8.17. As mentioned previously, modeled OMR

restrictions in April based on the single-year loss threshold are not reflective of actual historical loss, which would have only triggered OMR restrictions in 2 out of 9 years in April (between water years 2010-2018). Therefore, it is likely that the estimated entrainment loss in April under the Alternative 2b underestimates future loss under this scenario. Condition of Approval 8.17 requires SWP exports to be curtailed in April and May. However, under the 2019 NMFS and USFWS BiOps, the CVP will not curtail spring exports to contribute to Delta outflow in the spring; therefore, OMR flows will become more negative than under Existing Conditions. More negative OMR flows increases the net flows towards the CVP and SWP export facilities. This is reflective in the estimated entrainment loss in April and May, which indicate an increase in loss for wet, above normal, and below normal water years under the Alternative 2b. Increased loss in April and May impacts the tail end of the emigrating CHNWR population which can lead to a reduction in life history diversity, an impact that is unmeasurable in the short-term, but likely significant over the long-term (Sturrock et al. 2019). Increases in the estimated entrainment loss and the potential for more negative OMR flows increases the probability of additional take of CHNSR under the Alternative 2b. Specifically, entrainment of salmon into the SWP export facilities and subsequent salvage, handling, transport, and release causes stress, dermal injury, and increased risk for disease contraction and exposure to predators, thereby decreasing survival and fitness, and ultimately reducing migratory success. More negative OMR flows near CCF and the CVP increases the probability of emigrating salmon being unable to maintain routes and exit the Delta. Additionally, negative OMR flows affect the ebbing tide signal that would normally cue fish to move out of the Old and Middle River corridor and back into the main migratory corridor of the San Joaquin River. Fish moving through the Old and Middle River corridor will experience an increase in net flows toward the export facilities, which can lead to faster transit times for juvenile entering the facilities. This would affect CHNSR migrating from both the Sacramento River basin and the San Joaquin River basin.

The estimated entrainment loss was lowest in critical years, which may reflect overall watershed survival differences between water year types. During wetter water years, more juveniles enter the Delta and are exposed to export operations (Newman and Brandes 2010; Brandes and McLain 2001). Lower salvage in drier years does not necessarily mean that OMR flow or export restrictions are providing better protections to the population. Often OMR flows are more negative in drier years even under export restrictions to preserve water quality per D-1641 because of reduced Delta inflow. Instead, lower salvage in dry years is related to potentially lower population abundance due to poor conditions in the rivers (NMFS 2019).

7.3.6. Entrainment of Juveniles Chinook Salmon at Barker Slough Pumping Plant

The presence of juvenile CHNWR and CHNSR near BSPP appears unlikely based on available monitoring data. Therefore, the likelihood of juvenile salmonid encounters with the screens due to the diversion of water is low and the overall effect of the intake on juvenile CHNWR and CHNSR from the Sacramento River basin is expected to be minimal. Furthermore, the fish screens are designed to avoid entrainment or impingement of juvenile salmonids. Thus, if juvenile salmonids did encounter the screens during water diversions, they would not likely be impacted. With respect to BSPP maintenance operations, including fish screen cleaning, sediment removal and aquatic weed removal, the likelihood of listed salmonids being present when these actions are being carried out is very low, particularly if these actions occur during the summer season when water temperatures are elevated.

8. Minimization of Take and Impacts of the Taking on Winter-run and Spring-run Chinook Salmon – Entrainment

This section describes how Conditions of Approval included in the ITP minimize take of CHNSR and CHNWR as a result of entrainment into the south Delta and CCF.

8.1. OMR Management as an Entrainment Minimization Measure

OMR Management in response to increases in loss of Covered Species at the south Delta salvage facilities minimizes take of juvenile Chinook salmon emigrating through the Delta. OMR Management was designed to reduce negative net OMR flows when it is triggered by loss of juvenile Chinook salmon at the export facilities. A less negative net OMR flow is accomplished by export reductions. OMR restrictions and export reductions provide protections by reducing the entrainment of additional Chinook salmon into the interior Delta, CCF, and the Tracy Fish Facility. As documented by the SST (2017), higher numbers of juvenile Chinook salmon are salvaged during times when OMR is more negative. Reductions in the average daily OMR will reduce entrainment of CHNWR and CHNSR into the interior Delta and increase their survival by reducing their emigration time through the Delta (Perry et al. 2016). Thus, it is important to have minimization measures that would regulate OMR to ultimately prevent or reduce the number of fish entrained into the interior Delta, CCF, or the Tracy Fish Facility, where they would experience high mortality rates. Minimization measures include daily loss thresholds that would be responsive to groups of fish beginning to show up at the pumping facilities and subsequently reduce OMR flows to avoid additional entrainment of fish. It is also important that minimization measures provide protection for the different life history strategies within each run, including the timing of emigration. Juvenile Chinook salmon are known to emigrate at different times; within a run of Chinook there can be early or late migrants, which helps to reduce the competition for critical habitat (Sturrock et al. 2015; Sturrock et al. 2019b).

8.2. Condition of Approval 8.17 - Export Curtailments for Spring Outflow

Under Condition of Approval 8.17, DWR will curtail exports from April 1 through May 31 each year to provide 50% of the current long-term average SWP contribution to incidental spring outflow under the 2008/2009 BiOps. These export curtailments will minimize take by increasing OMR flow during April and May; however, the magnitude of the benefits will not be equal to the benefits achieved during implementation of the 2008/2009 BiOps when both the SWP and CVP curtailed exports during this time period each year. However, Condition of Approval 8.17 will minimize take and related impacts of the taking to CHNWR and CHNSR as a result of SWP operations as authorized by the ITP, by increasing the likelihood of salmonids successfully exiting the Delta at Chipps Island and creating more suitable hydraulic conditions in the mainstem of the San Joaquin River with greater net downstream flows. Without Condition of Approval 8.17, loss of CHNWR and CHNSR is expected to be much greater in April and May, due to reduced downstream flows as confirmed by results of the Salvage-Density Method Analysis (see Section 7.3.5 – Salvage Density Method Analysis above).

8.3. Condition of Approval 8.1.2 – Salmon Monitoring Team and Condition of Approval 8.1.5.1 – Salmon Monitoring Team Real-time Risk Assessments

The Salmon Monitoring Team will provide expert advice on real-time management of operations that benefit emigrating CHNWR and CHNSR and conduct weekly risk assessments to assess the risk of CHNWR and CHNSR entrainment into the interior Delta and SWP/CVP facilities and the risk of exceeding 50%, 75% or 100% of the annual-loss threshold. The weekly risk assessments will evaluate a suite of monitoring data sources and hydrologic data sources characterizing salmonid presence and distribution within the Delta and hydrologic factors that influence entrainment risk. The expert advice and associated risk assessments, when elevated to the Water Operations Management Team (WOMT), can be used to determine when protective actions for CHNWR and CHNSR are needed to minimize take at the SWP. The Salmon Monitoring Team may recommend that OMR be managed at an average daily OMR index more positive than the current daily OMR index. Additionally, the Salmon Monitoring Team will determine when 5% of the CHNWR and CHNSR population is in the Delta each year, initiating the OMR management season (Condition of Approval 8.3.2). The reduction in the average daily OMR will reduce entrainment of CHNWR and CHNSR into the interior Delta and increase their survival by reducing their emigration time through the Delta (Perry et al. 2016).

8.4. Condition of Approval 8.1.3 - Water Operations Management Team and Condition of Approval 8.1.4 – Collaborative Approach to Real-time Risk Assessment

The WOMT is composed of manager-level representatives from Reclamation, DWR, CDFW, NMFS, USFWS and SWRCB. Each week WOMT considers expert advice provided to them by the Salmon Monitoring Team to make final determinations for CHNSR and CHNWR minimization needs and water operations. The WOMT has the authority request operational changes at the SWP to manage OMR to an average daily OMR index more positive than the current daily OMR index. Condition of Approval 8.1.4 (Collaborative Approach to Real-time Risk Assessment) described the process by which risk assessments and operational recommendations will be transmitted from the Salmon Monitoring Team to the WOMT, and to the Directors of CDFW and DWR if resolution is not achieved in WOMT. If the Directors of CDFW and DWR do not agree, the Director of CDFW may require DWR to implement an operational recommendation provided by CDFW. Reductions in the average daily OMR in response to risk assessments and operational advice will reduce entrainment of CHNWR and CHNSR into the interior Delta and increase their survival by reducing their emigration time through the Delta (Perry et al. 2016).

8.5. Condition of Approval 8.3 – Onset of OMR Management

Condition of Approval 8.3 describes the requirement to operate to a 14-day average OMR index of no more negative than -5,000 cfs from the onset of OMR to the End of OMR Management. It also describes the method DWR will use to calculate the OMR index and the timing with which operations will be changed in response to a threshold or requirement triggered by a Condition of Approval in the ITP.

The OMR Management period, December through June, overlaps with the emigration of juvenile CHNWR and CHNSR. Juvenile salmonids can spend up to three months rearing in the Delta before

making their entry into saltwater (del Rosario et al. 2013), which puts these fish at risk of being entrained into the interior Delta and salvage facilities. Conditions of Approval 8.3.1, 8.3.2, 8.3.3, 8.4.1, 8.4.2, 8.5.1, 8.5.2, 8.6.1, 8.6.2, 8.6.3, 8.6.4, 8.6.5, 8.7, and 8.8, as described below, require reductions in exports to achieve less negative OMR flows when specific conditions occur. Less negative OMR flows will reduce the potential for juvenile salmonids to be routed and entrained into the interior Delta and salvage facilities.

8.6. Condition of Approval 8.3.1 – Integrated Early Winter Pulse Protection

8.6.1. Introduction

Condition of Approval 8.3.1 describes the Integrated Early Winter Pulse Protection action to provide protections for adult DS, LFS, and CHNWR present in the Delta during the December-January timeframe each year. The action requires Permittee to reduce exports to achieve OMR flows no more negative than -2,000 cfs for 14 consecutive days if the following conditions occur between December 1 and January 31:

1. Running 3-day average of daily flows at Freeport $>$, and 25,000 cfs and
2. Running 3-day average of daily turbidity at Freeport \geq 50 NTU, or
3. Real-time monitoring indicates a high risk of entrainment.

This action may only occur once each water year and is immediately followed by an OMR limit of no more negative than -5,000 cfs and the ability to on-ramp the Turbidity Bridge Avoidance action (Condition of Approval 8.5.1). Combined, Conditions of Approval 8.3 and 8.3.1 allow for 14 days of OMR Management at -2,000 cfs, followed by an OMR limit of no more negative than 5,000 cfs until the End of OMR Management.

In water years that the Integrated Early Winter Pulse Protection and Adult LFS Protection do not trigger, the onset of OMR flow management begins when the Salmon Monitoring Team first determines that 5% of the CHNWR or CHNSR population has entered the Delta after January 1 with OMR managed at no more negative than a 14-day moving average of -5,000 cfs (unless Delta excess conditions occur). By January 1, on average 11.7% of the annual combined loss of natural YOY CHNWR has occurred based on historical SWP and CVP salvage for water years 2009 through 2019 (see discussion of Condition of Approval 8.3.2 – Salmonids Presence below). For the same timeframe, loss of CNHWR occurred in 7 of the 10 water years from 2009-2019 before the January 1 onset for OMR Management.

An OMR Management onset date of January 1 or later is after the beginning of the period in which early migrant CHNWR are present in the Delta in most years. As a result, an Integrated Early Winter Pulse Protection in December is likely to provide additional protections to early migrant CHNWR (see discussion of Condition of Approval 8.3.2 – Salmonids Presence below). Initiating this action in January would provide further protections to CHNWR by requiring more positive OMR flow management at -2,000 cfs instead of -5,000 cfs. This analysis was conducted to compare the timing of a December Integrated Early Winter Pulse Protection with CHNWR entry into the Delta and entrainment at the SWP and CVP export facilities.

8.6.2. Methods – Analyses of Recent Historical Data

8.6.2.1. Freeport Flow and Turbidity Data

As described in the DS analysis of Condition of Approval 8.3.1-Integrated Early Winter Pulse Protection, Freeport flow and turbidity data were obtained from the California Data Exchange Center (CDEC) for water years 2010 through 2019 (DWR 2019b). The 3-day rolling average of Freeport flow and turbidity were calculated in December and January. Integrated Early Winter Pulse Protection was assumed to have been triggered when flows were greater than 25,000 cfs and turbidity was greater than or equal to 50 NTU.

Based on historical flows and turbidity at Freeport, Integrated Early Winter Pulse Protection conditions occurred in seven water years in December and January from 2010 through 2019 (Table 17). Of those seven water years the Integrated Early Winter Pulse Protection would have triggered in 2011, 2013, and 2015 in December, accounting for 33% of the analyzed water years.

Water Year	Date
2010	January 21
2011	December 17
2012	January 25
2013	December 3
	December 24
2015	December 7
2017	January 10
2019	January 11

Table 17. Date that Integrated Early Winter Pulse Protection conditions occurred historically for water years 2010 through 2019.

8.6.2.2. Winter-Run Chinook Salmon Loss

As described in the analysis of Condition of Approval 8.3.2 – Salmonids below, for the purposes of this Effects Analysis, CDFW collected salvage data for the SWP and CVP export facilities from the CDFW Bay-Delta Region salvage database (CDFW 2019c) and calculated loss using the loss equation (CDFW 2018 and Attachment 6 to the ITP).

Loss data were evaluated for water years 2011, 2013, and 2015, consistent with the three years that First Flush conditions occurred in December. For each water year, natural YOY CHNWR loss data were analyzed to determine the first date of loss and the percent of annual loss that occurred prior to the start of First Flush conditions as noted in Table 17.

8.6.2.3. Winter-run Chinook Salmon Presence in the Delta

8.6.2.3.1. Sherwood Harbor Trawl

SacPAS reports juvenile salmonid presence in the Delta by using Sacramento River trawl catch data at Sherwood Harbor (RM 55) as an indicator of salmonid entry into the Delta. For CHNWR, daily cumulative catch at Sherwood Harbor was calculated for water years 2011, 2013, and 2015.

8.6.2.3.2. Knights Landing RST

CDFW operates a RST program at Knights Landing (RM 88) to document juvenile salmonid emigration through the Sacramento River. For CHNWR, the daily cumulative catch at Knights Landing was calculated for water years 2011, 2013, and 2015.

8.6.2.4. Delta Outflow Analysis

Net daily Delta outflow (cfs) data were obtained from DWR’s Dayflow database for water years 2011, 2013, and 2015. December Integrated Early Winter Pulse Protection conditions were overlaid with Delta outflow.

8.6.3. Results and Discussion

Historically, the CHNWR entrainment season began in December for seven out of ten water years between 2010 and 2019. During the same time period, Integrated Early Winter Pulse Protection conditions occurred in December of water years 2011, 2013, and 2015, with conditions occurring twice in December of water year 2013. For water years 2013 and 2015, Early Winter Pulse Protection conditions occurred prior to the CHNWR entrainment season (Table 18). For water year 2011, less than 2% of the annual cumulative loss of CHNWR occurred prior to initiation of Condition of Approval 8.3.1. By the start of the Integrated Early Winter Pulse Protection, average CHNWR passage at Knights Landing and Sherwood Harbor across the three water years was 58% and 50.3% (not including the “second” First Flush in 2013⁵), respectively (Figure 22).

Water Year	Date of Integrated Early Winter Pulse Protection	CHNWR	
		Date of First Loss	% Loss by First Flush
2011	December 17	December 3	1.6%
2013	December 3	December 4	0%
	December 24		32.6%
2015	December 7	December 24	0%

Table 18. CHNWR first date of loss and percent of loss by the start of Integrated Early Winter Pulse Protection conditions in December.

Based on this analysis, December Integrated Early Winter Pulse Protection conditions typically trigger before the CHNWR entrainment season begins but are not timed to provide protections for the initial 5% peak in CHNWR entry into the Delta. CHNWR that are in the Delta prior to the Integrated Early Winter Pulse Protection will not be afforded protections from OMR Management. Rather, Early Winter Pulse Protection conditions seem to coincide with large increases in CHNWR Delta entry, which may make Integrated Early Winter Pulse Protection appropriately timed to provide CHNWR entrainment protections when numbers of CNHWR in the Delta begin to increase. December initiation actions will provide minimization for CHNWR by potentially starting OMR restrictions prior to January 1 in 33% of water years. Further, managing OMR flow at -2,000 cfs during an Integrated Early Winter Pulse Protection event confines the zone of entrainment for DS as well as CHNWR, providing protections from entrainment into the SWP and CVP export facilities.

⁵ The second First Flush condition in 2013 coincides with 100% CHNWR passage at Knights Landing and Sherwood Harbor. Including these data, average passage at Knights Landing and Sherwood Harbor across the three water years was 68.5% and 62.7%, respectively.

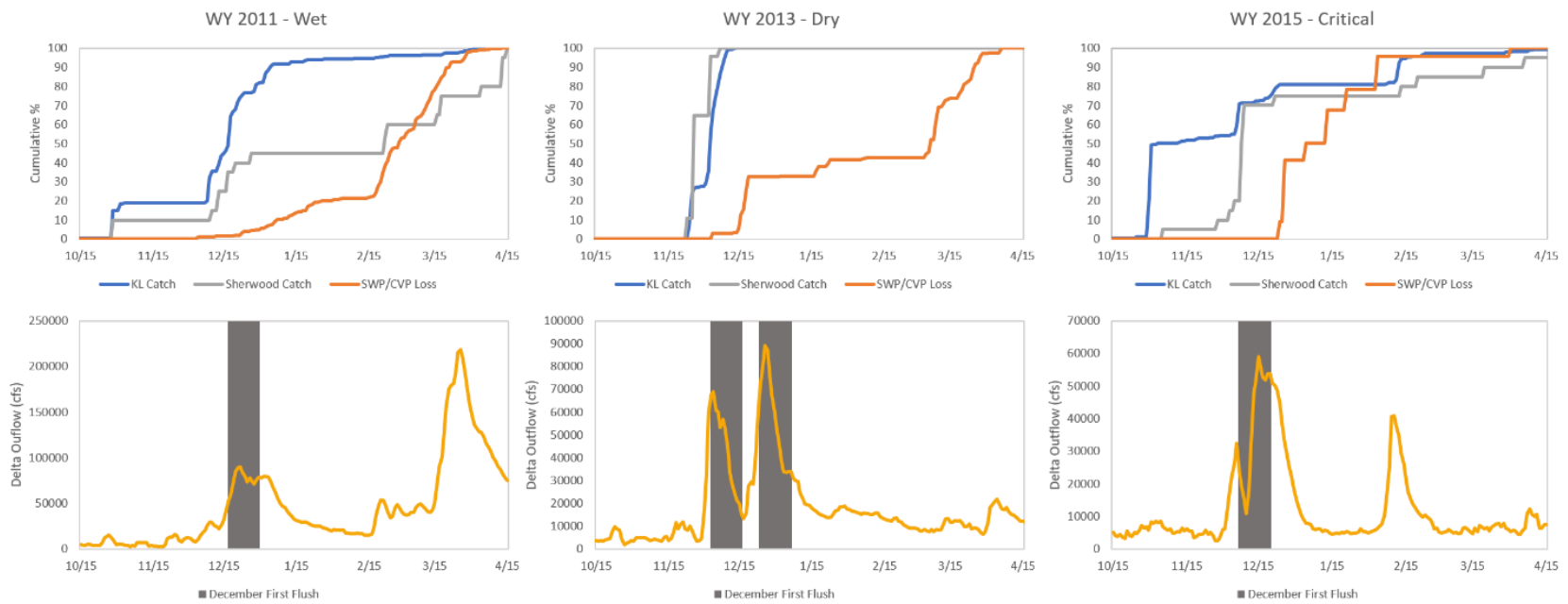


Figure 22. (Top row) Cumulative daily catch of YOY CHNWR at Knights Landing RST and Sherwood Harbor trawl overlaid with cumulative loss of natural YOY CHNWR at the SWP and CVP export facilities for water years 2011, 2013, and 2015. (Bottom row) Delta outflow (cfs) overlaid with the timing of December Integrated Early Winter Pulse Protection conditions.

8.7. Condition of Approval 8.3.2 - Onset of OMR Management – Salmonids Presence

8.7.1. Introduction

Condition of Approval 8.3.2 requires the OMR Management season to begin when the Salmon Monitoring Team determines that 5% of the CHNWR or CHNSR population is in the Delta beginning on January 1 each year, if an Integrated Early Pulse Protection (Condition of Approval 8.3.1) or restriction for Adult Longfin Smelt Entrainment Protection (Condition of Approval 8.3.3) has not occurred prior to January 1, to minimize entrainment of juvenile CHNWR and CHNSR. Specifically, after the Onset of OMR Management, exports shall be reduced to maintain a 14-day average OMR index no more negative than -5,000 cfs until the OMR Management season ends (Condition of Approval 8.8).

CHNWR juveniles have been recorded at Knights Landing as early as August (suggesting Delta entry as early as September) and as late as April, with most catches recorded between October and April (Jason Julienne personal communication 1/2020; CalFish 2019). Data from CDFW's Knights Landing RST Program and trawl and beach seine monitoring show timing of Delta entry for juvenile CHNSR ranges from November to May (Julienne 2016; Williams 2006).

For the purposes of this Effects Analysis, to analyze the timing of juvenile CHNSR and CHNWR entry and presence in the Delta on January 1, CDFW compared loss data to data from DOSS, SacPAS web-based service data (SacPAS 2019), and the Knights Landing RST data (CalFish 2019).

8.7.2. Methods

8.7.2.1. Loss Analysis

Salvage data for the SWP and CVP export facilities were collected from the CDFW Bay-Delta Region salvage database (CDFW 2019c). Loss was calculated from salvage data using the loss equation (CDFW 2018 and Attachment 6 to the ITP). The database identified salmon runs based on the Delta Model LAD criteria (USFWS 1997) and included specimen information pertaining to fork length and presence of an adipose fin (as an indication of natural versus hatchery fish).

Salvage and loss data available included water years 1993 until 2019; however, analyses were limited to water years 1995 through 2019 for consistency with available monitoring data reported in SacPAS. For natural YOY CHNWR and CHNSR, loss data were analyzed to determine the date that first loss occurred at each facility and the percent of total annual loss that occurred at each facility by January 1. This analysis focuses on natural YOY CHNWR and CHNSR as the OMR Management period principally provides protection to this specific origin and lifestage of CHNWR and CHNSR.

8.7.2.2. DOSS Analysis

DOSS develops weekly and annual reports during each water year starting in October and ending the second week in June. Beginning late in water year 2014, DOSS began estimating the percent of natural YOY CHNWR and CHNSR present in the Delta. DOSS estimates salmonid presence in the Delta by combining cumulative Knights Landing RST, Sacramento River trawl, and Sacramento River beach seine data and subtracting the cumulative percent of Chipps Island trawl catch data. DOSS also looks at Glenn-Colusa Irrigation District and Tisdale Weir data as tracking locations for salmonid entry into the Delta.

For CHNWR presence analyses, DOSS estimated dates for 5% entry into the Delta were evaluated for water years 2016 to 2019. Water year 2015 was omitted because there was no 5% presence of CHNWR

noted in 2015. Instead, 25% presence was noted on November 12, 2014. For CHNSR presence analyses, DOSS estimated dates for 5% entry into the Delta were evaluated for water years 2015 to 2019. Data were also summarized for DOSS's estimate of the percent of natural YOY CHNWR and CHNSR populations present in the Delta on January 1 for each water year.

8.7.2.3. SacPAS Analysis

SacPAS reports juvenile salmonid presence in the Delta by using Sacramento River trawl catch data at Sherwood Harbor (RM 55) as an indicator of salmonid entry into the Delta. The USFWS conducts monitoring at Sherwood Harbor three days a week between October and May using a Kodiak trawl and three days a week in April, July, August, and September using a midwater trawl. During May and June, USFWS samples twice a week using a midwater trawl.

SacPAS reports the percent cumulative catch in increments at Sherwood Harbor at the end of the monitoring season. This cumulative catch does not represent the percentage of fish passing through the river, nor does it include sampling efficiency like the RBDD RST used to develop the CHNWR juvenile production index (JPI). Instead, the cumulative catch provides an estimate of salmonid entry into the Delta and is used as an action trigger for operating the DCC gates. Data collected at Sherwood Harbor is used to calculate the Sacramento Trawl Catch Index for implementing RPA Action IV.1.2 for closure of the DCC when juvenile salmonids are at risk of entrainment into the interior Delta.

For CHNWR and CHNSR presence analyses, the 5% annual cumulative catch for each run was calculated for water years 1995 through 2019. Data were also analyzed to determine the percent of the annual cumulative catch on January 1 for each water year.

8.7.2.4. Knights Landing RST Analysis (Winter-run Chinook Salmon)

Historically, monitoring at Knights Landings occurred between October and June with daily sampling (weather and river conditions permitting). Beginning in the fall of 2015, CDFW began sampling the RST in earlier in the fall to better track early CHNWR migrants. Specifically, the sampling season began in early September in 2015 and 2019 and late August in 2016, 2017, and 2018.

In addition to the Sacramento River Trawl and the Sacramento Beach Seine Catch Indices, the Knights Landing Catch Index is also used as an action trigger for closing the DCC. Each Catch Index can independently trigger a change to DCC gate operations based on increased concern for juvenile routing into the Interior Delta.

YOY CHNWR presence at Knights Landing RST was compared to presence at Sherwood Harbor and at the SWP/CVP export facilities to characterize CHNWR emigration timing through the Delta. Knights Landing RST data includes water years 2001 through 2019.

8.7.3. Results

8.7.3.1. Winter-run Chinook Salmon Delta Entry

8.7.3.1.1. Loss Analysis

For water years 1995 through 2019, the average first date of loss for natural YOY CHNWR at the SWP and CVP export facilities was December 26 (Table 19). For the same timeframe, loss of CHNWR occurred in 18 out of 25 years before January 1. Additionally, across the 25 years of analysis, 11.7% of the annual combined loss occurred before January 1.

		SWP Natural CHNWR	CVP Natural CHNWR	SWP/CVP Natural CHNWR	SWP Natural CHNWR	CVP Natural CHNWR	SWP/CVP Natural CHNWR
Brood Year	Water Year	Date of First Loss			% Loss by January 1		
Average		3-Jan	28-Dec	26-Dec	13.03	8.06	11.70
Median		26-Dec	20-Dec	18-Dec	0.75	4.00	1.07
1994	1995	12/16/1994	12/16/1994	12/16/1994	15.14	7.47	14.62
1995	1996	1/3/1996	12/18/1995	12/18/1995	0.00	12.01	0.99
1996	1997	12/10/1996	12/12/1996	12/10/1996	24.87	4.00	18.40
1997	1998	12/6/1997	12/4/1997	12/4/1997	79.46	27.76	68.02
1998	1999	1/24/1999	1/27/1999	1/24/1999	0.00	0.00	0.00
1999	2000	1/2/2000	1/27/2000	1/2/2000	0.00	0.00	0.00
2000	2001	12/12/2000	12/18/2000	12/12/2000	0.83	1.29	0.86
2001	2002	12/6/2001	12/5/2001	12/5/2001	45.58	14.54	40.58
2002	2003	12/23/2002	12/18/2002	12/18/2002	19.26	13.77	18.81
2003	2004	12/25/2003	12/15/2003	12/15/2003	0.74	4.20	1.07
2004	2005	1/2/2005	1/6/2005	1/2/2005	0.00	0.00	0.00
2005	2006	12/20/2005	12/12/2005	12/12/2005	10.55	7.28	10.14
2006	2007	12/18/2006	12/27/2006	12/18/2006	0.75	2.51	1.58
2007	2008	1/13/2008	1/11/2008	1/11/2008	0.00	0.00	0.00
2008	2009	2/24/2009	12/30/2008	12/30/2008	0.00	3.53	0.52
2009	2010	1/26/2010	12/8/2009	12/8/2009	0.00	0.52	0.18
2010	2011	12/23/2010	12/3/2010	12/3/2010	3.87	16.92	5.60
2011	2012	2/6/2012	1/25/2012	1/25/2012	0.00	0.00	0.00
2012	2013	12/4/2012	12/4/2012	12/4/2012	35.49	14.09	32.61
2013	2014	3/6/2014	3/3/2014	3/3/2014	0.00	0.00	0.00
2014	2015	12/26/2014	12/24/2014	12/24/2014	45.43	31.07	41.26
2015	2016	12/28/2015	1/12/2016	12/28/2015	24.77	0.00	15.35
2016	2017	12/20/2016	12/20/2016	12/20/2016	18.89	32.00	20.90
2017	2018	3/1/2018	2/5/2018	2/5/2018	0.00	0.00	0.00
2018	2019	1/2/2019	12/29/2018	12/29/2018	0.00	8.57	0.92

Table 19. Date of first loss and percent of annual loss by January 1 for natural YOY CHNWR at the SWP and CVP export facilities for water years 1995 through 2019.

8.7.3.1.2. DOSS & SacPAS Analyses

Based on water years 2016 to 2019, DOSS estimated on average that 5% of the natural YOY CHNWR population entered the Delta by November 16 (Figure 23). By January 1, DOSS estimated on average that 55.2% of natural YOY CHNWR entered the Delta.

Using empirical data from SacPAS for water years 1995 through 2019, on average 5% of the natural YOY CHNWR catch at the entrance of the Delta occurred by December 16, one month later than estimated by DOSS (Figure 23). By January 1, on average 31.9% of the natural YOY CHNWR catch was observed.



Figure 23. Natural YOY CNHWR entrainment periods at the SWP and CVP export facilities for water years 1995 to 2019. The green box and gold diamond indicate the date that 5% of the CHNWR population (catch) was present in the Delta for each water year as indicated by DOSS and SacPAS, respectively. The shaded blue box indicates the January 1 through June 30 time period each year.

8.7.3.1.3. Knights Landing RST Analysis

Using empirical data from Knights Landing for water years 2001 through 2019, on average 5% of the YOY CHNWR catch occurred by November 28, one month earlier than 5% presence at Sherwood Harbor (Figures 24 and 25). By January 1, on average 57.8% of the natural YOY CHNWR catch was observed. These data are more aligned with the DOSS estimates for 5% salmonid passage into the Delta than observed catch at Sherwood Harbor, indicating that DOSS is effectively using Knights Landing RST to predict salmonid entry into the Delta.

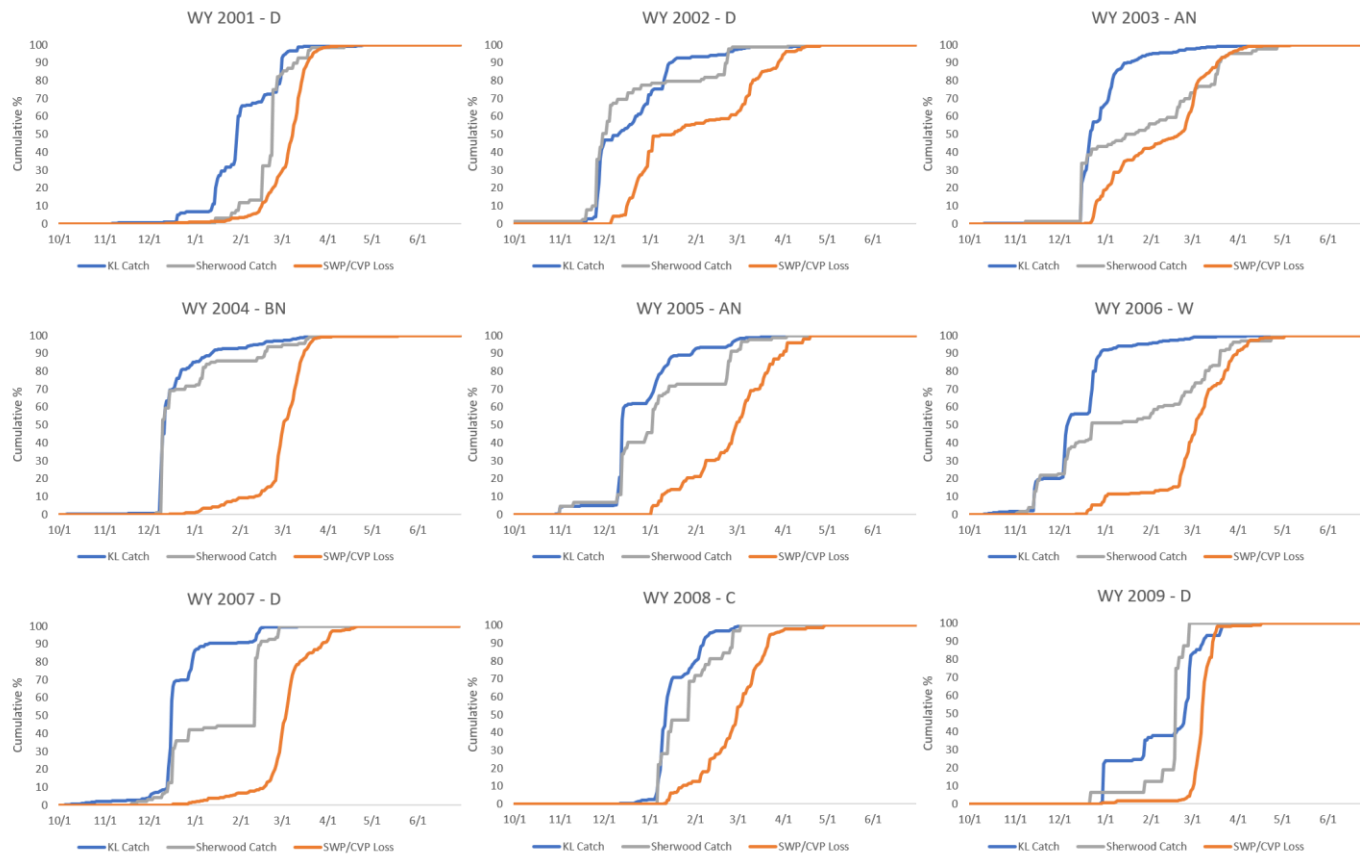


Figure 24. Cumulative daily catch of YOY CHNWR at Knights Landing RST and Sherwood Harbor trawl overlaid with cumulative loss of natural YOY CHNWR at the SWP and CVP export facilities for water years 2001 to 2009. Each figure title includes the abbreviation for water years type: C= Critical; D=Dry; BN=Below Normal; AN=Above Normal; W=Wet.

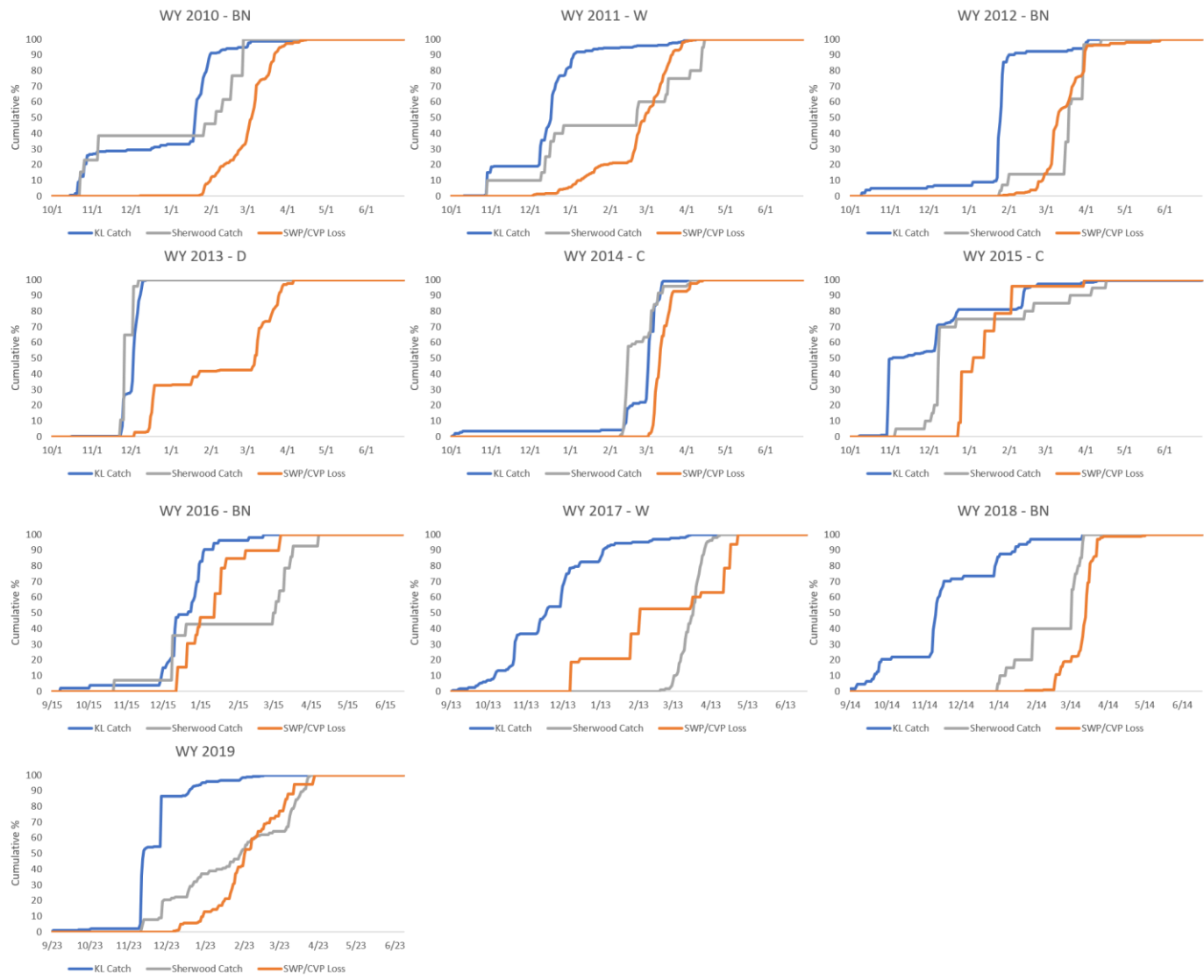


Figure 25. Cumulative daily catch of YOY CHNWR at Knights Landing RST and Sherwood Harbor trawl overlaid with cumulative loss of natural YOY CHNWR at the SWP and CVP export facilities for water years 2010 to 2019. Each figure title includes the abbreviation for water years type: C= Critical; D=Dry; BN=Below Normal; AN=Above Normal; W=Wet.

8.7.3.2. Spring-run Chinook Salmon

8.7.3.2.1. Loss Analysis

For water years 1995 through 2019, the average first date of loss for natural YOY CHNWR combined at the SWP and CVP export facilities was February 18 (Table 20). For the same timeframe, loss of CHNSR occurred on or before January 1 only in water year 2002.

		SWP Natural CHNSR	CVP Natural CHNSR	SWP/CVP Natural CHNSR	SWP Natural CHNSR	CVP Natural CHNSR	SWP/CVP Natural CHNSR
Brood Year	Water Year	Date of First Loss			% Loss by January 1		
Average		4-Mar	23-Feb	18-Feb	0.00	0.01	0.00
Median		6-Mar	2-Mar	22-Feb	0.00	0.00	0.00
1994	1995	2/22/1995	2/27/1995	2/22/1995	0.00	0.00	0.00
1995	1996	2/25/1996	2/7/1996	2/7/1996	0.00	0.00	0.00
1996	1997	2/18/1997	2/8/1997	2/8/1997	0.00	0.00	0.00
1997	1998	5/11/1998	2/22/1998	2/22/1998	0.00	0.00	0.00
1998	1999	2/23/1999	2/2/1999	2/2/1999	0.00	0.00	0.00
1999	2000	2/15/2000	2/13/2000	2/13/2000	0.00	0.00	0.00
2000	2001	3/13/2001	3/16/2001	3/13/2001	0.00	0.00	0.00
2001	2002	3/6/2002	1/1/2002	1/1/2002	0.00	0.15	0.07
2002	2003	1/18/2003	1/7/2003	1/7/2003	0.00	0.00	0.00
2003	2004	1/18/2004	3/2/2004	1/18/2004	0.00	0.00	0.00
2004	2005	2/25/2005	3/2/2005	2/25/2005	0.00	0.00	0.00
2005	2006	2/25/2006	2/9/2006	2/9/2006	0.00	0.00	0.00
2006	2007	3/08/2007	3/2/2007	3/2/2007	0.00	0.00	0.00
2007	2008	3/18/2008	3/11/2008	3/11/2008	0.00	0.00	0.00
2008	2009	3/15/2009	3/15/2009	3/15/2009	0.00	0.00	0.00
2009	2010	3/9/2010	3/20/2010	3/9/2010	0.00	0.00	0.00
2010	2011	1/31/2011	1/3/2011	1/3/2011	0.00	0.00	0.00
2011	2012	3/13/2012	3/10/2012	3/10/2012	0.00	0.00	0.00
2012	2013	3/23/2013	3/17/2013	3/17/2013	0.00	0.00	0.00
2013	2014	3/13/2014	3/13/2014	3/13/2014	0.00	0.00	0.00
2014	2015	4/19/2015	3/30/2015	3/30/2015	0.00	0.00	0.00
2015	2016	3/22/2016	2/11/2016	2/11/2016	0.00	0.00	0.00
2016	2017	2/16/2017	3/14/2017	2/16/2017	0.00	0.00	0.00
2017	2018	3/19/2018	3/14/2018	3/14/2018	0.00	0.00	0.00
2018	2019	2/19/2019	3/16/2019	2/19/2019	0.00	0.00	0.00

Table 20. Date of first loss and percent of annual loss by January 1 for natural YOY CHNSR at the SWP and CVP export facilities for water years 1995 through 2019.

8.7.3.2.2. DOSS & SacPAS Analyses

Based on water years 2015 to 2019, DOSS estimated on average that 5% of the natural YOY CHNSR population entered the Delta by December 27 (Figure 26). By January 1, DOSS estimated on average that 7.2% of natural YOY CHNSR entered the Delta.

Using empirical data from SacPAS for water years 1995 through 2019, on average 5% of the natural YOY CHNSR catch at the entrance of the Delta occurred by February 10, over one month later than estimated by DOSS (Figure 26). By January 1, on average 3.97% of the natural YOY CHNSR catch was observed.

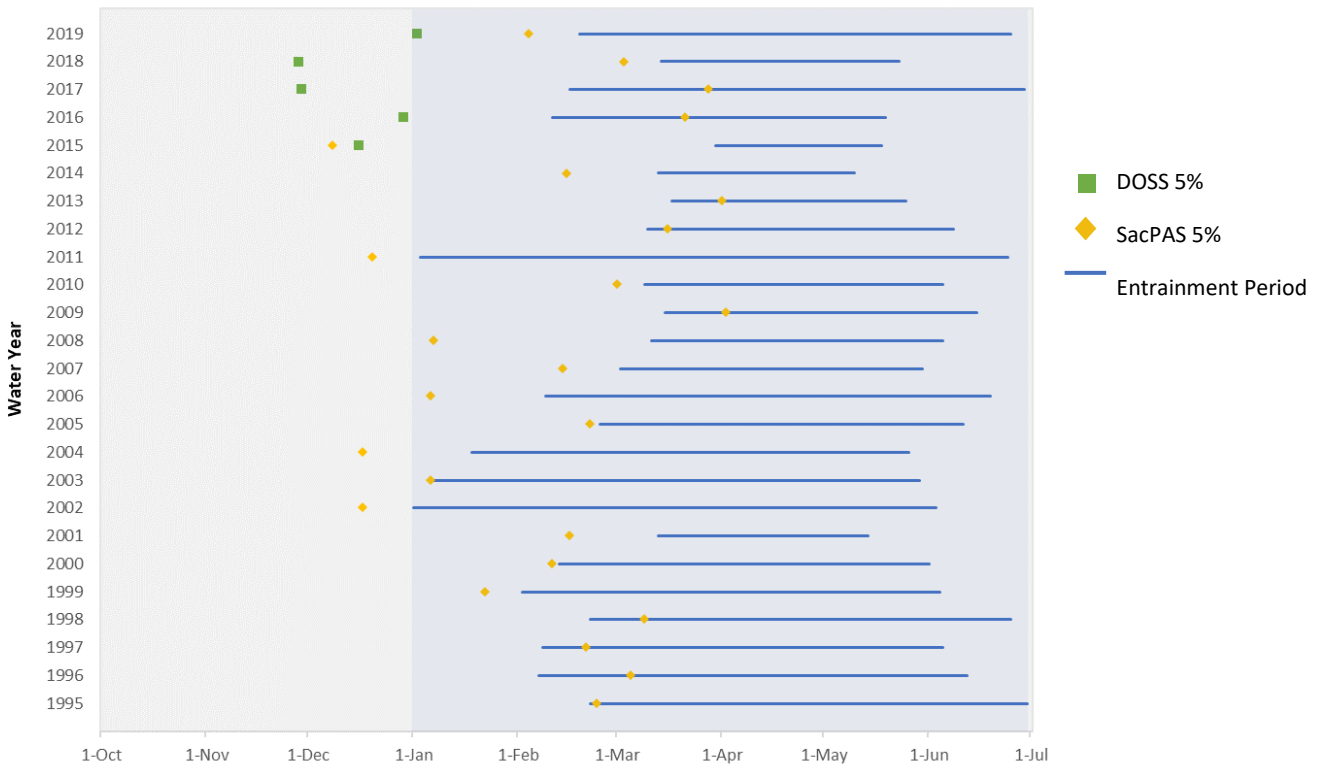


Figure 26. Natural YOY CHNSR salvage periods at the SWP and CVP export facilities for water years 1995 to 2019. The green box and gold diamond indicate the date that 5% of the CHNSR population (catch) was present in the Delta for each water year as indicated by DOSS and SacPAS, respectively. The shaded blue box indicates the January 1 through June 30 time period each year.

8.7.4. Discussion

DOSS predictions for salmonid entry into the Delta are generally earlier than predicted by empirical data at Sherwood Harbor but are consistent with monitoring presence at Knights Landing. As a result, it is possible that DOSS provides a conservative estimate for presence in the Delta. Figures 24 and 25 show that Knights Landing RST cumulative catch data provides for better early detection of CHNWR than Sherwood Harbor catch data at the entry of the Delta. For instance, in water year 2017 Sherwood Harbor detected presence at the entry of the Delta after CHNWR were detected at the export facilities. Using travel speeds identified in Hendrix et al. (2017), salmonids can enter the Delta within 2.5 days after detection at Knights Landing. As indicated in the Methods section, Knights Landing RST does not provide a passage estimate for salmonids nor is it 100% effective at catching all salmonids in the Sacramento River and it is therefore reasonable to assume that salmonids may pass Knights Landing

even earlier than documented by sampling. However, Knights Landing RST can provide an early warning for salmonid entry into the Delta.

Based on historical data, more than 5% of the YOY CHNWR are present in the Delta before 5% of YOY CHNSR enter the Delta, and before CHNSR are salvaged at the export facilities. Natural YOY CHNWR were detected in the Delta (Sherwood Harbor or SWP/CVP export facilities) prior to January 1 in 20 out of 25 water years from 1995 to 2019 and are present in the Delta as early as September. Approximately 31.9% of the CHNWR population is present in the Delta by January 1 (as indicated by Sherwood Harbor Trawl data). By January 1, on average, 11.7% of the total annual loss of natural CHNWR has occurred at the SWP and CVP combined, which at that time are all early migrants. Disproportionate take of CHNWR migration strategies (early, peak, and late) can lead to a decrease in life history diversity (Sturrock et al. 2019). Life history diversity is the foundation for the portfolio effect for each salmonid species. This portfolio effect contributes to population sustainability and abundance by distributing risk throughout the run and reducing intraspecific competition (Sturrock et al. 2015; Carlson and Satterthwaite 2011; Greene et al. 2010; Healey 1991).

Beginning OMR Management after January 1 but when 5% of CHNWR or CHNSR are estimated to be present in the Delta, as described in Condition of Approval 8.3.2 (Salmonids Presence), if an Integrated Early Winter Pulse Protection (Condition of Approval 8.3.1) or Adult Longfin Smelt Entrainment Protection (Condition of Approval 8.3.3) does not occur prior to January 1, is inconsistent with the 2009 NMFS BiOp RPA Action IV.2.3 that required OMR Management of -5,000 cfs beginning January 1. Beginning OMR Management on or after January 1 will provide some minimization of take of older juvenile Chinook salmon by limiting OMR flow to no more negative than a 14-day moving average of -5,000 cfs (or less if an Integrated Early Winter Pulse Protection occurs). Limiting OMR flow will confine the zone of entrainment during juvenile CHNWR and CHNSR migration through the Delta and reduce take of both species at the salvage facilities.

Implementing the November and December daily loss thresholds (Conditions of Approval 8.6.2) for older juvenile Chinook salmon will further minimize take by limiting OMR flow to no more negative than -5,000 cfs for five days when daily loss thresholds are exceeded prior to January 1.

8.8. Condition of Approval 8.3.3 – Adult Longfin Smelt Entrainment Protection

Maintaining a 14-day average OMR index no more negative than -5,000 cfs after December 1 in response to salvage of adult LFS or advice from the Smelt Monitoring Team to minimize take of adult LFS will benefit CHNWR as they are migrating through the Delta during this period. Knight's Landing RST and Sacramento Trawl data show that the majority of emigrating CHNWR will enter the Delta in December. Reducing the magnitude of reverse flows at Old and Middle Rivers will reduce entrainment of CHNWR into the interior Delta and increase their survival by reducing their emigration time through the Delta (Perry et al. 2016).

8.9. Condition of Approval 8.4.1 – OMR Management for Adult Longfin Smelt

Condition of Approval 8.4.1 may result in OMR requirements less negative than -5,000cfs, to minimize entrainment of adult LFS, from the Onset of OMR Management and through February 28. Approximately 55.2% of juvenile natural CHNWR and 7.2% of juvenile natural CHNSR have entered the Delta by January 1. Reducing the magnitude of reverse flows, from the Onset of OMR Management until February 28, in response to Smelt Monitoring Team risk assessments and operational advice, will reduce entrainment of CHNWR and CHNSR into the interior Delta and increase their survival by reducing their emigration time through the Delta (Perry et al. 2016).

8.10. Condition of Approval 8.4.2 – Larval and Juvenile Longfin Smelt Entrainment Protection

Reducing the magnitude of reverse flows, between January 1 and June 30, to a 14-day average OMR index no more negative than -5,000 cfs in response to LFS larvae and juvenile presence in the south Delta, salvage, or Smelt Monitoring Team advice, will reduce entrainment of CHNWR and CHNSR into the interior Delta and increase their survival by reducing their emigration time through the Delta (Perry et al. 2016). Further OMR restrictions (more positive than -5,000 cfs) required as a part of this Condition of Approval may result in additional protections from entrainment for CHNSR and CHNWR.

8.11. Condition of Approval 8.5.1 – Turbidity Bridge Avoidance

Condition of Approval 8.5.1 requires management of exports in order to maintain daily average turbidity at Bacon Island (OBI) less than 12 NTU. If turbidity cannot be maintained at less than 12 NTU after 5 days Permittee shall manage exports to achieve an OMR no more negative than -2,000 cfs until the daily average turbidity at Bacon Island drops below 12 NTU. However, if 5 consecutive days of -2,000 cfs OMR flows do not reduce daily average turbidity at Bacon Island below 12 NTU, the Smelt Monitoring Team may convene to assess the risk of entrainment of DS and provide a recommendation to WOMT regarding changes in operations that could be conducted to minimize the risk of entrainment of DS.

OMR flow is a surrogate indicator of the influence of export pumping at the export facilities on hydrodynamics in the south Delta. The management of OMR flow, in combination with other environmental variables, can minimize or avoid entrainment of fish in the south Delta and salvage facilities. Condition of Approval 8.5.1 has the potential to benefit juvenile CHNWR and CHNSR from February (potentially January) until April 1 if the turbidity criteria cannot be maintained and OMR flows are temporarily (until turbidity criteria are met) restricted to no more negative than -2,000 cfs. Approximately 55.2% of juvenile natural CHNWR and 7.2% of juvenile natural CHNSR have entered the Delta by January 1. The turbidity bridge avoidance action would provide another potential OMR reduction during the OMR Management period which could help to reduce entrainment of migrating juvenile salmonids into the south Delta and salvage facilities.

8.12. Condition of Approval 8.5.2 – Larval and Juvenile Delta Smelt Protection

The management of OMR flow, in combination with other environmental variables, can minimize or avoid entrainment of fish in the south Delta and salvage facilities. Condition of Approval 8.5.2 restricts south Delta exports from March 15 to June 30, to maintain a 14-day average of OMR index no more negative than -5,000 cfs if the five-day cumulative salvage of juvenile DS is greater than, or equal to, one plus the average prior three years FMWT index. Risk assessments will also be conducted by the Smelt Monitoring Team to determine the future risk of entrainment and take of larval and juvenile DS. The Smelt Monitoring Team may recommend further restrictions on exports to maintain a more positive OMR than -5,000 cfs as warranted by risk assessment of continued DS salvage. Low risk requires an OMR limit between -4,000 cfs to -5,000 cfs, medium risk requires an OMR limit between -2,500 cfs to -4,000 cfs, and a high risk requires an OMR limit between -1,250 cfs to -2,500 cfs. OMR limits resulting from a medium or high risk will provide minimization of take and related impacts to emigrating juvenile CHNWR and CHNSR during this time period. OMR flow reductions will help to avoid additional entrainment of fish, and therefore reduce the amount of loss at the salvage facilities.

8.13. Condition of Approval 8.6.2 – Early-Season Natural Winter-run Chinook Salmon Discrete Daily Loss Threshold

8.13.1. Introduction

As required by Conditions of Approval 8.3, 8.3.1, and 8.3.2 Permittee will initiate OMR Management and a restriction of OMR to -5,000 cfs after an Integrated Early Winter Pulse Protection event or the Onset of OMR Management. If an Integrated Early Winter Pulse Protection Event does not occur and OMR Management does not begin until January 1 or later, salmonids moving through the Delta in November and December would not be provided with entrainment protections via OMR restrictions. Yearling CHNSR are present in the Delta from October through December (Brandes et al. 2000), and juvenile CHNWR are present as early as September (Jason Julienne personal communication 1/2020; CalFish 2019). Condition of Approval 8.6.2 describes a discrete daily loss threshold to provide entrainment minimization for older juvenile Chinook salmon (CHNWR and yearling CHNSR) in November and December.

Condition of Approval 8.6.2, Early-season Natural Winter-run Chinook Salmon Discrete Daily Loss Threshold, requires Permittee to restrict OMR flows to minimize take of natural CNHWR during the early part of their migration through the Delta. Specifically, Condition of Approval 8.6.2 requires Permittee to restrict OMR to no more negative than -5,000 cfs for five consecutive days when the daily loss of natural older juveniles exceeds the following daily thresholds, which are based on salvage data for juvenile Chinook salmon at the SWP and CVP salvage facilities from water years 2010 to 2018:

- November 1-November 30: 6 older juvenile Chinook salmon
- December 1-December 31: 26 older juvenile Chinook salmon

CDFW conducted the following analysis to evaluate the effectiveness of Condition of Approval 8.6.2 in minimizing take of juvenile natural CHNWR and CHNSR.

8.13.2. Methods

The Early-Season Natural Winter-run Chinook Salmon Discrete Daily Loss Threshold (Condition of Approval 8.6.2) uses discrete daily loss thresholds for older juvenile Chinook salmon that were developed using salvage data for juvenile Chinook salmon collected from SWP and CVP salvage facilities from water years 2010 to 2018. The data was gathered from the CDFW Bay-Delta Region salvage database (CDFW 2019c), which included information required to calculate loss and salvage using the Chinook Salmon Loss Estimation Equation (CDFW 2018 and Attachment 6 to the ITP). The database identified salmon runs based on the Delta Model LAD criteria (USFWS 1997).

The discrete daily loss thresholds for November and December were developed using calculated loss of older juvenile Chinook salmon (see Section 7.3.4 – Historical Loss of Juvenile Chinook Salmon at the Salvage Facilities above). An “older juvenile” is identified using the same method as in the NMFS 2009 BiOp: any non-clipped Chinook salmon greater than or equal to the minimum fork length requirements for CHNWR on the day it was sampled is considered to be an older juvenile. Older juvenile Chinook salmon incorporate all the LAD CHNWR and act as a surrogate for yearling CHNSR that may not have been identified as CHNSR, but instead another salmon race based on LAD criteria.

Loss data for older juvenile Chinook salmon was summed for each day and used to calculate the average daily loss of older juvenile Chinook salmon in November and December from water years 2010 to 2018. Days with zero loss were not used in this analysis. Only the days that had a loss value for older juvenile Chinook salmon were used in calculating the average daily loss for each month. These days represent days when salvage was occurring in the south Delta and thus provide a more accurate representation of daily loss, rather than averaging over the entire month and including days of zero salvage. In other words, the salvage thresholds link the responsive action to an elevated (above average) daily loss. To evaluate the minimization provided by the early-season discrete daily loss thresholds, the thresholds were applied to historic loss of older juvenile Chinook salmon observed in water years 2010 through 2018 to evaluate how often they would have been exceeded during each month of that time period.

8.13.3. Results

Only one day of loss occurred during the month of November from water years 2010 to 2018 (in 2011), so this value represents the discrete daily loss value for November. Loss occurred in December during all years except 2014 and 2018. The discrete daily loss threshold values for November and December are 6 fish/day and 26 fish/day, respectively. After a discrete daily loss threshold is exceeded Permittee will reduce exports to achieve an OMR flow no more negative than -5,000 cfs for five consecutive days.

Implementation of the November threshold during water years 2010 to 2018 would have resulted in only one year with a threshold exceeded in November (Figure 28). Implementation of the December threshold during this time period would have occurred in every water year except 2014 and 2018 (Figures 27 through 33), and daily loss thresholds would have only been exceeded in four of those years (2011, 2013, 2015, and 2016). However, in some years these thresholds were exceeded at or near the same time when an Integrated Early Winter Pulse Protection (Condition of Approval 8.3.1) would have occurred. Based on analysis of historic data, Integrated Early Winter Pulse Protections would have occurred on 12/17/2010, 12/3/2012, and 12/7/2014. Because the Integrated Early Winter Pulse Protection requirement is more restrictive than the discrete daily loss thresholds, the thresholds would not be controlling OMR flows under these circumstances.

Older Juvenile Chinook Salmon Daily Loss Trigger Performance

December, Water Year 2010

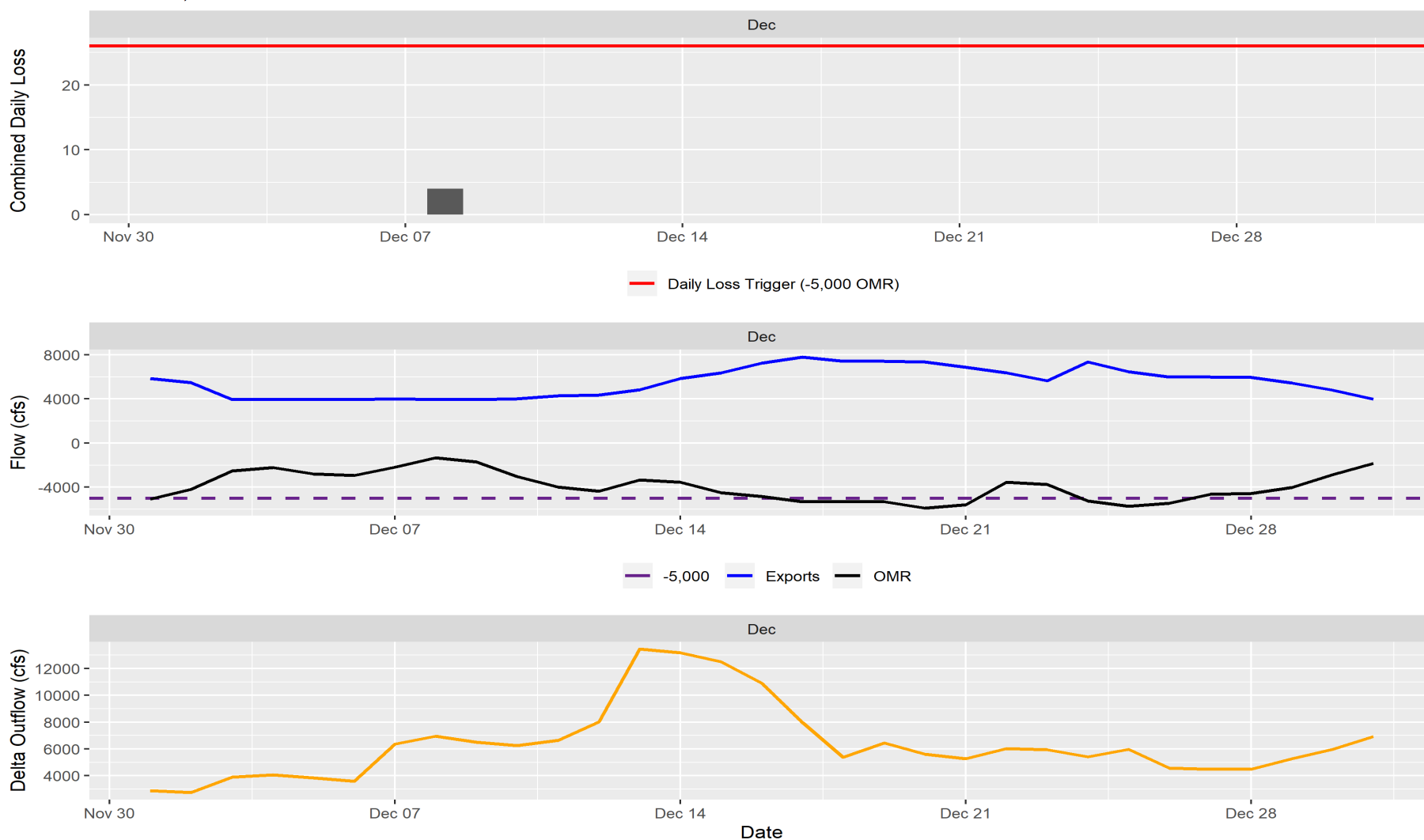


Figure 27: Daily Loss Threshold Plot for December of Water Year 2010. Observed daily combined loss of LAD older juvenile Chinook salmon. The daily loss threshold for December is 26 fish/day. The red line in the top figure represents this daily loss threshold. The bottom figures show historical combined exports at SWP and CVP, OMR flow, and Delta outflow for reference of hydrology during the times when loss was occurring.

Older Juvenile Chinook Salmon Daily Loss Trigger Performance November-December, Water Year 2011

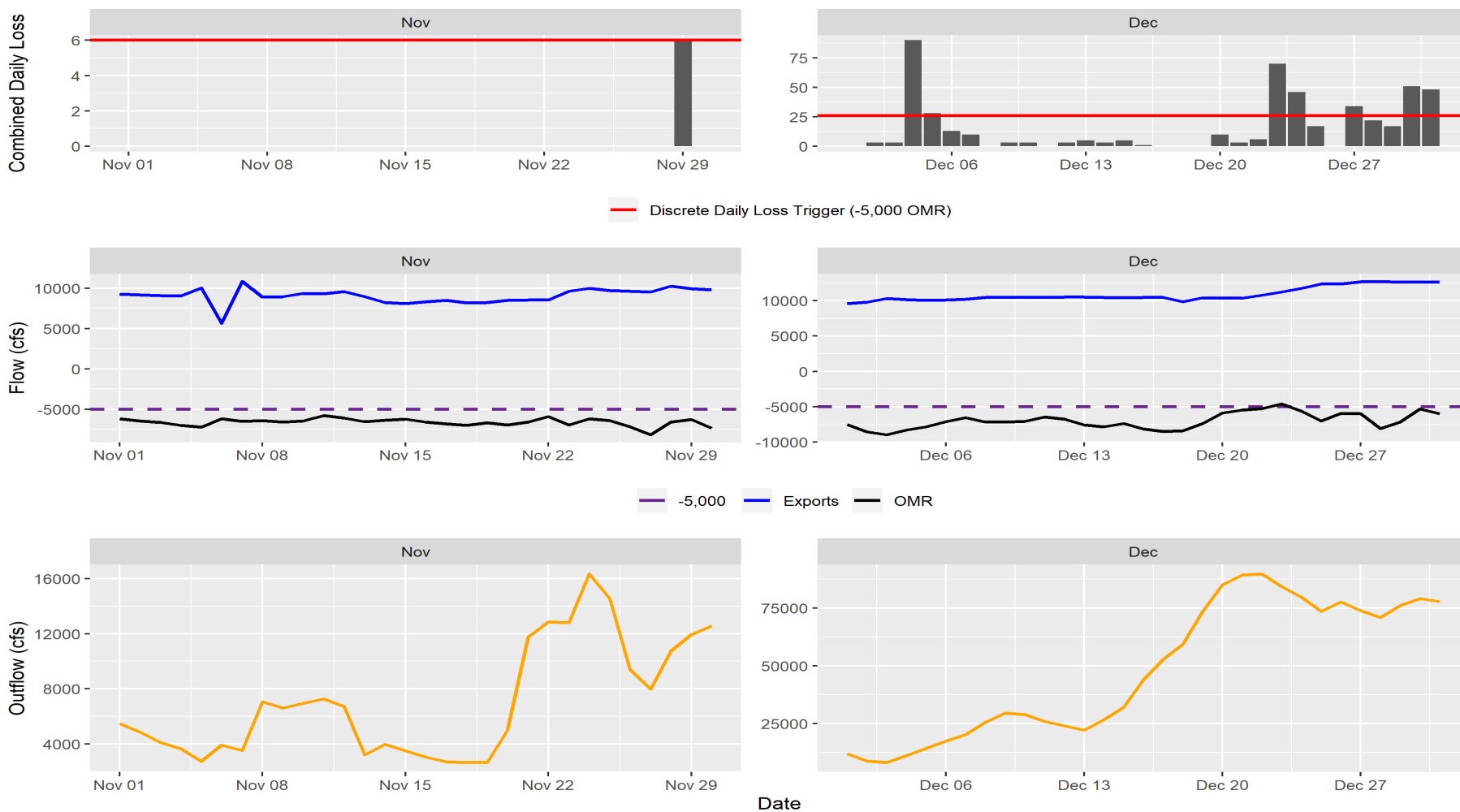


Figure 28: Daily Loss Threshold Plot for November and December of Water Year 2011. Observed daily combined loss of LAD older juvenile Chinook salmon. The daily loss threshold for November is 6 fish/day and for December it is 26 fish/day. The red lines in the top figure represent these daily loss thresholds. The bottom figures show historical combined exports at SWP and CVP, OMR flow, and Delta outflow for reference of hydrology during the times when loss was occurring.

Older Juvenile Chinook Salmon Daily Loss Trigger Performance
December, Water Year 2012



Figure 29: Daily Loss Threshold Plot for December of Water Year 2012. Observed daily combined loss of LAD older juvenile Chinook salmon. The daily loss threshold for December is 26 fish/day. The red line in the top figure represents this daily loss threshold. The bottom figures show historical combined exports at SWP and CVP, OMR flow, and Delta outflow for reference of hydrology during the times when loss was occurring.

Older Juvenile Chinook Salmon Daily Loss Trigger Performance
December, Water Year 2013

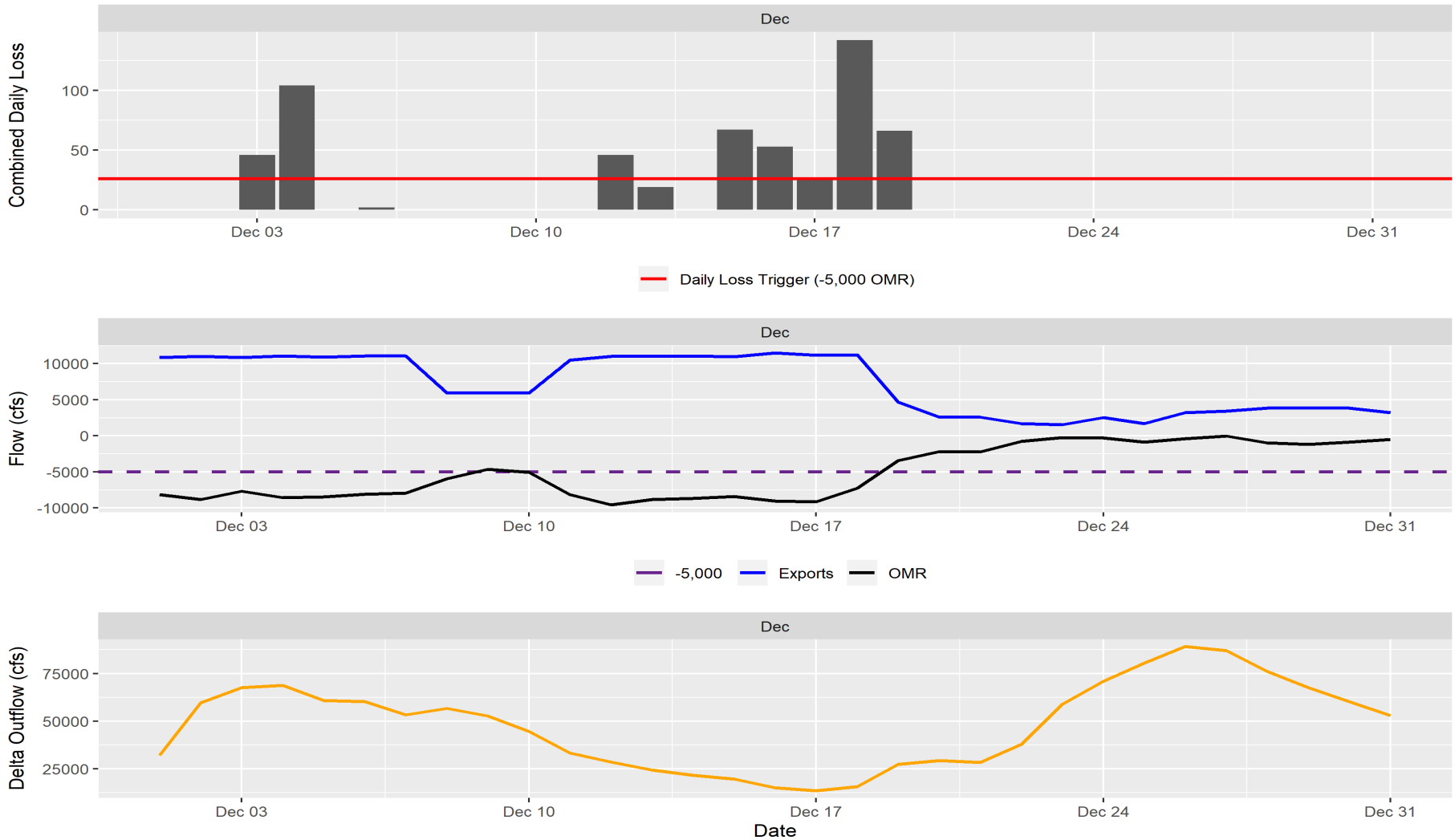


Figure 30: Daily Loss Threshold Plot for December of Water Year 2013. Observed daily combined loss of LAD older juvenile Chinook salmon. The daily loss threshold for December is 26 fish/day. The red line in the top figure represents this daily loss threshold. The bottom figures show historical combined exports at SWP and CVP, OMR flow, and Delta outflow for reference of hydrology during the times when loss was occurring.

Older Juvenile Chinook Salmon Daily Loss Trigger Performance December, Water Year 2015

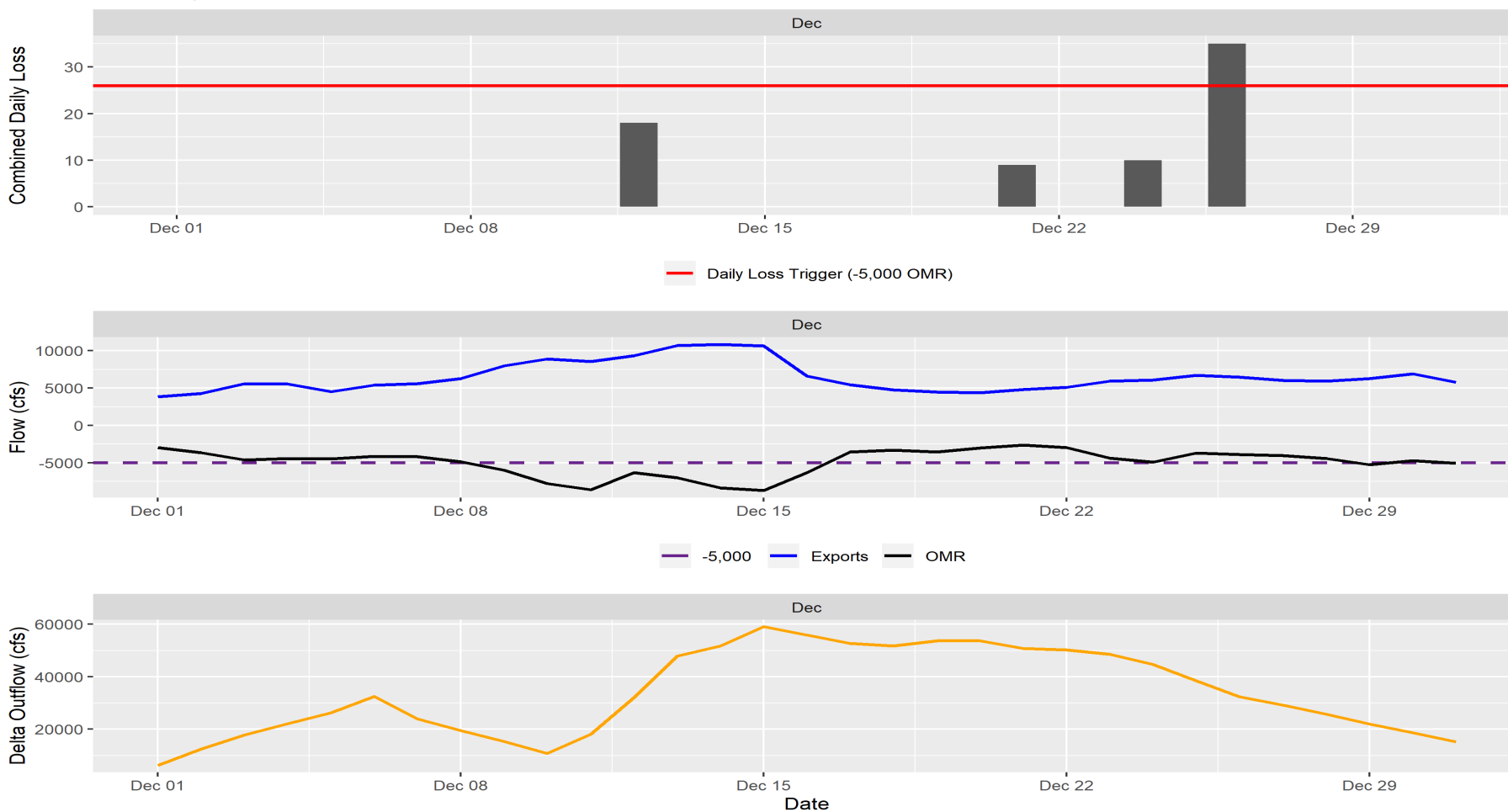


Figure 31: Daily Loss Threshold Plot for December of Water Year 2015. Observed daily combined loss of LAD older juvenile Chinook salmon. The daily loss threshold for December is 26 fish/day. The red line in the top figure represents this daily loss threshold. The bottom figures show historical combined exports at SWP and CVP, OMR flow, and Delta outflow for reference of hydrology during the times when loss was occurring.

Older Juvenile Chinook Salmon Daily Loss Trigger Performance December, Water Year 2016

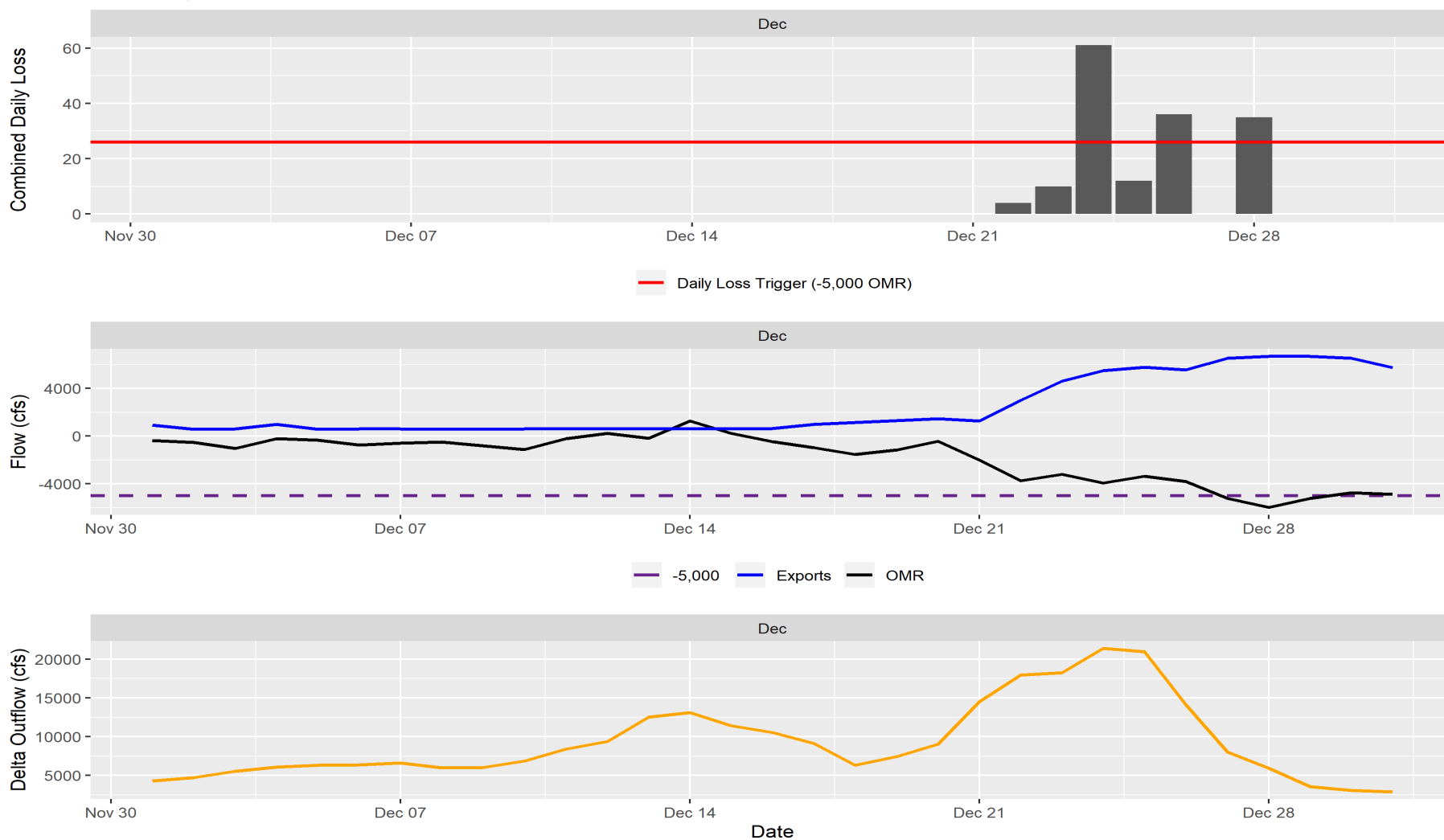


Figure 32: Daily Loss Threshold Plot for December of Water Year 2016. Observed daily combined loss of LAD older juvenile Chinook salmon. The daily loss threshold for December is 26 fish/day. The red line in the top figure represents this daily loss threshold. The bottom figures show historical combined exports at SWP and CVP, OMR flow, and Delta outflow for reference of hydrology during the times when loss was occurring.

Older Juvenile Chinook Salmon Daily Loss Trigger Performance
December, Water Year 2017

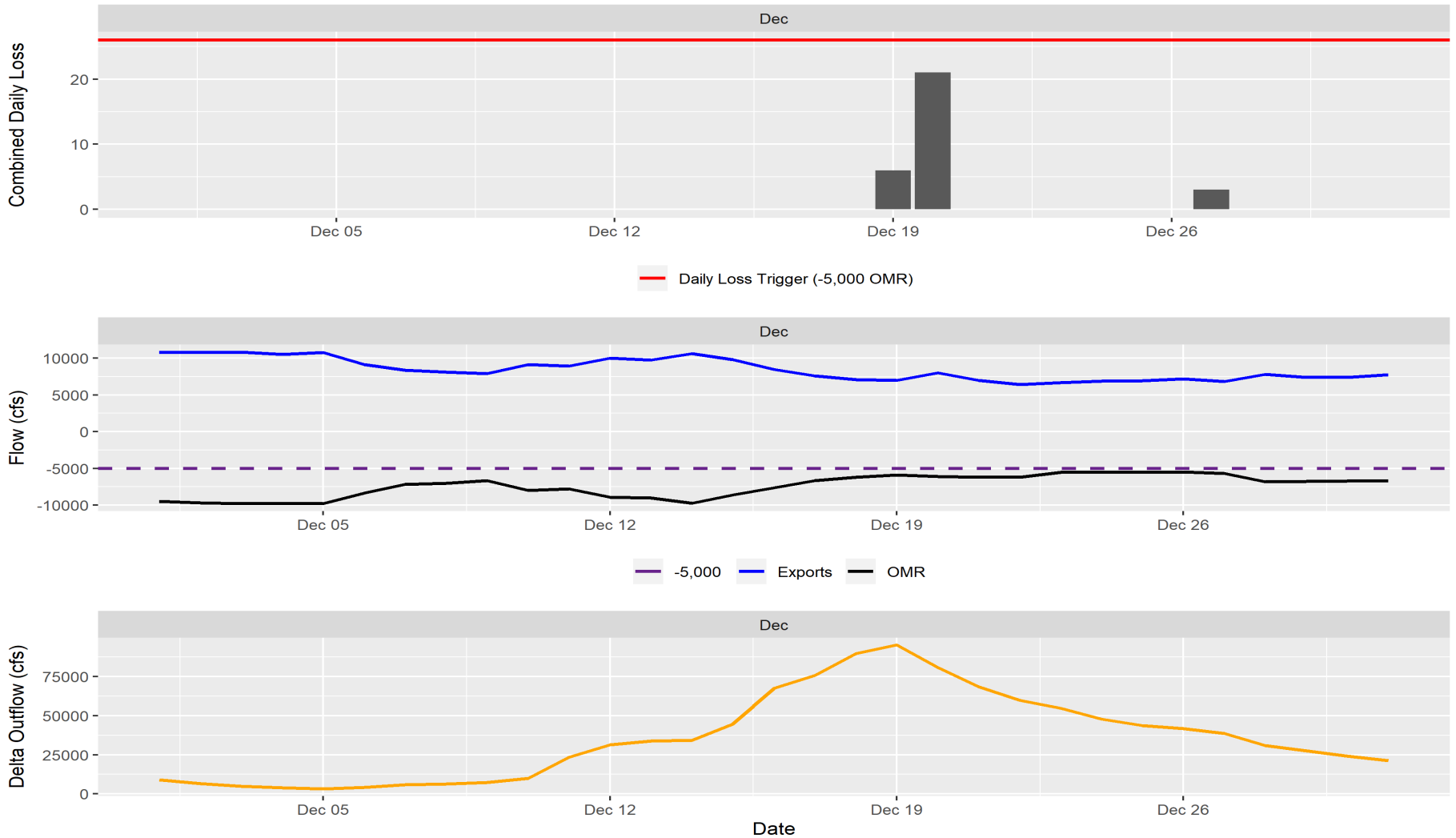


Figure 33: Daily Loss Threshold Plot for December of Water Year 2017. Observed daily combined loss of LAD older juvenile Chinook salmon. The daily loss threshold for December is 26 fish/day. The red line in the top figure represents this daily loss threshold. The bottom figures show historical combined exports at SWP and CVP, OMR flow, and Delta outflow for reference of hydrology during the times when loss was occurring.

8.13.4. Discussion

Daily loss thresholds for older juvenile Chinook salmon in November and December were developed by CDFW to minimize Project take of juvenile Chinook salmon (Table 21). Take is minimized when joint salvage exceeds the daily loss threshold, requiring the Project to reduce exports to achieve an OMR flow no more negative than -5,000 cfs for five days to reduce the subsequent entrainment of salmonids into the south Delta and export facilities. The daily loss thresholds in November and December were designed specifically for early-migrant CHNWR and yearling CHNSR. These two life history variants are important life-history strategies for CHNWR and CHNSR.

Date	Minimization Threshold	Threshold Response
November 1 -November 30	Daily loss of older juvenile Chinook salmon is greater than or equal to 6 fish per day.	Reduce exports to achieve an average net OMR flow of -5,000 cfs for a minimum of 5 consecutive days.
December 1- December 31	Daily loss of older juvenile Chinook salmon is greater than or equal to 26 fish per day.	Reduce exports to achieve an average net OMR flow of -5,000 cfs for a minimum of 5 consecutive days.

Table 21: Daily Loss Thresholds for December and November. Proposed daily Loss threshold values for each month and corresponding OMR reduction requirements when exceeded.

8.14. Condition of Approval 8.6.1 – Single-Year Loss Threshold – Natural Winter-run Chinook Salmon and Condition of Approval 8.6.3 Mid- and Late-Season Natural Winter-Run Chinook Salmon Daily Loss Threshold

8.14.1. Introduction

Condition of Approval 8.6.1, Winter-run Chinook Salmon Single-year Loss Threshold, requires Permittee to restrict OMR flows to minimize take of natural and hatchery-origin CHNWR. This analysis focuses on the extent to which take and impacts of the taking on CHNWR are minimized through implementation of the single-year loss threshold for natural CHNWR loss as described below. An analysis for the proposed hatchery-origin CHNWR single-year loss threshold is provided in Section 8.15 of this document. The single-year loss threshold for natural CHNWR as described in Condition of Approval 8.6.1 is equivalent to loss of 1.17% of the JPE. If 50% of the single-year loss threshold is exceeded, OMR would be restricted to a 14-day moving average of no more negative than -3,500 cfs for at least 14 days. If 75% of a single-year loss threshold is exceeded, OMR would be restricted to a 14-day moving average of no more negative than -2,500 cfs for at least 14 days.

Condition of Approval 8.6.3, Mid-and Late-season Natural Winter-run Chinook Salmon Daily Loss Threshold, requires Permittee to restrict OMR flows to minimize take of natural CNHWR during the peak and end of their migration through the Delta. Specifically, Condition of Approval 8.6.3 requires Permittee to restrict OMR to no more negative than -3,500 cfs for five consecutive days when the daily

loss of natural older juveniles exceeds the following daily thresholds based on the juvenile production estimate (JPE) reported in January of the same year:

- January 1 – January 31: 0.00635% of the CHNWR JPE
- February 1 – February 28: 0.00991% of the CHNWR JPE
- March 1 – March 31: 0.0146% of the CHNWR JPE
- April 1 – April 30: 0.00507% of the CHNWR JPE
- May 1 – May 31: 0.0077% of the CHNWR JPE

NMFS provides a JPE for natural CHNWR annually, which is used to determine the authorized level of incidental take for natural CHNWR under Section 7 of the ESA, for operation of the CVP/SWP pumping facilities in the south Delta. The following components are currently used to estimate the natural CHNWR JPE each year: total in-river escapement, adult female estimate, adult female estimate minus pre-spawn mortality, average fecundity, total viable eggs, estimated egg-to-fry survival based on JPI at RBDD/total viable eggs, fry equivalents of juvenile production at RBDD (JPI), fry-to-smolt survival estimates from October to February at RBDD, number of smolts at RBDD, and estimated smolt survival from Red Bluff to the Delta. Historical natural CHNWR JPEs are provided in Table 22.

Water Year	Natural CHNWR JPE
1994	90,500
1995	31,491
1996	338,107
1997	165,069
1998	138,316
1999	454,792
2000	289,724
2001	370,221
2002	1,864,802
2003	2,136,747
2004	1,896,649
2005	881,719
2006	3,831,286
2007	3,739,069
2008	589,911
2009	617,783
2010	1,179,633
2011	332,012
2012	162,051
2013	532,809
2014	1,196,387
2015	124,521
2016	101,716
2017	166,189
2018	201,409

Table 22. Annual natural CHNWR JPE for water years 1994-2018.

For the purposes of this Effects Analysis, CDFW conducted the following analysis to evaluate the effectiveness of Conditions of Approval 8.6.1 (Natural Winter-run Chinook Salmon Single-year Loss Threshold) and 8.6.3 (Mid- and Late-season Natural Winter-run Chinook Salmon Daily Loss Threshold), in minimizing take of juvenile natural CHNWR and CHNSR.

8.14.2. Methods

For this analysis, salvage data of Chinook salmon collected at the SWP and CVP salvage facilities from water years 2010 to 2018 was summarized from the CDFW Bay-Delta Region salvage database (CDFW 2019c) and loss was calculated using the loss equation (CDFW 2018 and Attachment 6 to the ITP). The database identified salmon runs based on the Delta Model LAD criteria (USFWS 1997).

For the purpose of this analysis, loss was calculated for natural CHNWR and older juvenile Chinook salmon. An “older juvenile” is identified as any non-clipped Chinook salmon that is greater than or equal to the minimum fork length requirements for CHNWR on the day that it was sampled. Older juvenile Chinook salmon incorporates all the LAD CHNWR and acts as a surrogate for the yearling CHNSR that may not have been identified as CHNSR based on the LAD criteria.

8.14.2.1. Single-Year Loss Threshold for Natural Winter-Run Chinook Salmon Analysis

The single-year loss threshold for natural CHNWR in Condition of Approval 8.6.1 (1.17% of the JPE) was applied to natural CHNWR loss data from water years 2010 to 2018 to evaluate the protectiveness during this time period based on the number of times loss at the salvage facilities would have exceeded 50% and 75% of the threshold as well as exceeded the threshold entirely. This was evaluated by calculating the single-year loss threshold of 1.17% of the JPE, as well as calculating the 50% and 75% loss thresholds for each year and comparing these numbers to the actual loss that occurred. The single-year loss threshold for natural CHNWR also serves to minimize take of CHNSR, although it is not formally linked to CHNSR loss at the salvage facilities. Loss of YOY CHNSR was also analyzed to evaluate any potential protections this measure would have provided.

8.14.2.2. Daily Percent Loss of Winter-Run Chinook Salmon JPE Threshold Analysis

Condition of Approval 8.6.2 was developed by CDFW to increase protections for older juvenile Chinook salmon from January through May. The daily loss thresholds differ from the 2009 NMFS BiOp daily loss density triggers for older juvenile chinook salmon (RPA Action IV.2.3) as they are based on a daily percentage of the JPE and are not dependent upon the amount of water exported through the pumping facilities. Daily loss thresholds were calculated by averaging historical daily percent loss of JPE, per month, of older juvenile Chinook salmon. Therefore, the daily loss thresholds incorporate the relationship between loss and export operations at SWP and CVP when salvage is likely to occur. This approach does not incorporate the volume of water exported to avoid describing conditions when loss should occur but there are no longer fish to entrain; during such a situation, the loss density approach (Action IV.2.3) could be biased low and would no longer describe the relationship between loss and export operations.

To develop the daily loss thresholds in Condition of Approval 8.6.2, calculated loss of older juvenile Chinook salmon was summed for each day and was used to calculate the daily percent loss of the CHNWR JPE. The daily percent loss was then used to calculate the average daily percent loss of the JPE

for each month: January, February, March, April, and May. Days with zero loss were not used in this analysis. Only the days that had a loss value for older juvenile Chinook salmon were used in finding the average daily loss for each month. These days represent when salvage conditions were occurring in the south Delta and thus provide a more accurate representation of daily loss and link the OMR response to times when the daily loss is elevated. To evaluate the protectiveness of the daily loss thresholds, the thresholds were applied to the loss of older juvenile Chinook salmon in water years 2010 through 2018 to understand how often they would have been exceeded during each month of that time period.

8.14.3. Results

8.14.3.1. Natural Winter-run Chinook Salmon Single-Year Loss Threshold Analysis

The natural CHNWR single-year loss threshold, would have provided protections for natural CHNWR in two years, 2011 and 2012. Table 23 provides a summary for each water year, including the single-year loss threshold using the 1.17% of the JPE, the observed loss, and the 50% and 75% loss thresholds.

Water Year	JPE	50% Threshold	75% Threshold	Single-Year Loss Threshold (1.17% of JPE)	Total Observed Loss
2010	1,179,633	6,901	10351	13,802	1689
2011	332,012	1,942	2913	3,885	4401
2012	162,051	948	1422	1,896	2106
2013	532,809	3,117	4675	6,234	750
2014	1,196,387	6,999	10498	13,998	329
2015	124,521	728	1093	1,457	110
2016	101,716	595	893	1,190	60
2017	166,189	972	1458	1,944	115
2018	201,409	1,178	1767	2,356	682

Table 23: Single-year Loss Thresholds. Single-year loss thresholds calculated for natural CHNWR, with the 50% and 75% loss thresholds. The total observed loss is combined loss of LAD natural CHNWR from SWP and CVP. The green highlighted years represent the years when the single-year loss thresholds would have been exceeded.

In water years 2011 and 2012, protections would have been provided for natural CHNWR as a result of the 50%, 75%, and single-year loss thresholds being exceeded. Figure 34 depicts the data from Table 23.

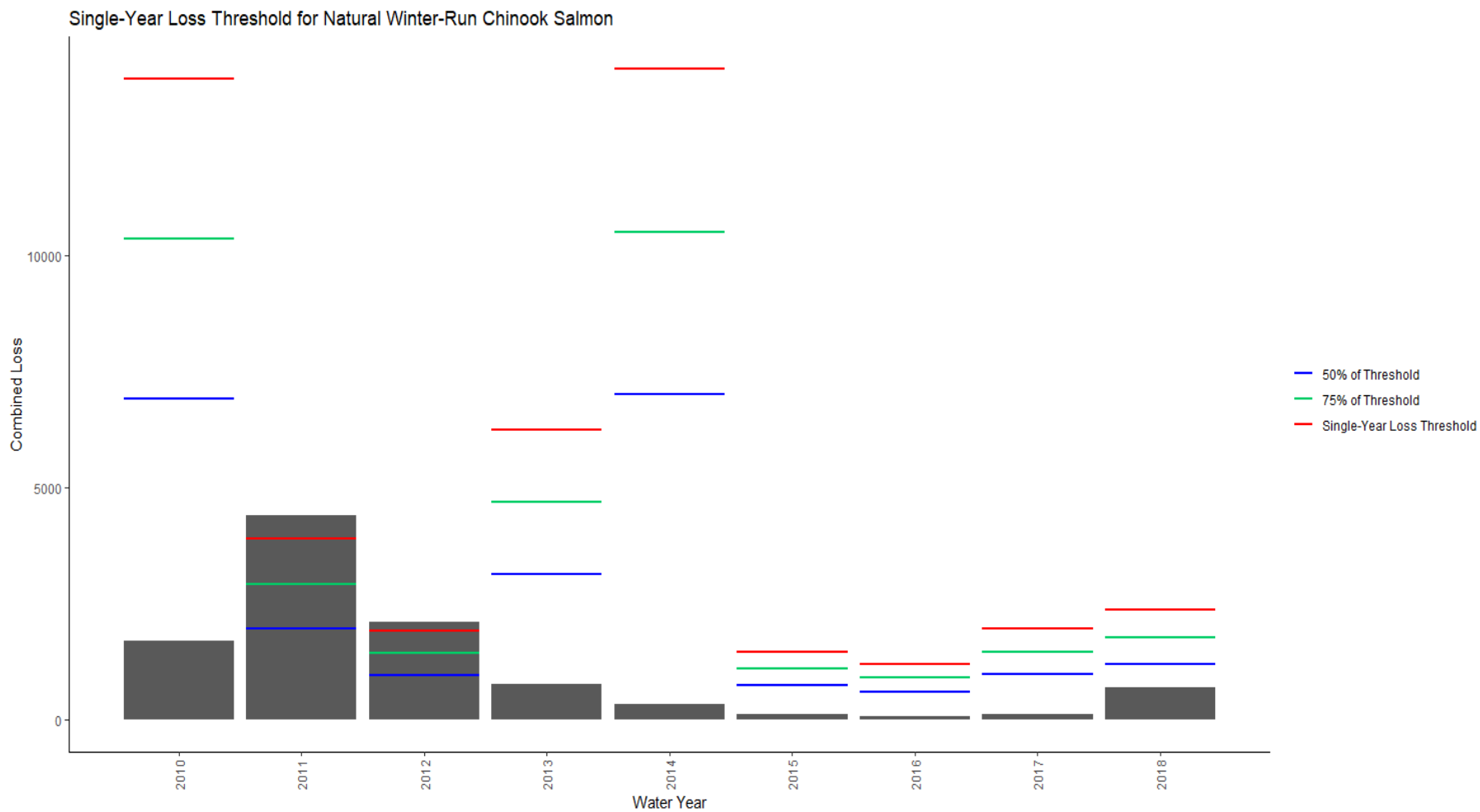


Figure 34: Single-year Loss Threshold Performance Plot 2010-2018. Observed loss of LAD natural CHNWR from water years 2010 to 2018. The blue bars represent the 50% loss threshold calculated for each year; any loss that exceeds these blue bars represents when the 50% loss threshold would have been exceeded. The green bars represent the 75% loss threshold calculated for each year; any loss that exceeds these green bars represents when the 75% loss threshold would have been exceeded. The red bars represent the single-year loss threshold that is set for each year (1.17% of the JPE); any loss that exceeds the red bar represents when the single-year loss threshold would have been exceeded.

As described in Condition of Approval 8.6.1, when the 50% loss threshold is exceeded, OMR would be restricted to a 14-day moving average OMR index of no more negative than -3,500 cfs for at least 14 days. When a 75% loss is exceeded, OMR would be restricted to a 14-day moving average OMR index of no more negative than -2,500 cfs for at least 14 days. If the single-year loss threshold is exceeded in any year, DWR and Reclamation would seek technical assistance from CDFW, USFWS, and NMFS on operations for the remainder of the management season. In 2011, the 50% loss threshold would have been exceeded around February 24th and the 75% loss threshold would have been exceeded around March 11th. In 2012, the 50% loss threshold would have been exceeded around March 9th and the 75% loss threshold would have been exceeded around March 21st. The single-year loss threshold would have been exceeded around March 20 in 2011 and around March 31 in 2012. Peak salvage and loss of YOY CHNSR occurred after the 50%, 75%, and single-year loss thresholds were exceeded in 2011 and 2012. Figures 35 and 36 show the cumulative loss of CHNSR and natural CHNWR in the two years that the natural CHNWR single-year loss threshold would have been exceeded.

Cumulative Loss of Spring-Run and Natural Winter-Run Chinook Salmon

February 21-April 14, 2011

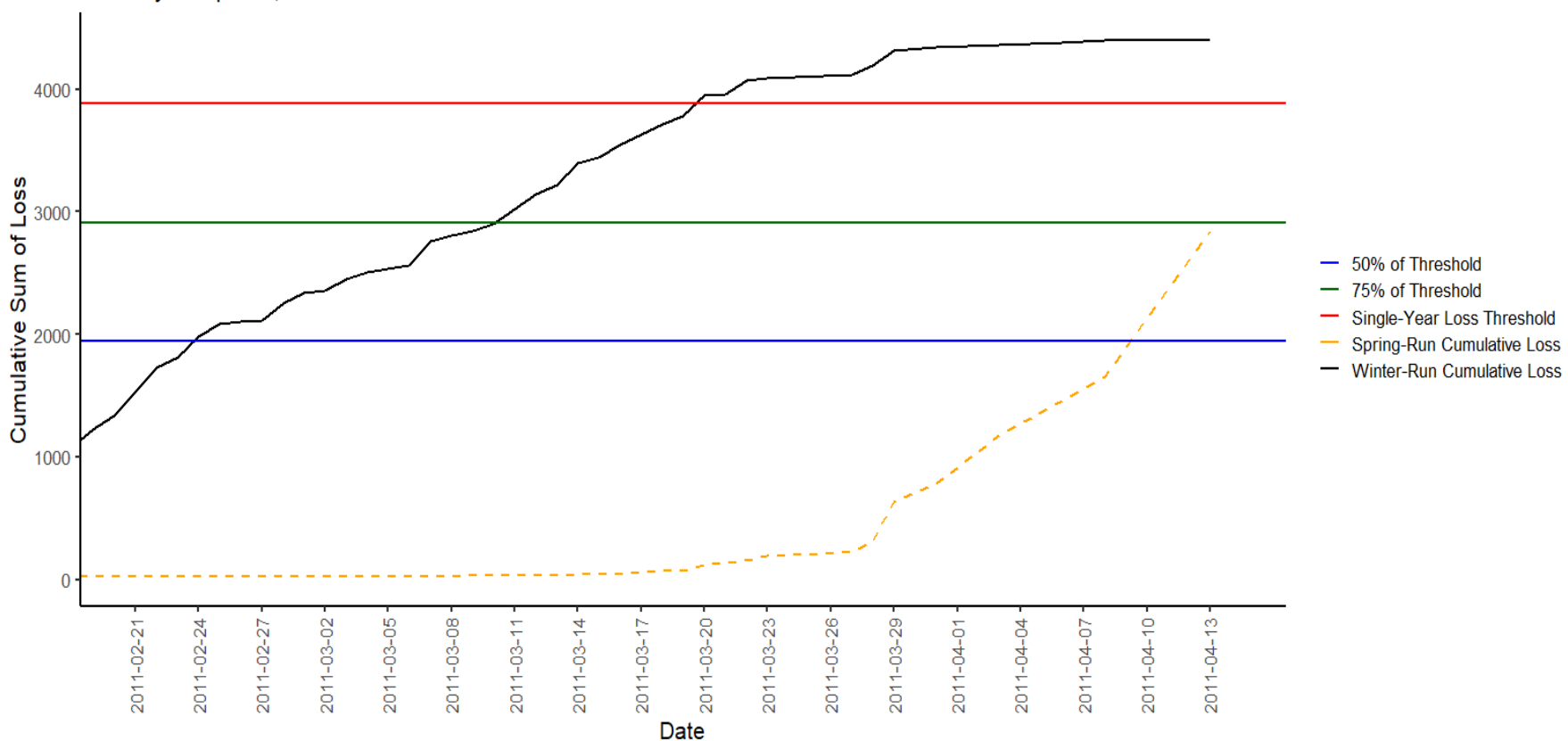


Figure 35: Single-year Loss Threshold Performance Plot for 2011. Cumulative loss of LAD CHNSR and natural CHNWR in 2011 from February 21 – April 14 at SWP and CVP. The blue line is the 50% threshold. The green line is the 75% threshold. The red line is the single-year loss threshold for water year 2011 (1.17% of the JPE).

Cumulative Loss of Spring-Run and Natural Winter-Run Chinook Salmon

February 29-April 05, 2012

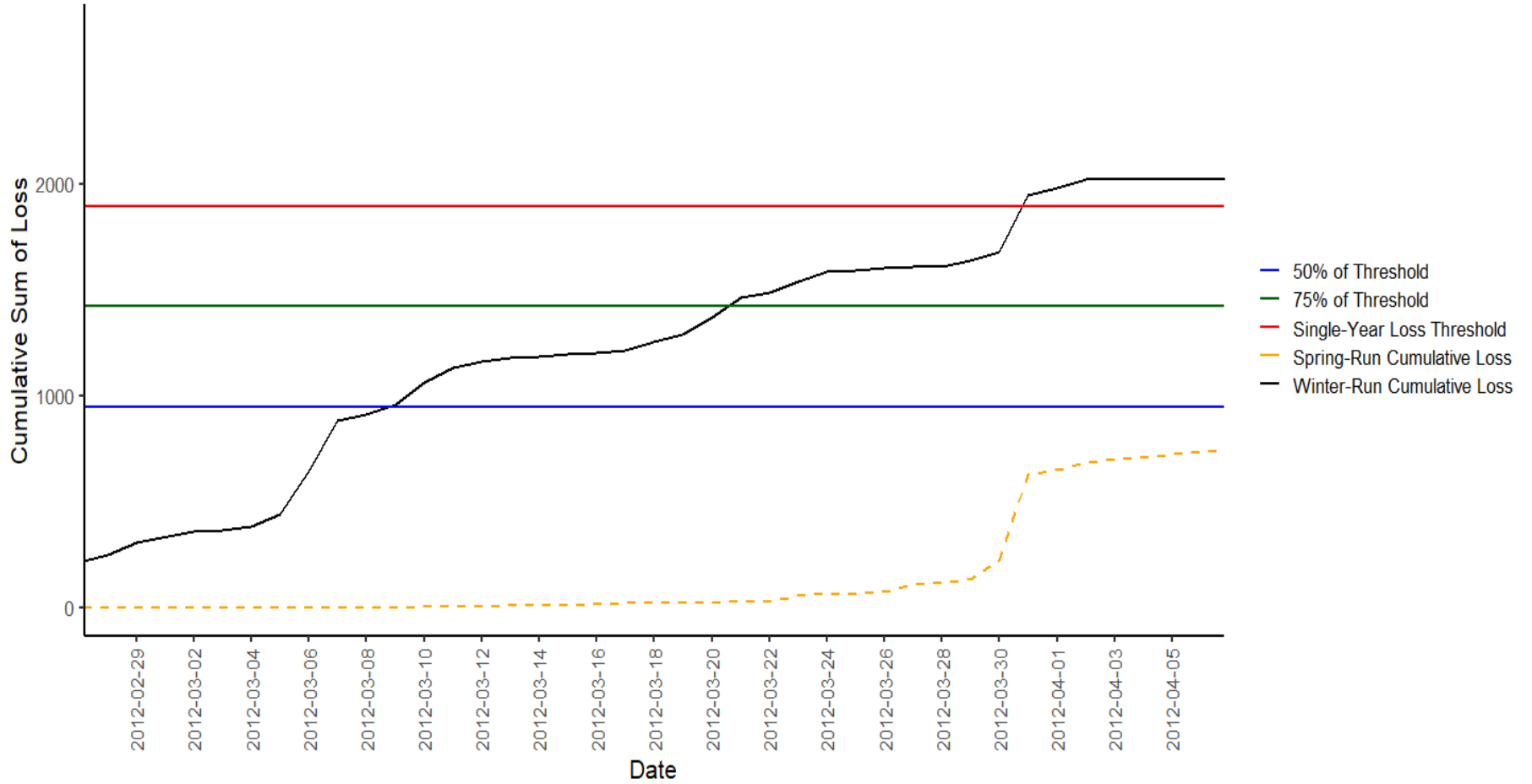


Figure 36: Single-year Loss Threshold Performance Plot for 2012. Cumulative loss of LAD CHNSR and natural CHNWR in 2012 from February 29 – April 05 at SWP and CVP. The blue line is the 50% threshold. The green line is the 75% threshold. The red line is the single-year loss threshold for water year 2012 (1.17% of the JPE).

8.14.3.2. Mid- and Late- Season Natural Winter-run Chinook Salmon Daily Loss Threshold Analysis

This Condition of Approval was developed by CDFW to minimize take and related impacts of the taking to older juvenile Chinook salmon during OMR Management. This daily loss threshold complements the single-year loss threshold for juvenile natural CHNWR by acting as an early warning of higher risk conditions, which by reducing operations and generating less negative OMR flows, could help further reduce entrainment of juvenile natural CHNWR. Table 24 describes the daily percent loss of JPE threshold values that were calculated for each month (January through May). Figures 37-52 show observed daily combined loss of LAD older juvenile Chinook salmon at SWP and CVP overlaid with the threshold for each month (January-May) for water years 2010-2018. During these water years, the threshold would have been exceeded in a total of six years: 2011, 2012, 2015, 2016, 2017, and 2018 (see Figures 39-42 and 47-52).

Month	Daily % Loss of JPE
January	0.00635%
February	0.00991%
March	0.0146%
April	0.00507%
May	0.0077%

Table 24: Daily Percent Loss of Natural Winter-Run JPE Thresholds for January, February, March, April, and May. The daily percent loss of natural CHNWR JPE threshold values set for each month for combined loss of older juvenile Chinook salmon using the Delta LAD Model (USFWS 1997).

Older Juvenile Chinook Salmon Daily Percent Loss of JPE Performance

January - March 2010

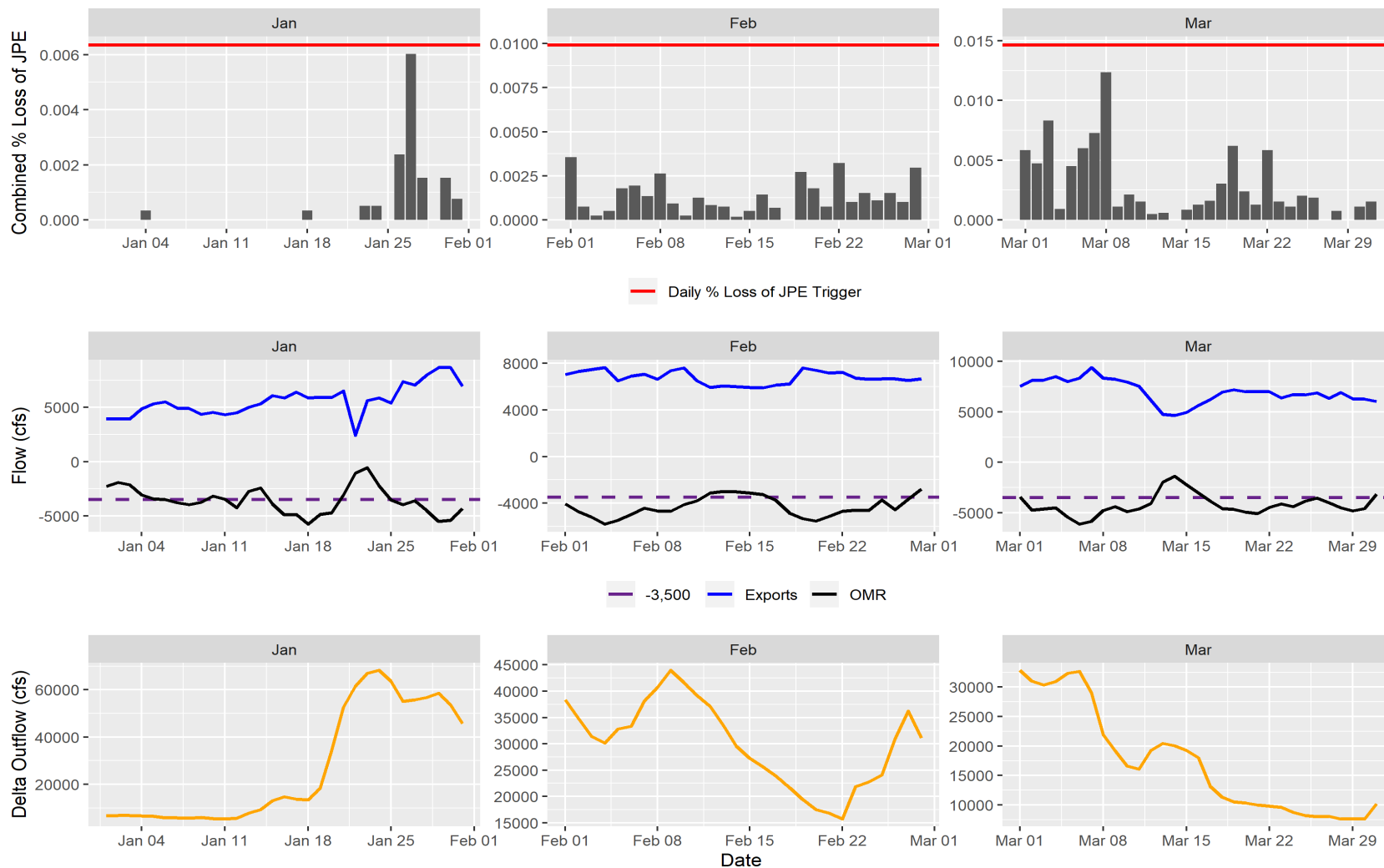


Figure 37: Daily Percent Loss of JPE Threshold Performance Plot for January-March 2010. Observed daily combined loss of LAD older juvenile Chinook salmon at SWP and CVP. Each month has its own daily percent loss of CHNWR JPE threshold. Daily Loss; January = 0.00635% of JPE, February = 0.00991%, March = 0.0146% of JPE, April = 0.00507% of JPE, and May = 0.0077% of JPE. The red lines in the top figures represent the daily percent loss of CHNWR JPE thresholds. The bottom figures show historical combined exports at SWP and CVP, OMR flow, and Delta outflow for reference of hydrology during the times when loss was occurring.

Older Juvenile Chinook Salmon Daily Percent Loss of JPE Performance

April - May 2010

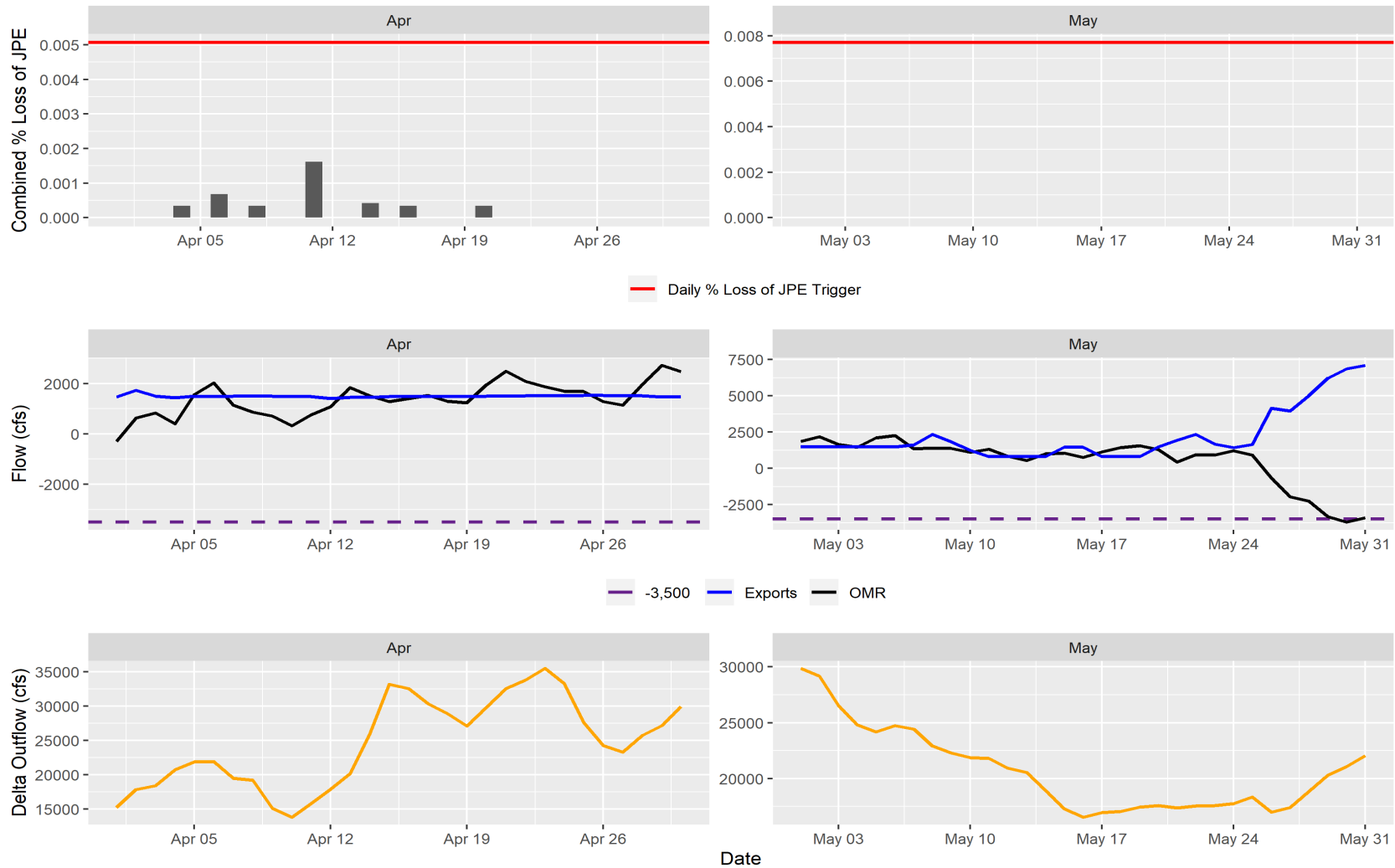


Figure 38: Daily Percent Loss of JPE Threshold Performance Plot for April-May 2010. Observed daily combined loss of LAD older juvenile Chinook salmon at SWP and CVP. Each month has its own daily percent loss of CHNWR JPE threshold. Daily Loss; January = 0.00635% of JPE, February = 0.00991%, March = 0.0146% of JPE, April = 0.00507% of JPE, and May= 0.0077% of JPE. The red lines in the top figures represent the daily percent loss of CHNWR JPE thresholds. The bottom figures show historical combined exports at SWP and CVP, OMR flow, and Delta outflow for reference of hydrology during the times when loss was occurring.

Older Juvenile Chinook Salmon Daily Percent Loss of JPE Performance
January - March 2011

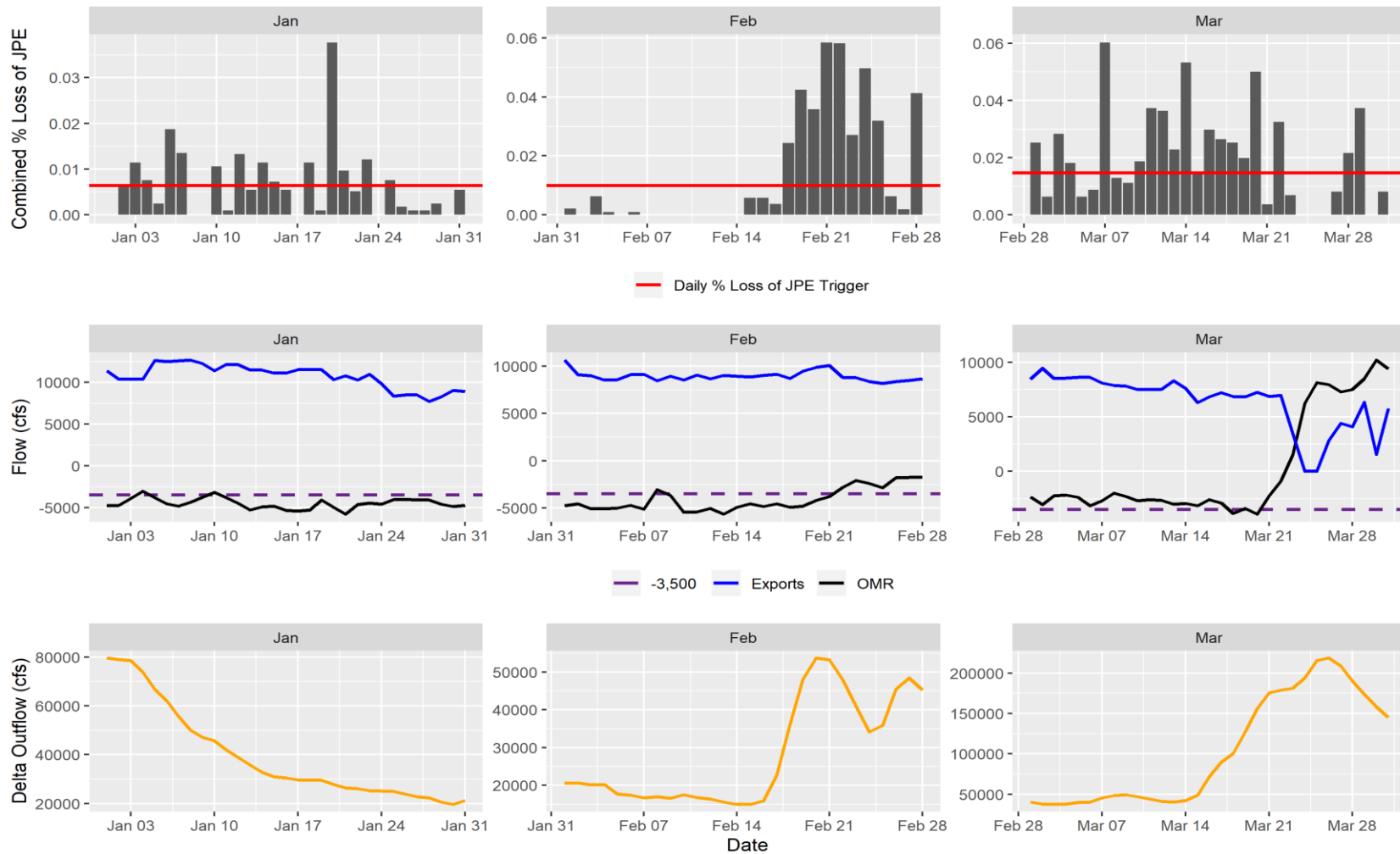


Figure 39: Daily Percent Loss of JPE Threshold Performance Plot for January- March 2011. Observed daily combined loss of LAD older juvenile Chinook salmon at SWP and CVP. Each month has its own daily percent loss of CHNWR JPE threshold. Daily Loss; January = 0.00635% of JPE, February = 0.00991%, March = 0.0146% of JPE, April = 0.00507% of JPE, and May = 0.0077% of JPE. The red lines in the top figures represent the daily percent loss of CHNWR JPE thresholds. The bottom figures show historical combined exports at SWP and CVP, OMR flow, and Delta outflow for reference of hydrology during the times when loss was occurring.

Older Juvenile Chinook Salmon Daily Percent Loss of JPE Performance

April - May 2011

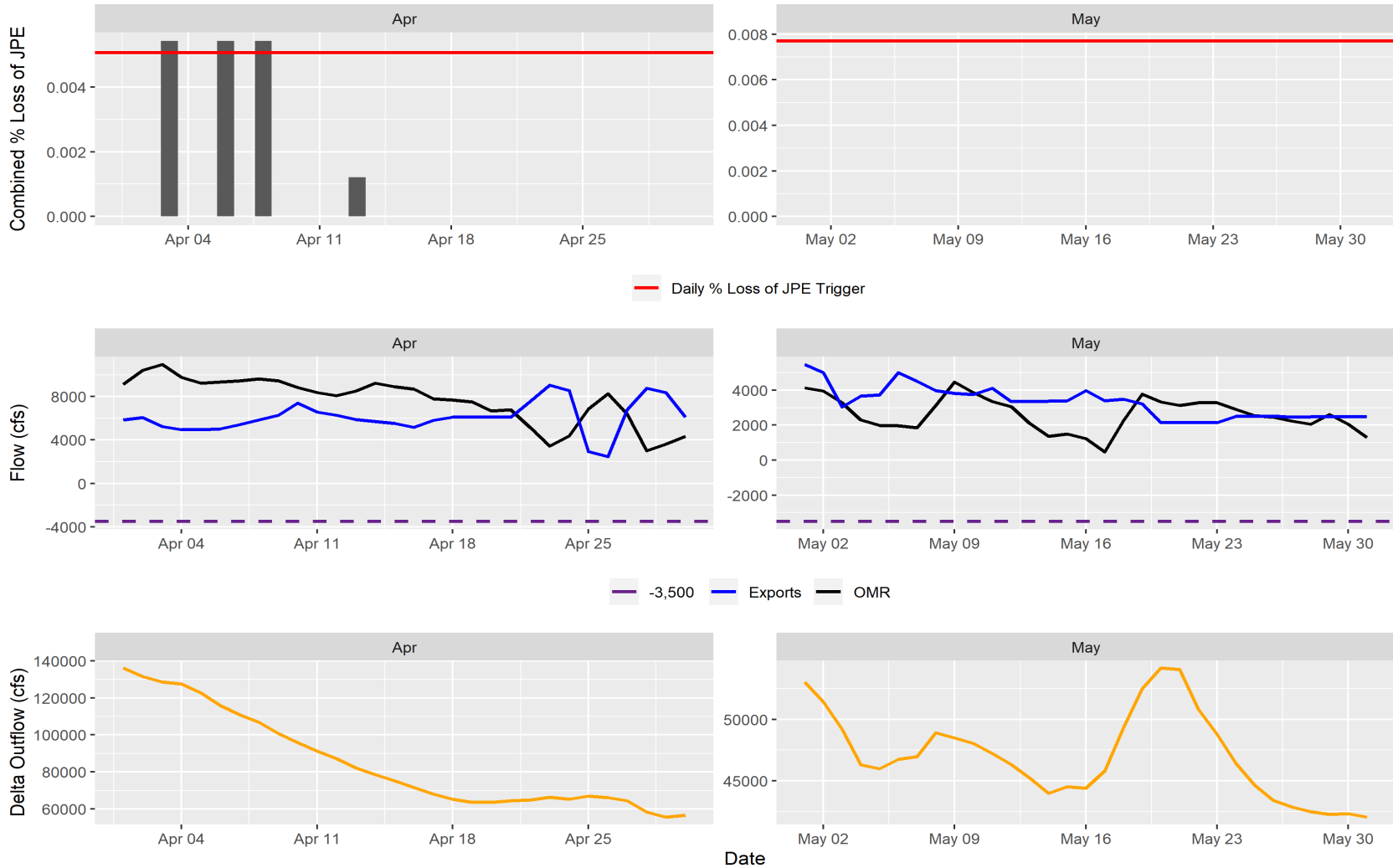


Figure 40: Daily Percent Loss of JPE Thresholds Performance Plot for April-May 2011. Observed daily combined loss of LAD older juvenile Chinook salmon at SWP and CVP. Each month has its own daily percent loss of CHNWR JPE threshold. Daily Loss; January = 0.00635% of JPE, February = 0.00991%, March = 0.0146% of JPE, April = 0.00507% of JPE, and May= 0.0077% of JPE. The red lines in the top figures represent the daily percent loss of CHNWR JPE thresholds. The bottom figures show historical combined exports at SWP and CVP, OMR flow, and Delta outflow for reference of hydrology during the times when loss was occurring.

Older Juvenile Chinook Salmon Daily Percent Loss of JPE Performance
January - March 2012

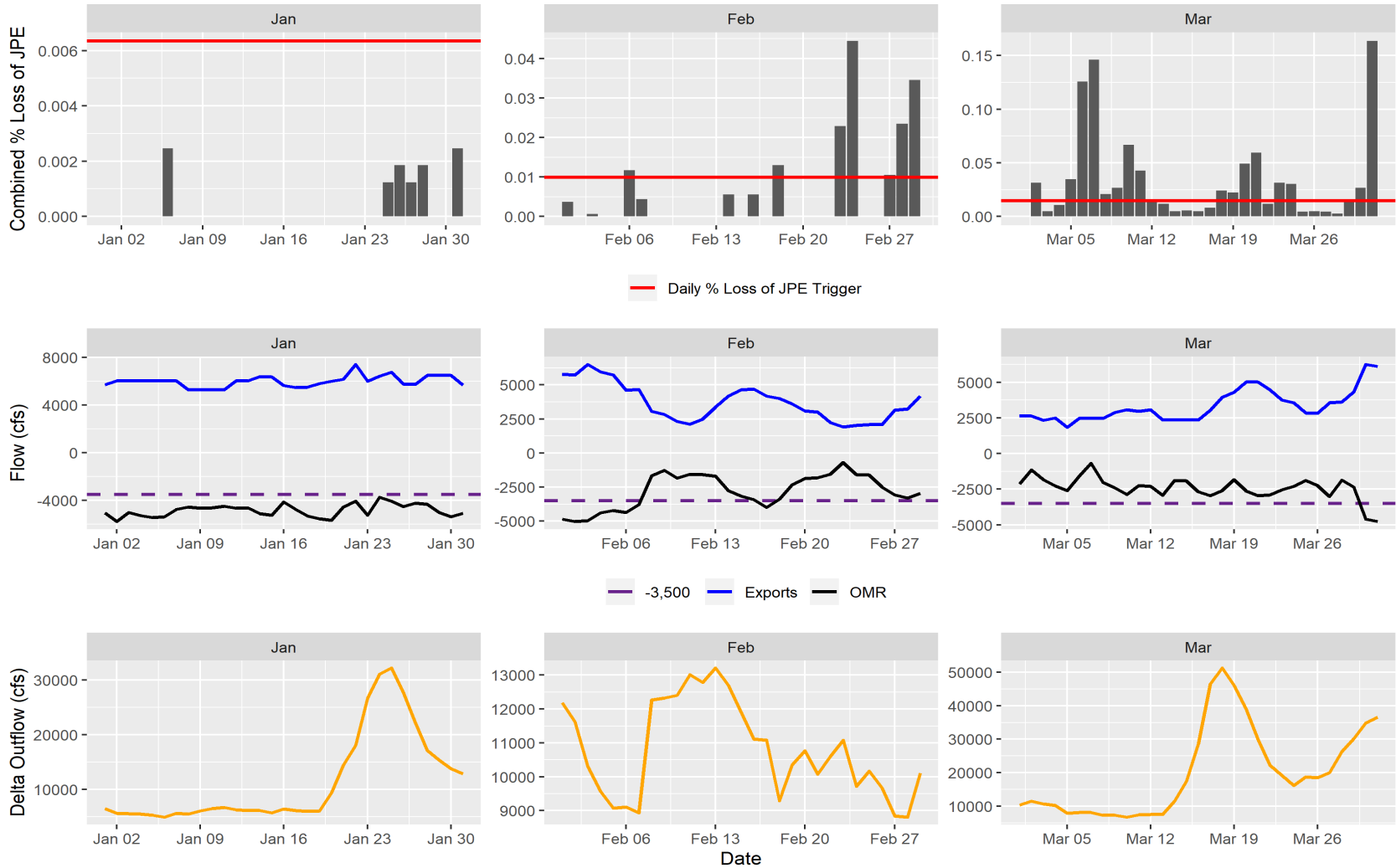


Figure 41: Daily Percent Loss of JPE Threshold Performance Plot for January-March 2012. Observed daily combined loss of LAD older juvenile Chinook salmon at SWP and CVP. Each month has its own daily percent loss of CHNWR JPE threshold. Daily Loss; January = 0.00635% of JPE, February = 0.00991% of JPE, March = 0.0146% of JPE, April = 0.00507% of JPE, and May = 0.0077% of JPE. The red lines in the top figures represent the daily percent loss of WR JPE thresholds. The bottom figures show historical combined exports at SWP and CVP, OMR flow, and Delta outflow for reference of hydrology during the times when loss was occurring.

Older Juvenile Chinook Salmon Daily Percent Loss of JPE Performance

April - May 2012

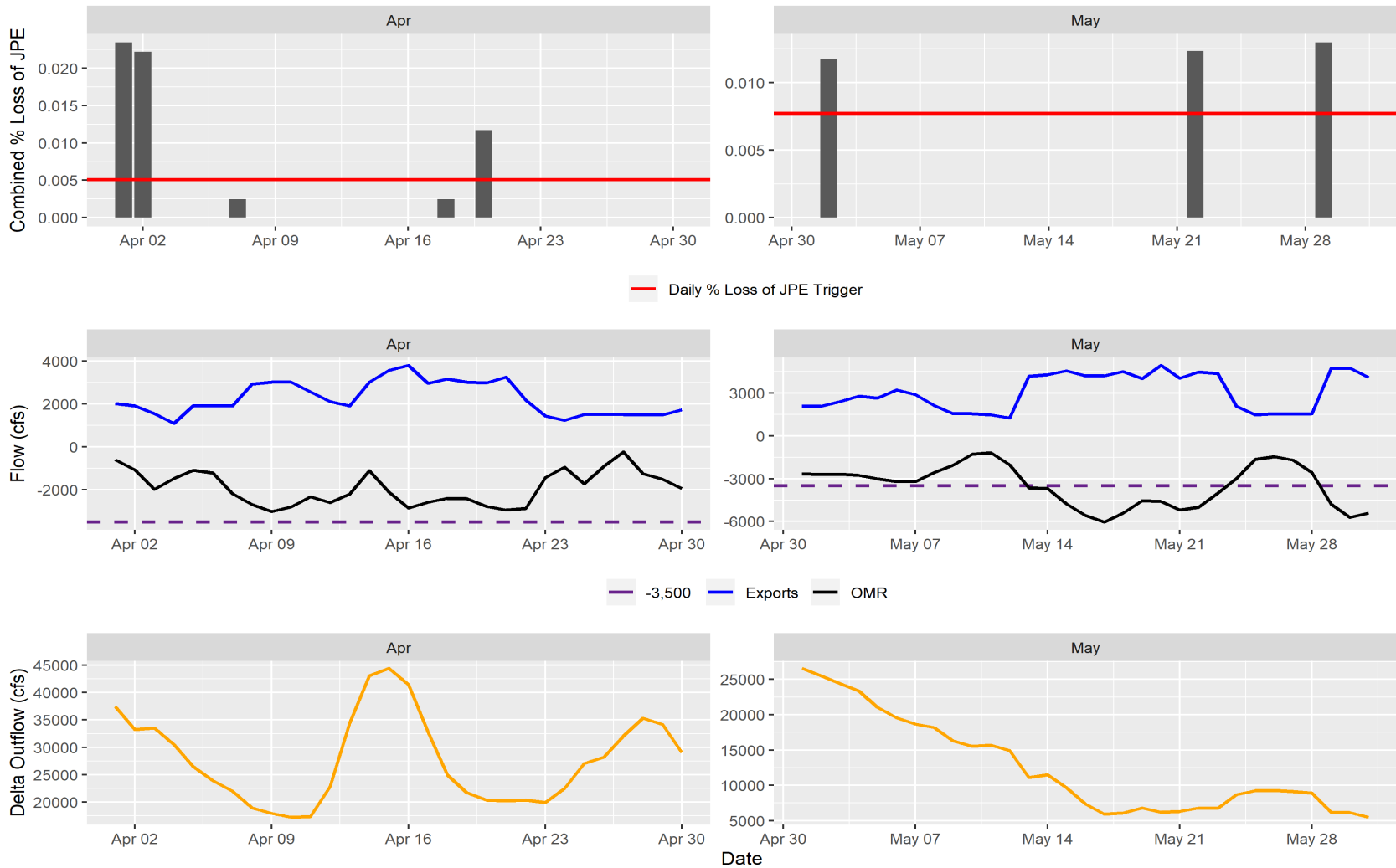


Figure 42: Daily Percent Loss of JPE Threshold Performance Plot for April-May 2012. Observed daily combined loss of LAD older juvenile Chinook salmon at SWP and CVP. Each month has its own daily percent loss of CHNWR JPE threshold. Daily Loss; January = 0.00635% of JPE, February = 0.00991%, March = 0.0146% of JPE, April = 0.00507% of JPE, and May = 0.0077% of JPE. The red lines in the top figures represent the daily percent loss of CHNWR JPE thresholds. The bottom figures show historical combined exports at SWP and CVP, OMR flow, and Delta outflow for reference of hydrology during the times when loss was occurring.

Older Juvenile Chinook Salmon Daily Percent Loss of JPE Performance

January - March 2013

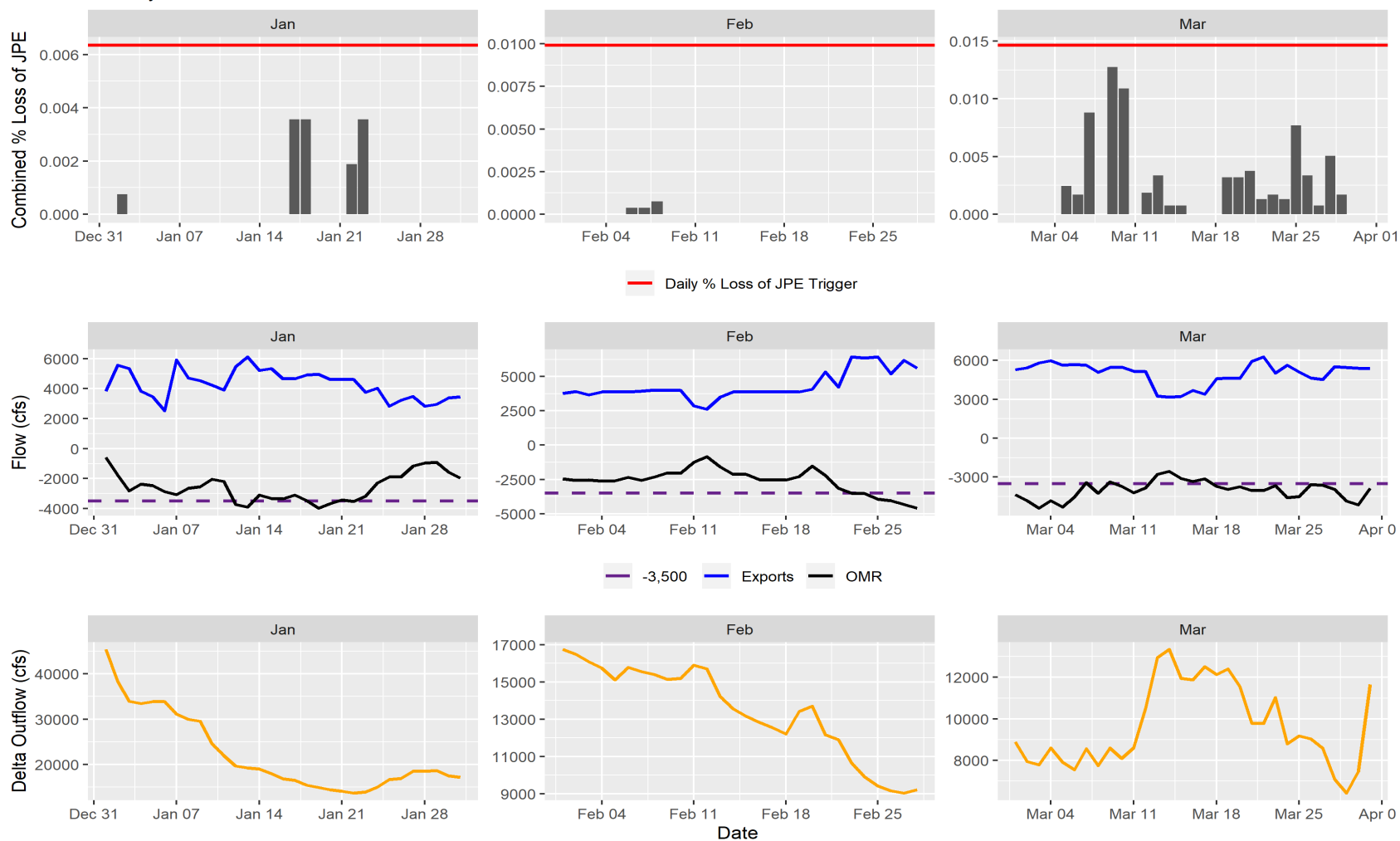


Figure 43: Daily Percent Loss of JPE Threshold Performance Plot for January-March 2013. Observed daily combined loss of LAD older juvenile Chinook salmon at SWP and CVP. Each month has its own daily percent loss of CHNWR JPE threshold. Daily Loss; January = 0.00635% of JPE, February = 0.00991%, March = 0.0146% of JPE, April = 0.00507% of JPE, and May = 0.0077% of JPE. The red lines in the top figures represent the daily percent loss of CHNWR JPE triggers. The bottom figures show historical combined exports at SWP and CVP, OMR flow, and Delta outflow for reference of hydrology during the times when loss was occurring.

Older Juvenile Chinook Salmon Daily Percent Loss of JPE Performance

April - May 2013

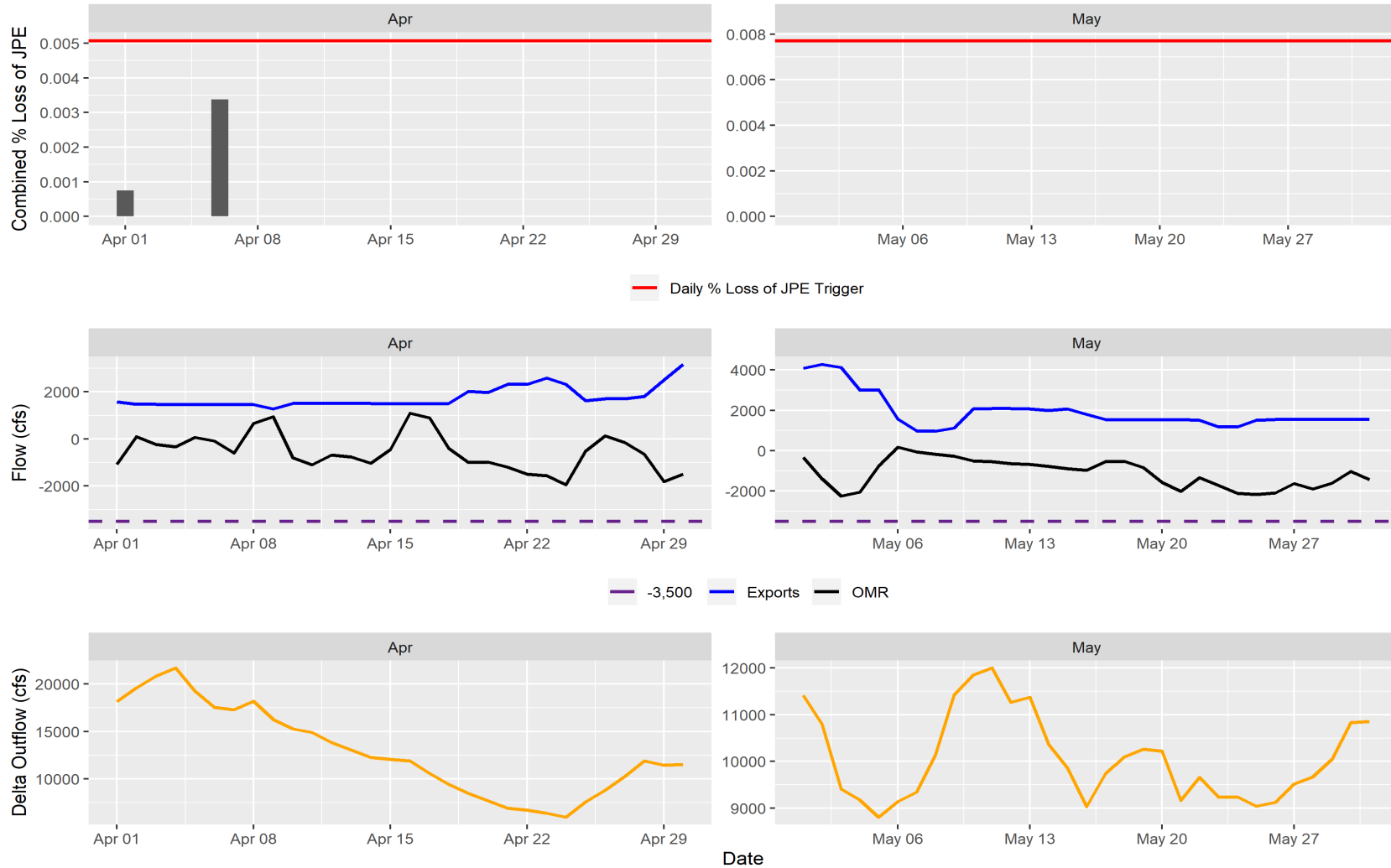


Figure 44: Daily Percent Loss of JPE Threshold Performance Plot for April-May 2013. Observed daily combined loss of LAD older juvenile Chinook salmon at SWP and CVP. Each month has its own daily percent loss of CHNWR JPE threshold. Daily Loss; January = 0.00635% of JPE, February = 0.00991%, March = 0.0146% of JPE, April = 0.00507% of JPE, and May= 0.0077% of JPE. The red lines in the top figures represent the daily percent loss of CHNWR JPE thresholds. The bottom figures show historical combined exports at SWP and CVP, OMR flow, and Delta outflow for reference of hydrology during the times when loss was occurring.

Older Juvenile Chinook Salmon Daily Percent Loss of JPE Performance

January - March 2014

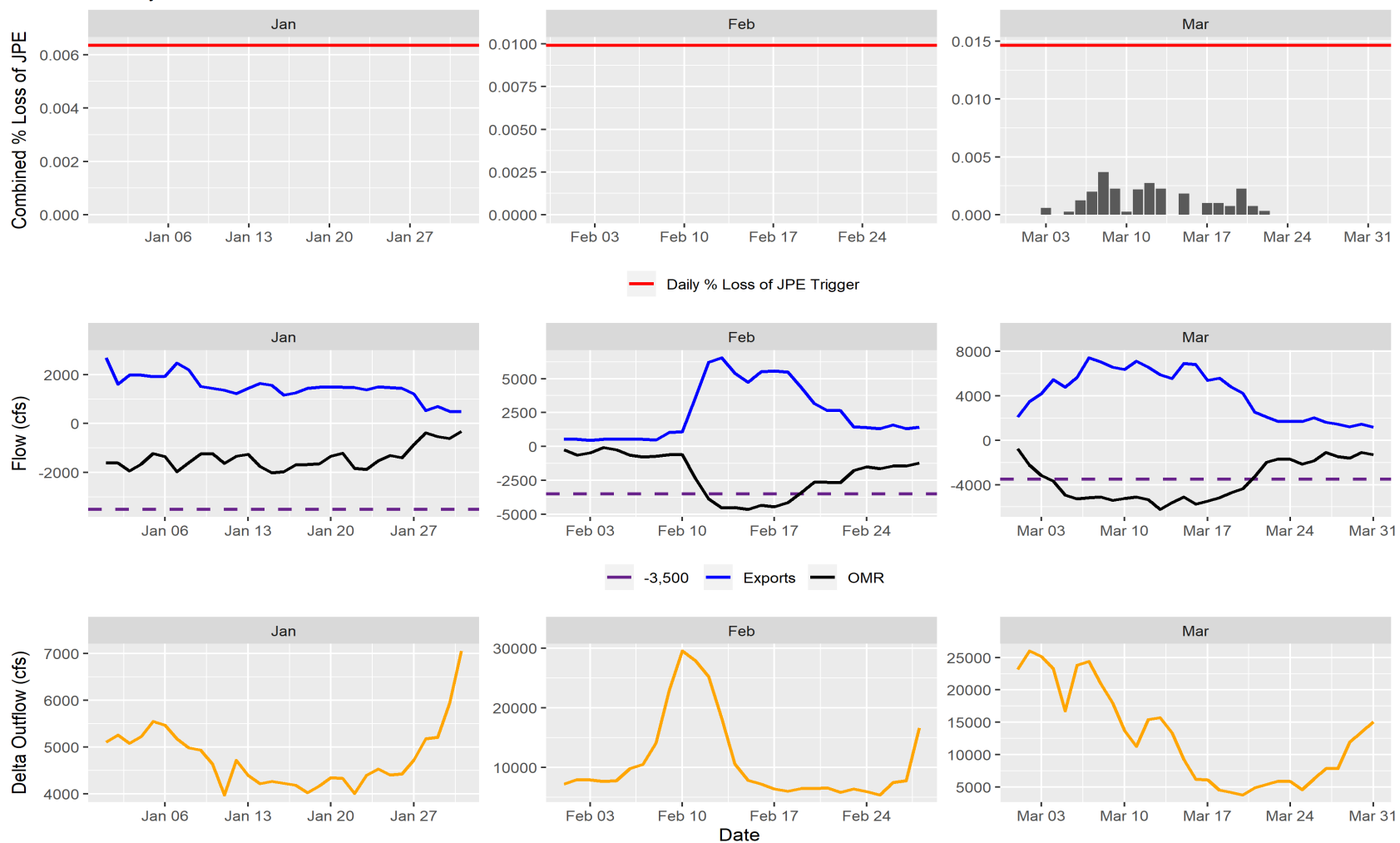


Figure 45: Daily Percent Loss of JPE Threshold Performance Plot for January-March 2014. Observed daily combined loss of LAD older juvenile Chinook salmon at SWP and CVP. Each month has its own daily percent loss of CHNWR JPE threshold. Daily Loss; January = 0.00635% of JPE, February = 0.00991% of JPE, March = 0.0146% of JPE, April = 0.00507% of JPE, and May = 0.0077% of JPE. The red lines in the top figures represent the daily percent loss of CHNWR JPE thresholds. The bottom figures show historical combined exports at SWP and CVP, OMR flow, and Delta outflow for reference of hydrology during the times when loss was occurring.

Older Juvenile Chinook Salmon Daily Percent Loss of JPE Performance

April - May 2014

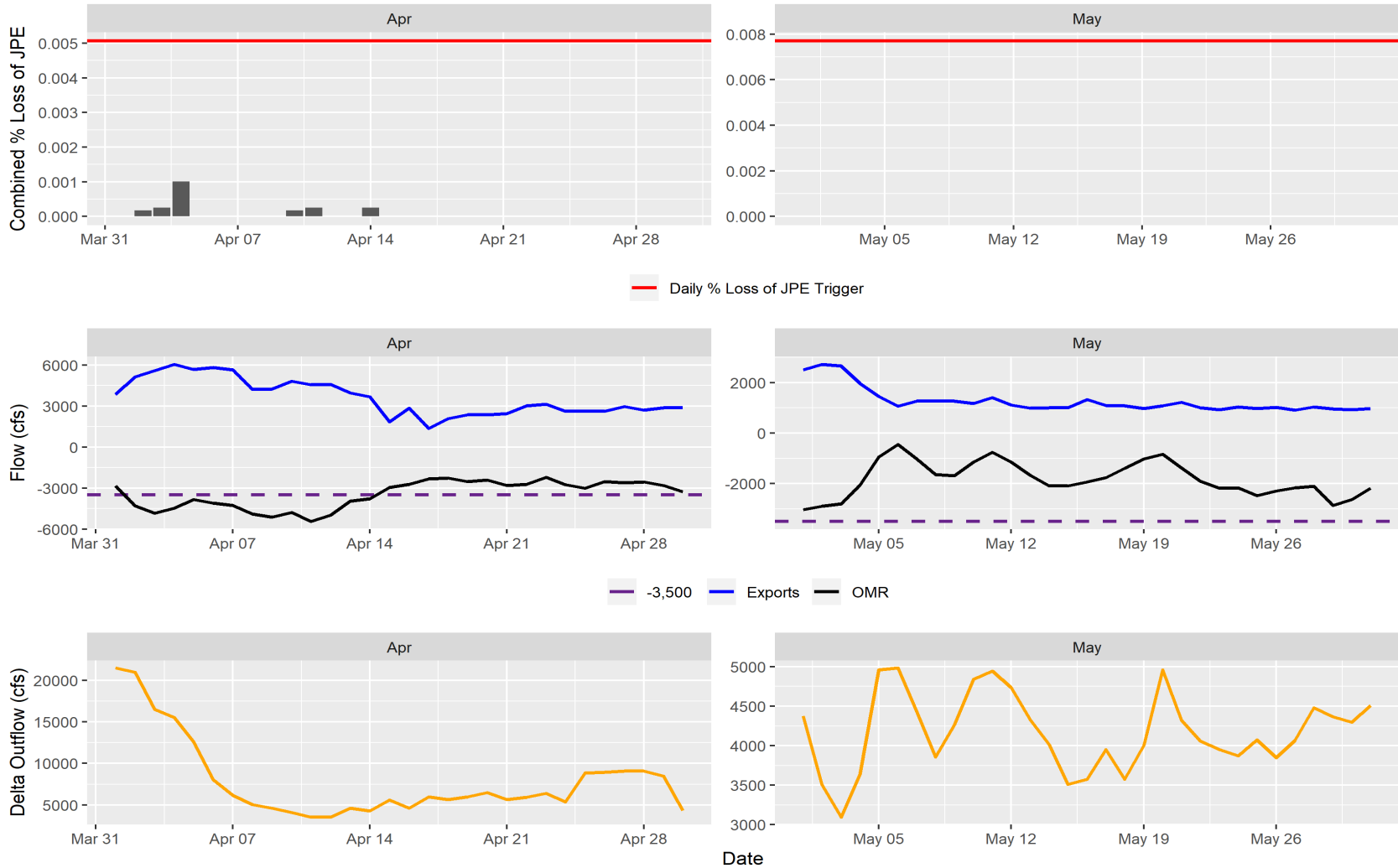


Figure 46: Daily Percent Loss of JPE Threshold Performance Plot for April-May 2014. Observed daily combined loss of LAD older juvenile Chinook salmon at SWP and CVP. Each month has its own daily percent loss of CHNWR JPE threshold. Daily Loss; January = 0.00635% of JPE, February = 0.00991%, March = 0.0146% of JPE, April = 0.00507% of JPE, and May= 0.0077% of JPE. The red lines in the top figures represent the daily percent loss of CHNWR JPE thresholds. The bottom figures show historical combined exports at SWP and CVP, OMR flow, and Delta outflow for reference of hydrology during the times when loss was occurring.

Older Juvenile Chinook Salmon Daily Percent Loss of JPE Performance January - March 2015

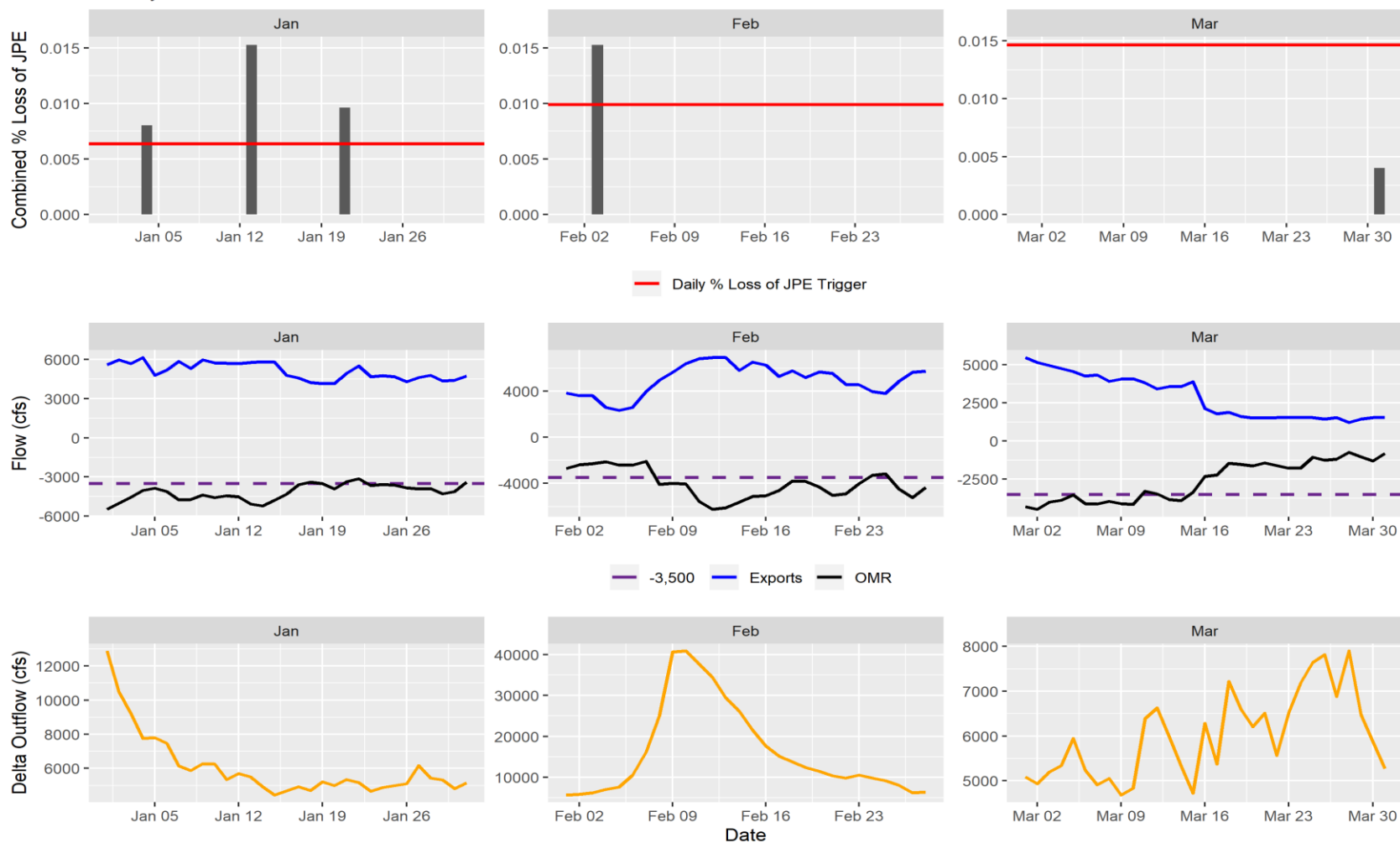


Figure 47: Daily Percent Loss of JPE Threshold Performance Plot for January-March 2015. Observed daily combined loss of LAD older juvenile Chinook salmon at SWP and CVP. Each month has its own daily percent loss of CHNWR JPE threshold. Daily Loss; January = 0.00635% of JPE, February = 0.00991%, March = 0.0146% of JPE, April = 0.00507% of JPE, and May = 0.0077% of JPE. The red lines in the top figures represent the daily percent loss of CHNWR JPE thresholds. The bottom figures show historical combined exports at SWP and CVP, OMR flow, and Delta outflow for reference of hydrology during the times when loss was occurring. No loss occurred in April or May.

Older Juvenile Chinook Salmon Daily Percent Loss of JPE Performance January - March 2016



Figure 48: Daily Percent Loss of JPE Threshold Performance Plot for January-March 2016. Observed daily combined loss of LAD older juvenile Chinook salmon at SWP and CVP. Each month has its own daily percent loss of CHNWR JPE threshold. Daily Loss; January = 0.00635% of JPE, February = 0.00991% of JPE, March = 0.0146% of JPE, April = 0.00507% of JPE, and May = 0.0077% of JPE. The red lines in the top figures represent the daily percent loss of CHNWR JPE thresholds. The bottom figures show historical combined exports at SWP and CVP, OMR flow, and Delta outflow for reference of hydrology during the times when loss was occurring. No loss occurred in April or May.

Older Juvenile Chinook Salmon Daily Percent Loss of JPE Performance

January - March 2017

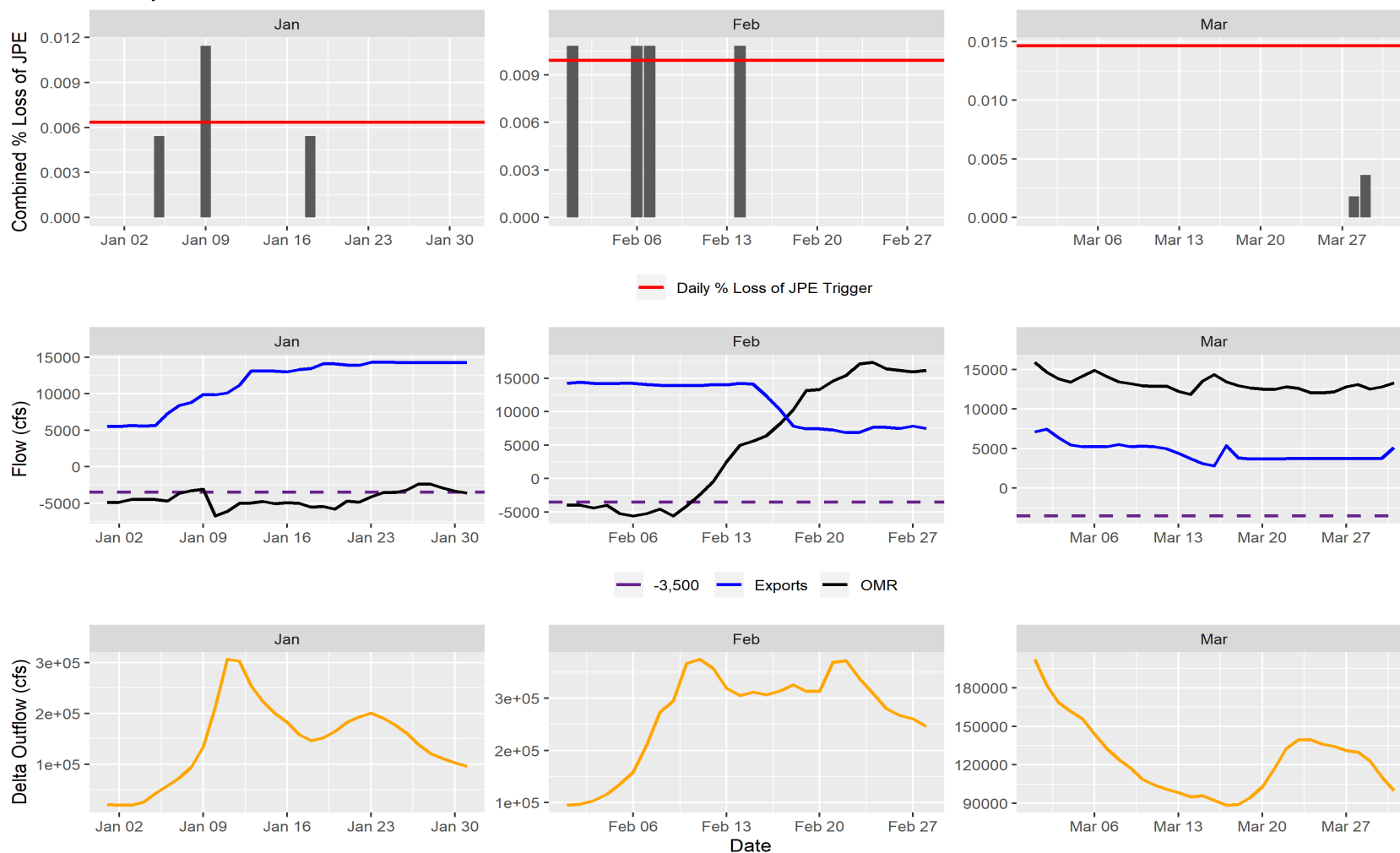


Figure 49: Daily Percent Loss of JPE Threshold Performance Plot for January-March 2017. Observed daily combined loss of LAD older juvenile Chinook salmon at SWP and CVP. Each month has its own daily percent loss of CHNWR JPE threshold. Daily Loss; January = 0.00635% of JPE, February = 0.00991%, March = 0.0146% of JPE, April = 0.00507% of JPE, and May = 0.0077% of JPE. The red lines in the top figures represent the daily percent loss of CHNWR JPE thresholds. The bottom figures show historical combined exports at SWP and CVP, OMR flow, and Delta outflow for reference of hydrology during the times when loss was occurring.

Older Juvenile Chinook Salmon Daily Percent Loss of JPE Performance

April - May 2017

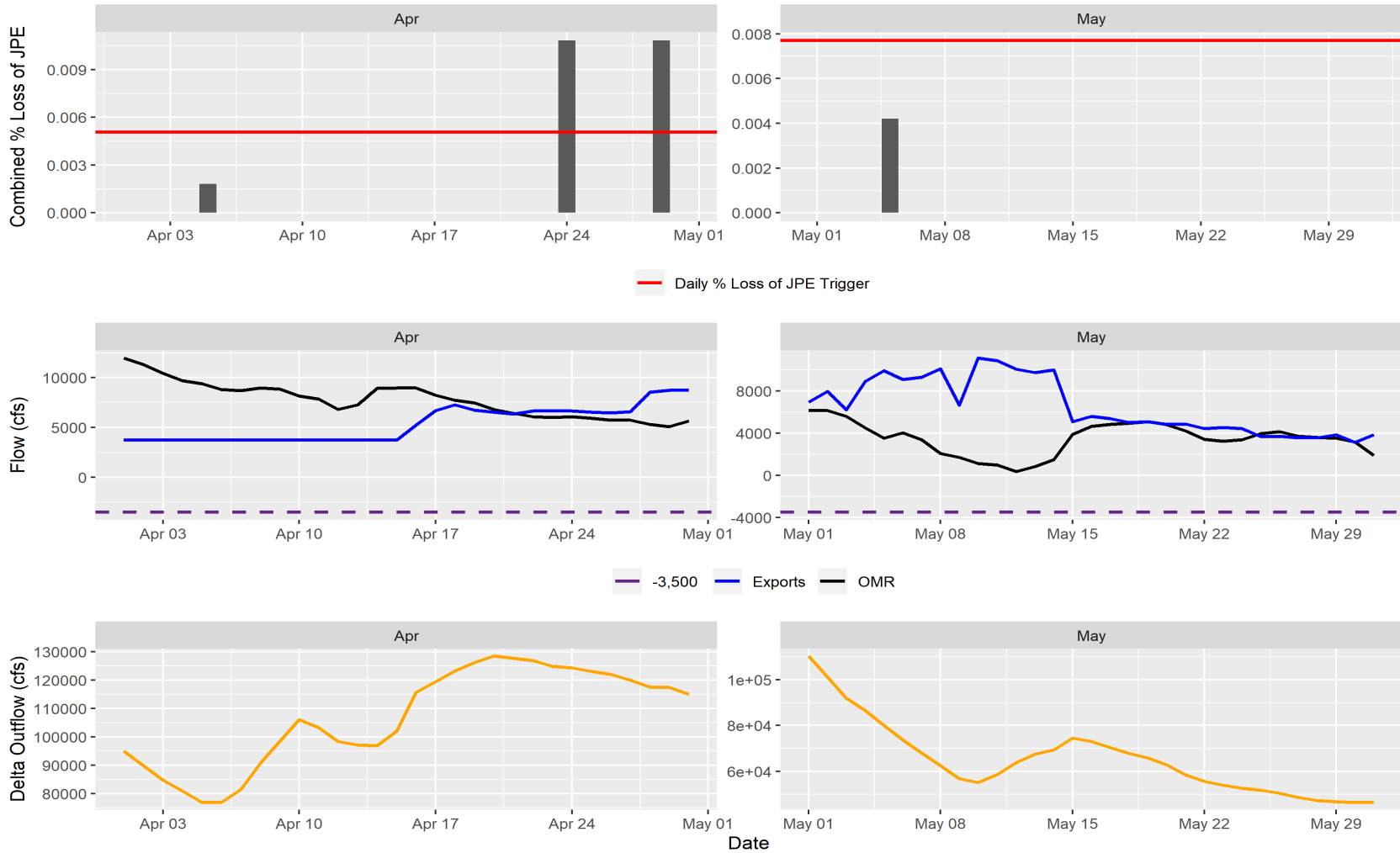


Figure 50: Daily Percent Loss of JPE Threshold Performance Plot for April-May 2017. Observed daily combined loss of LAD older juvenile Chinook salmon at SWP and CVP. Each month has its own daily percent loss of CHNWR JPE threshold. Daily Loss; January = 0.00635% of JPE, February = 0.00991%, March = 0.0146% of JPE, April = 0.00507% of JPE, and May= 0.0077% of JPE. The red lines in the top figures represent the daily percent loss of CHNWR JPE thresholds. The bottom figures show historical combined exports at SWP and CVP, OMR flow, and Delta outflow for reference of hydrology during the times when loss was occurring.

Older Juvenile Chinook Salmon Daily Percent Loss of JPE Performance January - March 2018

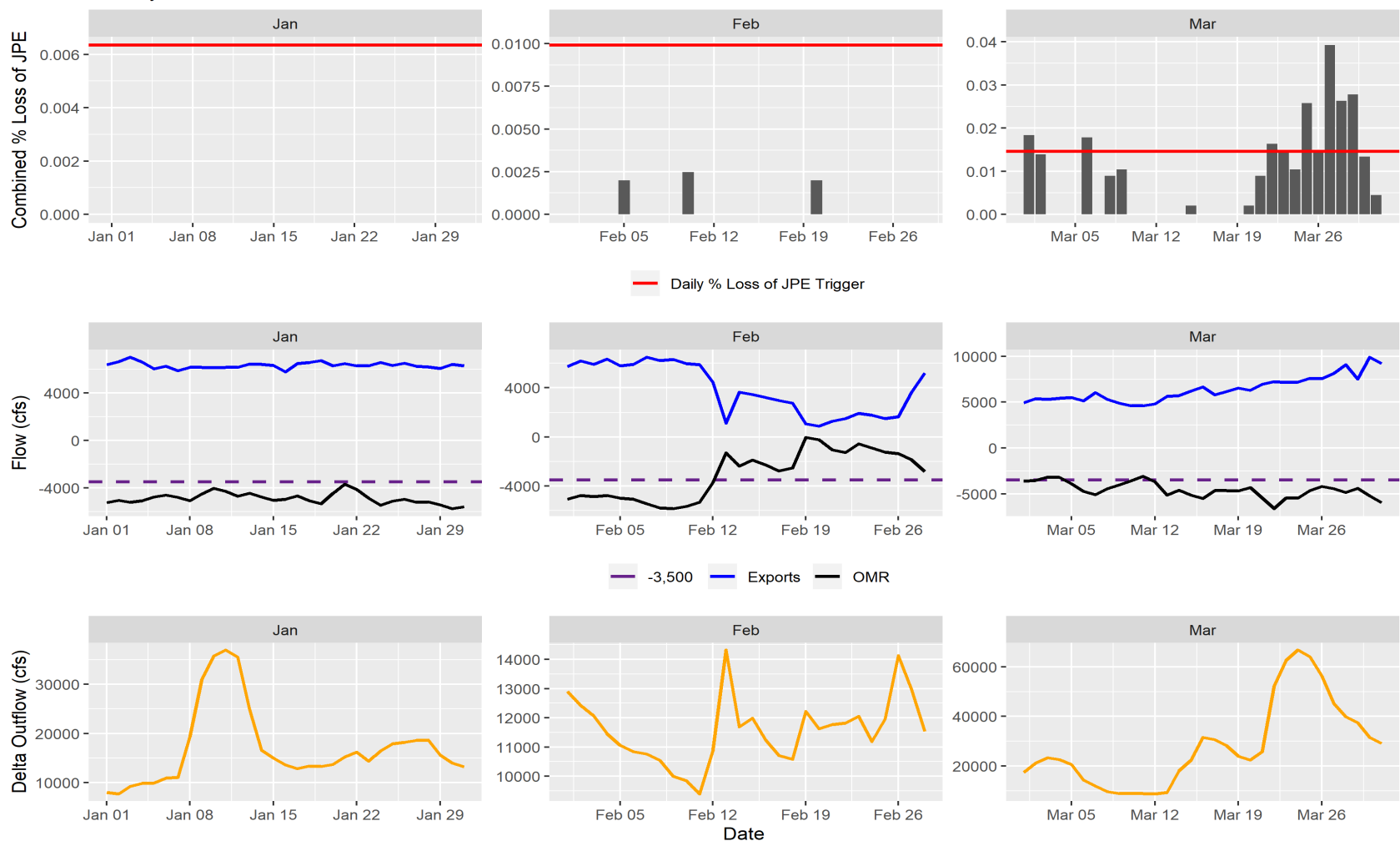


Figure 51: Daily Percent Loss of JPE Threshold Performance Plot for January-March 2018. Observed daily combined loss of LAD older juvenile Chinook salmon at SWP and CVP. Each month has its own daily percent loss of CHNWR JPE threshold. Daily Loss; January = 0.00635% of JPE, February = 0.00991%, March = 0.0146% of JPE, April = 0.00507% of JPE, and May = 0.0077% of JPE. The red lines in the top figures represent the daily percent loss of CHNWR JPE thresholds. The bottom figures show historical combined exports at SWP and CVP, OMR flow, and Delta outflow for reference of hydrology during the times when loss was occurring.

Older Juvenile Chinook Salmon Daily Percent Loss of JPE Performance

April - May 2018

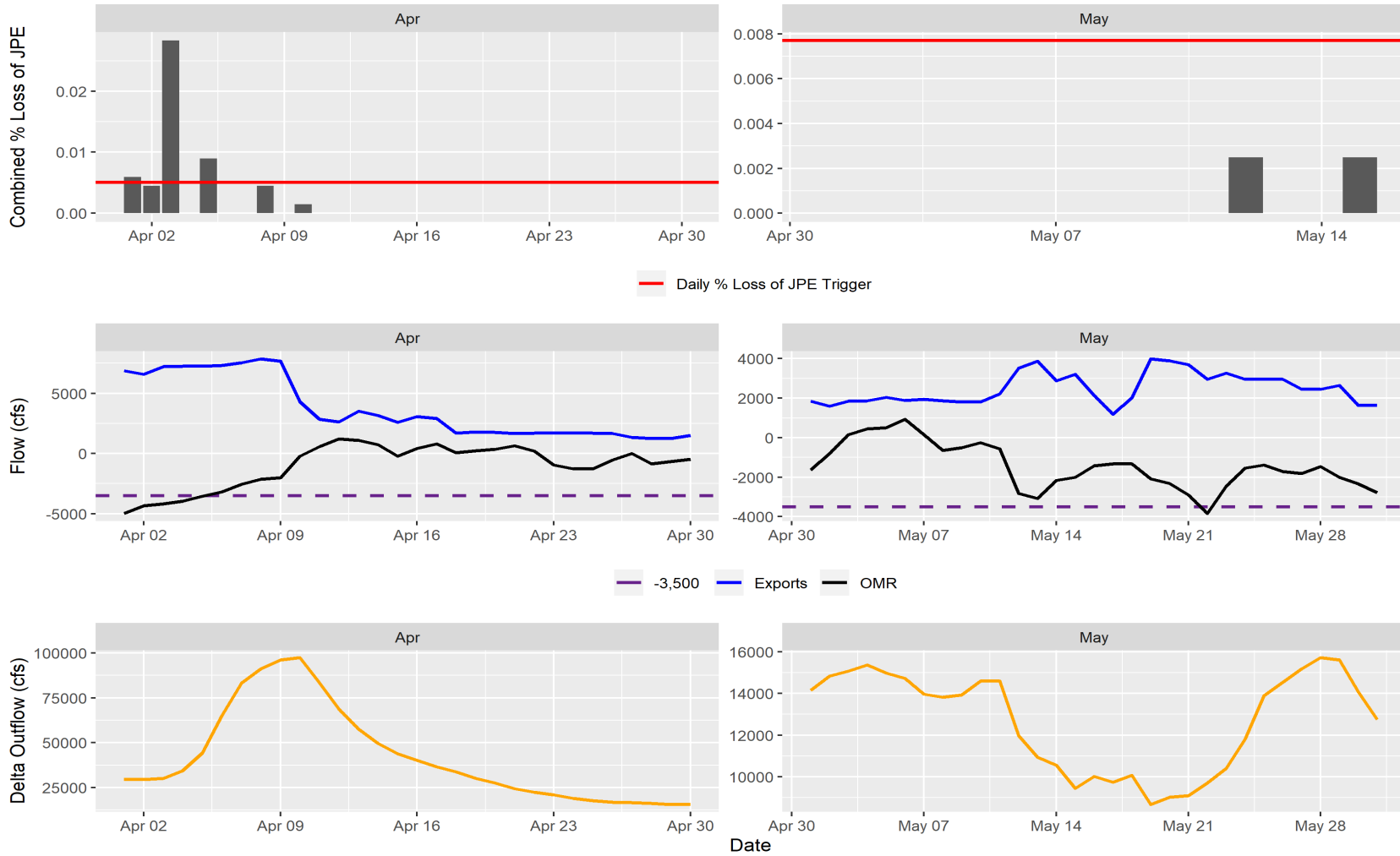


Figure 52: Daily Percent Loss of JPE Threshold Performance Plot for April-May 2018. Observed daily combined loss of LAD older juvenile Chinook salmon at SWP and CVP. Each month has its own daily percent loss of CHNWR JPE threshold. Daily Loss; January = 0.00635% of JPE, February = 0.00991%, March = 0.0146% of JPE, April = 0.00507% of JPE, and May = 0.0077% of JPE. The red lines in the top figures represent the daily percent loss of CHNWR JPE thresholds. The bottom figures show historical combined exports at SWP and CVP, OMR flow, and Delta outflow for reference of hydrology during the times when loss was occurring.

8.14.4. Discussion

The single-year loss threshold would have provided protections for juvenile natural CHNWR in two years during the 2010-2018 time period in late February and March. However, this measure would not have preserved the different life history strategies earlier in the migration season (November-February). The single-year loss threshold only provides minimization through OMR restrictions when the 50% and 75% of the threshold and the threshold are exceeded, usually later in the natural CHNWR migration season in late February and March. The single-year loss threshold does not provide OMR restrictions for the majority of the peak salvage season of CHNWR, January through March. Thus, managing to the single-year loss threshold alone allows for a large amount of juvenile CHNWR loss to occur during their emigration period through the Delta.

Migration and salvage of CHNWR occurs earlier than YOY CHNSR. Salvage and loss of YOY CHNSR peak near the end of the salvage and loss season of CHNWR. The level of protectiveness that the natural CHNWR single-year threshold provides for YOY CHNSR is unclear, however it has the potential to decrease entrainment with reduced OMR flows earlier in their migration and salvage period during February and March.

The daily percent loss of CHNWR JPE threshold developed by CDFW would likely minimize take earlier in the migration season (January and February) than the single-year loss threshold and contribute to preserving life history diversity within CHNWR. The daily loss threshold would minimize take of juvenile natural CHNWR and yearling CHNSR (older juveniles) by requiring reductions in exports to achieve an OMR index no more negative than -3,500 cfs on a five-day average. YOY CHNSR may also receive protections if this measure is triggered when YOY CHNSR are present in the interior Delta (January through June; peak presence March through May). However, the level of protection for CHNSR is uncertain and was not analyzed in this analysis of Conditions of Approval 8.6.1 and 8.6.3.

When the daily percent loss of the CHNWR JPE is greater than or equal to the daily loss threshold, OMR restrictions would be required. Specifically, Permittee would be required to reduce OMR to achieve an average net OMR flow value of -3,500 cfs for five consecutive days (Table 25). OMR flow reductions would help to avoid additional entrainment of fish, and therefore reduce the amount of loss at the salvage facilities. In the ITP Application and Alternative 2b, Permittee committed to avoid exceeding the proposed single-year loss thresholds. These additional daily loss thresholds developed by CDFW are intended to more evenly distribute loss over the migration season, to avoid reaching the 50% and 75% thresholds and exceeding the single-year loss thresholds. In combination with the single-year loss threshold (Condition of Approval 8.6.1) for natural CHNWR, the mid- to late-season CHNWR daily loss threshold will minimize entrainment of natural CHNWR and yearling CHNSR into the south Delta and export facilities and thus minimize take of Covered Species.

Date	Minimization Threshold	Threshold Response
January 1 – January 31	Daily percent loss of WR JPE is greater than or equal to 0.00635% .	Reduce exports to achieve an average net OMR flow of -3,500 cfs for a minimum of 5 consecutive days.
February 1 – February 28	Daily percent loss of WR JPE is greater than or equal to 0.00991% .	
March 1 – March 31	Daily percent loss of WR JPE is greater than or equal to 0.0146% .	
April 1 – April 30	Daily percent loss of WR JPE is greater than or equal to 0.00507% .	
May 1 – May 31	Daily percent loss of WR JPE is greater than or equal to 0.0077% .	

Table 25: Minimization Thresholds for Older Juvenile Chinook Salmon. Daily loss threshold values for each month calculated as the percentage of the CHNWR JPE and corresponding OMR reduction requirements when exceeded.

8.15. Condition of Approval 8.6.1 – Single-year Loss Threshold – Hatchery Winter-Run Chinook Salmon

8.15.1. Introduction

Condition of Approval 8.6.1, Single-year Loss Threshold, requires Permittee to restrict OMR flows to minimize take of natural and hatchery-origin CHNWR. This analysis focuses on the extent to which take and impacts of the taking on CHNWR are minimized through implementation of the single-year loss threshold for hatchery-origin CHNWR loss as described below. An analysis for the proposed natural CHNWR single-year loss threshold is provided in Section 8.14 of this document. The single-year loss threshold for hatchery-origin CHNWR as described in Condition of Approval 8.6.1 is equivalent to loss of 0.12% of the JPE. If 50% of the single-year loss threshold is exceeded, OMR would be restricted to a 14-day moving average of no more negative than -3,500 cfs for at least 14 days. If 75% of a single-year loss threshold is exceeded, OMR would be restricted to a 14-day moving average of no more negative than -2,500 cfs for at least 14 days.

NMFS estimates a JPE for hatchery CHNWR annually, which is used to determine the authorized level of incidental take for hatchery CHNWR under Section 7 of the ESA, for operation of the CVP/SWP pumping facilities in the south Delta. The annual JPE for hatchery CHNWR is estimated using hatchery production and survival rates (i.e., acoustic telemetry subsamples) from release to Delta entry (i.e., Tower Bridge, Sacramento, CA). Historical hatchery CHNWR JPEs are provided in Table 26.

Water Year	Hatchery CHNWR JPE
1995	43,000
1996	60,000
1997	5,000
1998	42,000
1999	154,000
2000	30,000
2001	166,000
2002	252,684
2003	121,617
2004	114,400
2005	92,748
2006	94,913
2007	107,239
2008	38,290
2009	82,050
2010	108,725
2011	66,734
2012	96,525
2013	96,525
2014	308,880
2015	188,500
2016	155,400
2017	58,188
2018	92,904

Table 26. Annual hatchery CHNWR JPE for water years 1995-2018.

8.15.2. Methods

For this analysis, salvage data of CWT CHNWR collected at the SWP and CVP salvage facilities from water years 2010 to 2018 was used to evaluate the effectiveness of the single-year hatchery-origin CHNWR loss threshold. Salvage data was gathered from the CDFW Bay-Delta Region salvage database (CDFW 2019) and loss was calculated using the loss equation (CDFW 2018 and Attachment 6 to the ITP).

The single-year loss threshold for hatchery-origin CHNWR (0.12% of the JPE) was applied to hatchery-origin CHNWR loss data from water years 2010 to 2018 to evaluate the effectiveness during this time period based on the number of times the 50% and 75% of the threshold were exceeded as well as the threshold. This was evaluated by calculating the single-year loss threshold of 0.12% of the JPE, as well as calculating 50% and 75% of the loss thresholds for each year and comparing these numbers to the actual loss that occurred.

8.15.3. Results

The single-year loss threshold for hatchery-origin CHNWR would have provided protections via OMR reductions in 2010 and 2018. Table 27 provides a summary for each water year, including the single-year loss threshold using the 0.12% of the JPE, the observed loss, and the 50% and the 75% loss thresholds.

Water Year	JPE	50% Threshold	75% Threshold	Single-Year Loss Threshold (0.12% of JPE)	Total Observed Loss
2010	108,725	65	98	130	146
2011	66,734	40	60	80	0
2012	96,525	58	87	116	17
2013	96,525	58	87	116	9
2014	30,880	19	28	37	0
2015	188,500	113	170	226	9
2016	148,000	89	133	178	12
2017	58,188	35	52	70	0
2018	92,904	56	84	111	56

Table 27: Single-year Loss Thresholds for Hatchery-Origin CHNWR. Single-year loss thresholds calculated for hatchery-origin CHNWR with 50% and 75% of the loss threshold shown. The total observed loss is combined loss of LSNFH CHNWR at SWP and CVP.

In water year 2010, observed LSNFH CHNWR loss exceeded the 50%, 75%, and single-year loss threshold (Figure 53). The 50% loss threshold would have been exceeded around March 7 and the 75% loss threshold would have been exceeded around March 8 (Figure 54). The single-year loss threshold would have been exceeded around March 10, just two days after the 75% threshold. The single-year loss threshold would have been exceeded by a total of 16 fish.

In water year 2018, observed LSNFH CHNWR loss exceeded the 50% threshold around April 9 (Figure 53). This was also the last day of loss for 2018, no other thresholds were exceeded.

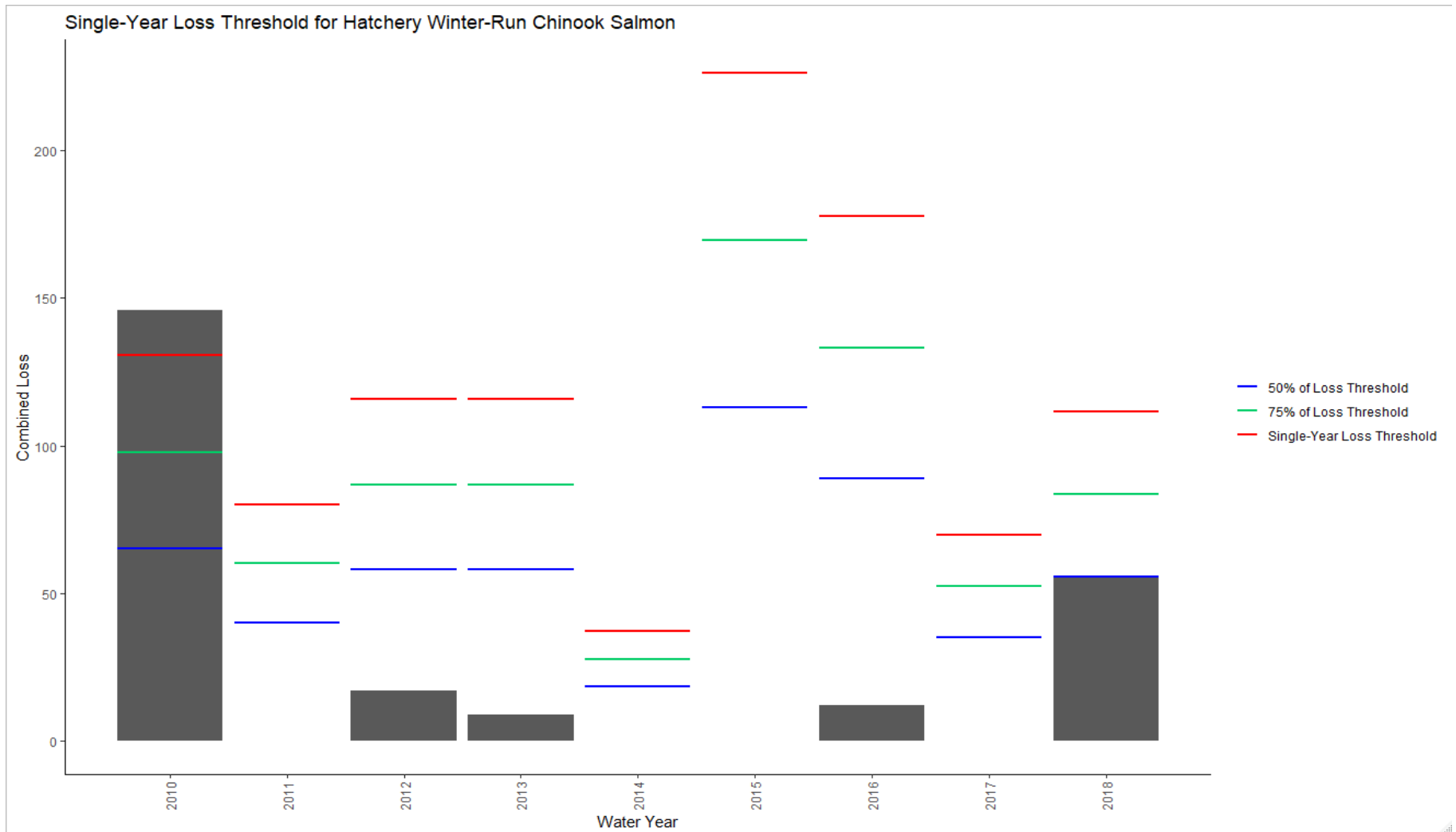


Figure 53: Hatchery-Origin CHNWR Single-year Loss Threshold. Observed loss of CWT LSNFH CHNWR from SWP and CVP (2010-2018) (grey bars). The blue lines represent the 50% loss threshold calculated for each year; any loss that exceeds these blue lines represents when the 50% loss threshold would have been exceeded. The green lines represent the 75% loss threshold calculated for each year; any loss that exceeds these green bars represents when the 75% loss threshold would have been exceeded. The red lines represent the single-year loss threshold that is set for each year (0.12% of the JPE); any loss that exceeds the red line represents when the single-year loss threshold would have been exceeded.

Cumulative Loss of Hatchery Winter-run Chinook Salmon

March 01-March 15, 2010

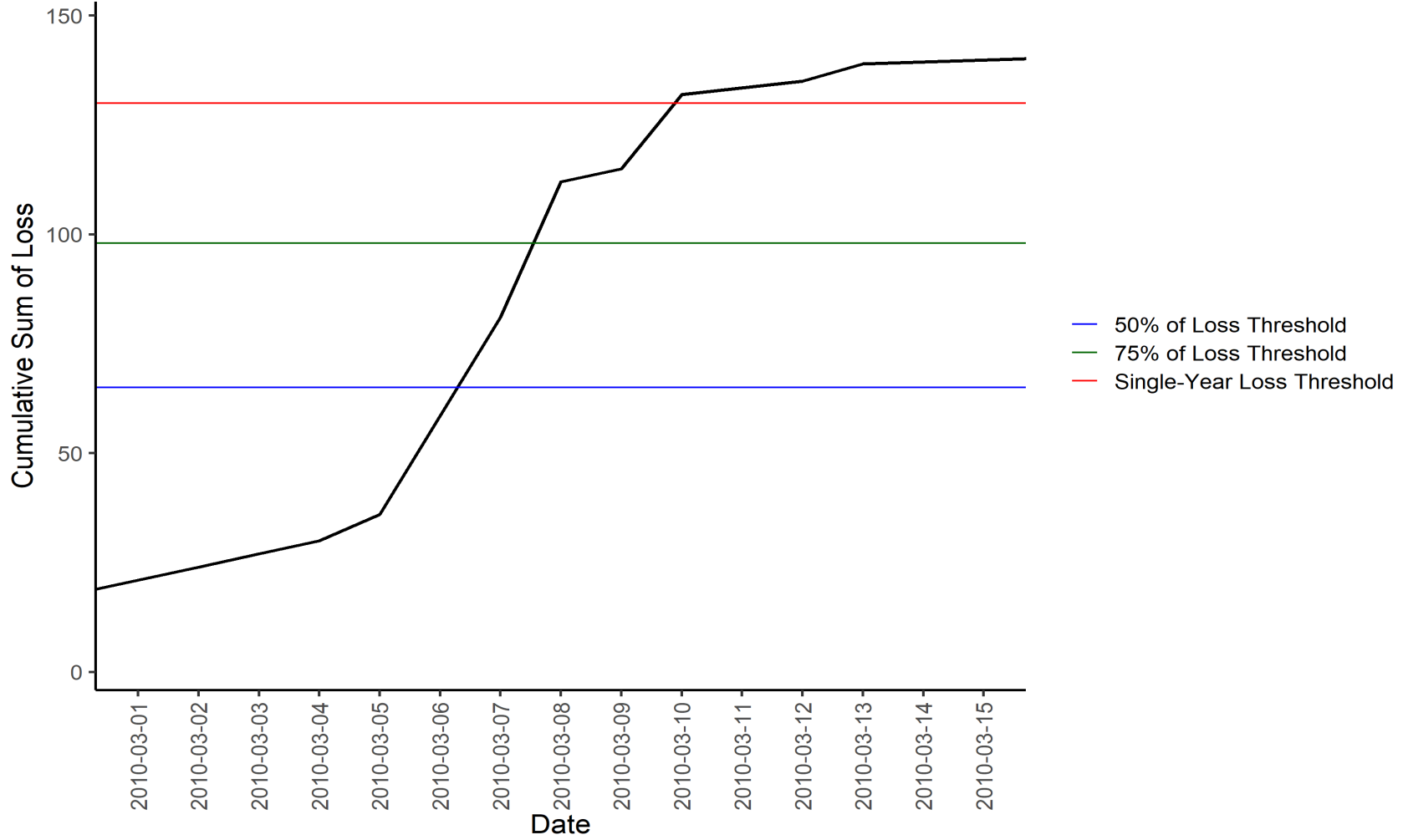


Figure 54: Hatchery-Origin CHNWR Single-year Loss Threshold Performance Plot 2010. Combined cumulative loss of CWT LSNFH CHNWR from March 01 – March 15, 2010. The blue line is the 50% threshold and the green line is the 75% threshold. The red line is the single-year loss threshold that was set for water year 2010 (0.12% of the JPE).

8.15.4. Discussion

Historically, loss of CWT LSNFH CHNWR has been low at both the SWP and CVP (Table 28) relative to loss of natural CHNWR.

Water Year	SWP	CVP	Total Loss
1999	72	0	72
2000	27	0	27
2001	54	0	54
2002	44	7	51
2003	497	53	550
2004	614	51	665
2005	27	7	34
2006	80	46	126
2007	27	16	43
2008	54	18	72
2009	0	13	13
2010	79	68	147
2011	0	0	0
2012	17	0	17
2013	9	0	9
2014	0	0	0
2015	9	0	9
2016	0	12	12
2017	0	0	0
2018	53	3	56

Table 28. Historical observed loss of CWT LSNFH CHNWR at SWP and CVP.

Condition of Approval 8.6.1 in the ITP would have provided more protections during 2010-2018 than the minimization measure for hatchery-origin CHNWR in the 2009 NMFS BiOp (Action IV.2.3 of the 2009 NMFS BiOp). Loss of LSNFH CHNWR never exceeded 0.5% of the release groups during implementation of the 2009 NMFS BiOp. Condition of Approval 8.6.1 in the ITP reduces the combined allowed loss threshold at SWP and CVP for CWT LSNFH CHNWR from 0.5% to 0.12%. Thus, take of hatchery-origin CHNWR is likely to be minimized by the single-year loss threshold, and provide additional minimization as compared to the NMFS 2009 BiOp. Additionally, OMR restrictions to -3,500 cfs and -2,500 cfs when 50% and 75% of the hatchery-origin CHNWR single-year loss threshold are exceeded will minimize entrainment of fish into the south Delta and salvage facilities. Further, by reducing additional entrainment of fish into the zone of entrainment, OMR flow reductions will ultimately help to reduce the amount of fish loss at the salvage facilities.

8.16. Condition of Approval 8.6.4 – Daily Spring-run Chinook Salmon Hatchery Surrogate Loss Threshold

Since the implementation of the 2009 NMFS BiOp and CDFW Consistency Determinations, take of LAD CHNSR has been as high as 73,800 in a season (CDFW 2019c). Changes to Project operations and Delta hydrology, including more negative OMR and increased exports as described in the FEIR, are expected to result in an increase in CHNSR take at the SWP south Delta export facilities (see Section 7.3.5 – Salvage Density Method Analysis above). To minimize take as a result of entrainment into the interior and south Delta and the Banks Pumping Plant, the ITP includes requirements to improve our understanding of CHNSR production and entrainment, and operational thresholds based on loss of CHNSR hatchery surrogates.

Several factors contribute to the challenge of developing specific measures to minimize take of CHNSR at the salvage facilities, including the current lack of rapid genetic testing, misidentification of runs based on LAD criteria (Fisher 1992 and USFWS 1997), and the absence of an annual abundance estimate. YOY CHNSR entering the Sacramento River and Delta often do not fit the LAD criteria because growth rates are dependent on food availability and water temperatures. Variations in seasonal water temperatures and presence of prey food items within accessible rearing habitat means that not all juvenile salmonids experience the same conditions while developing. This leads to an array of growth rates which makes pinpointing a race based on length difficult. RST data from Deer, Mill, and Butte Creeks show that YOY CHNSR most often fall into the CHNFR size range, with very few measuring as CHNSR using the LAD criteria (Figures 55-57).

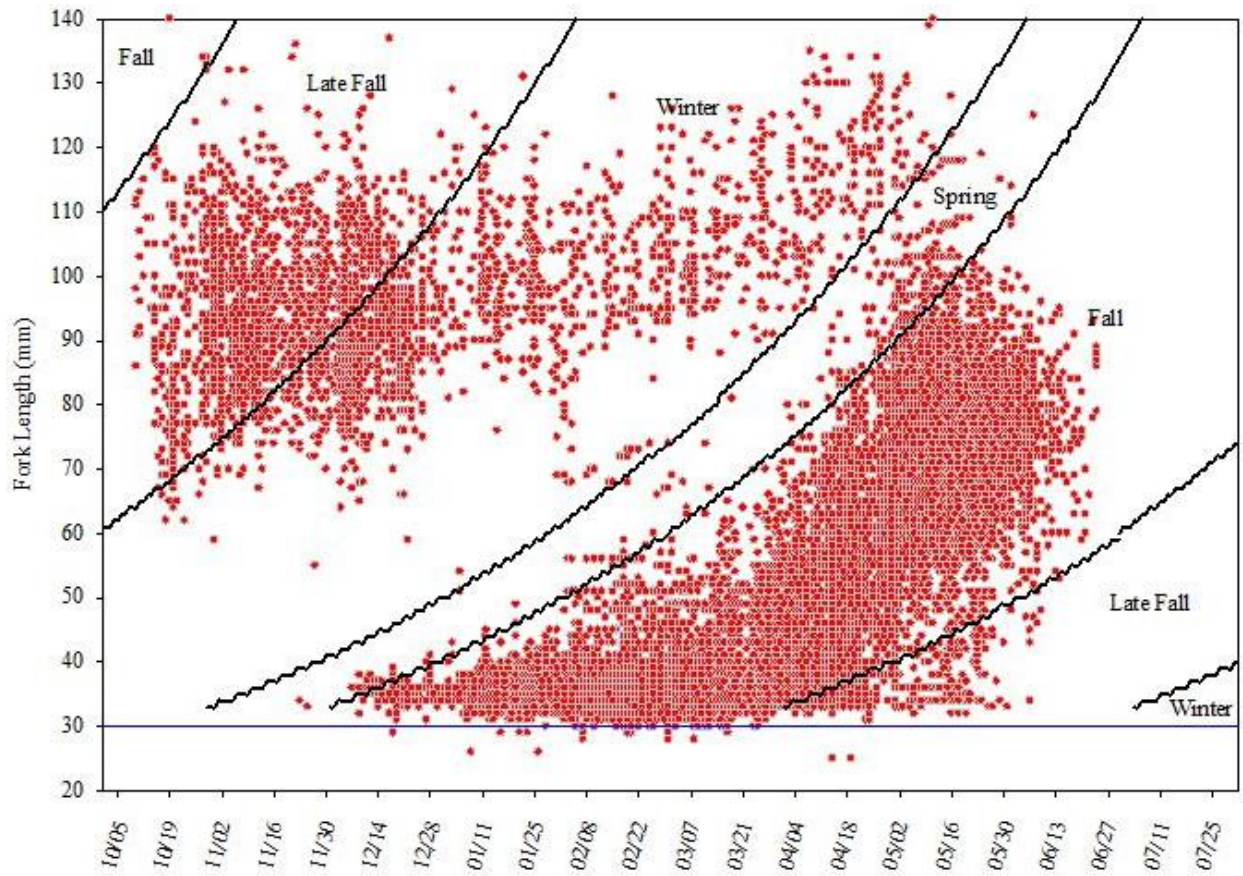


Figure 55. Mill Creek juvenile Chinook salmon RST catches October through June for years 1995-2010 plotted against Fisher (1992) growth curves, illustrating how the Fisher growth chart (LAD criteria) can incorrectly assign juvenile Mill Creek Chinook salmon by race (Johnson and Merrick 2012).

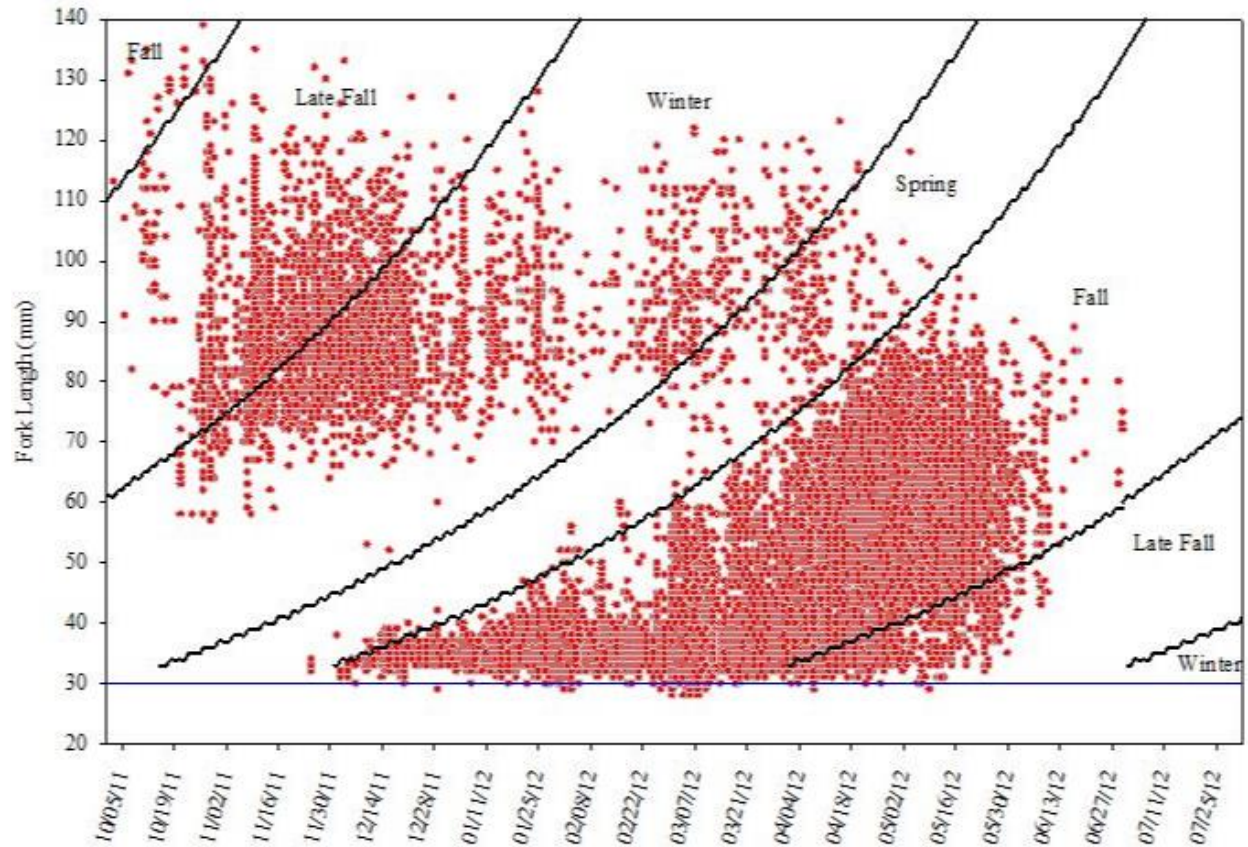


Figure 56. Deer Creek juvenile Chinook salmon RST catches October through June for years 1994-2010 plotted against Fisher (1992) growth curves, illustrating how the Fisher growth chart (LAD criteria) can incorrectly assign juvenile Deer Creek Chinook salmon by race (Johnson and Merrick 2012).

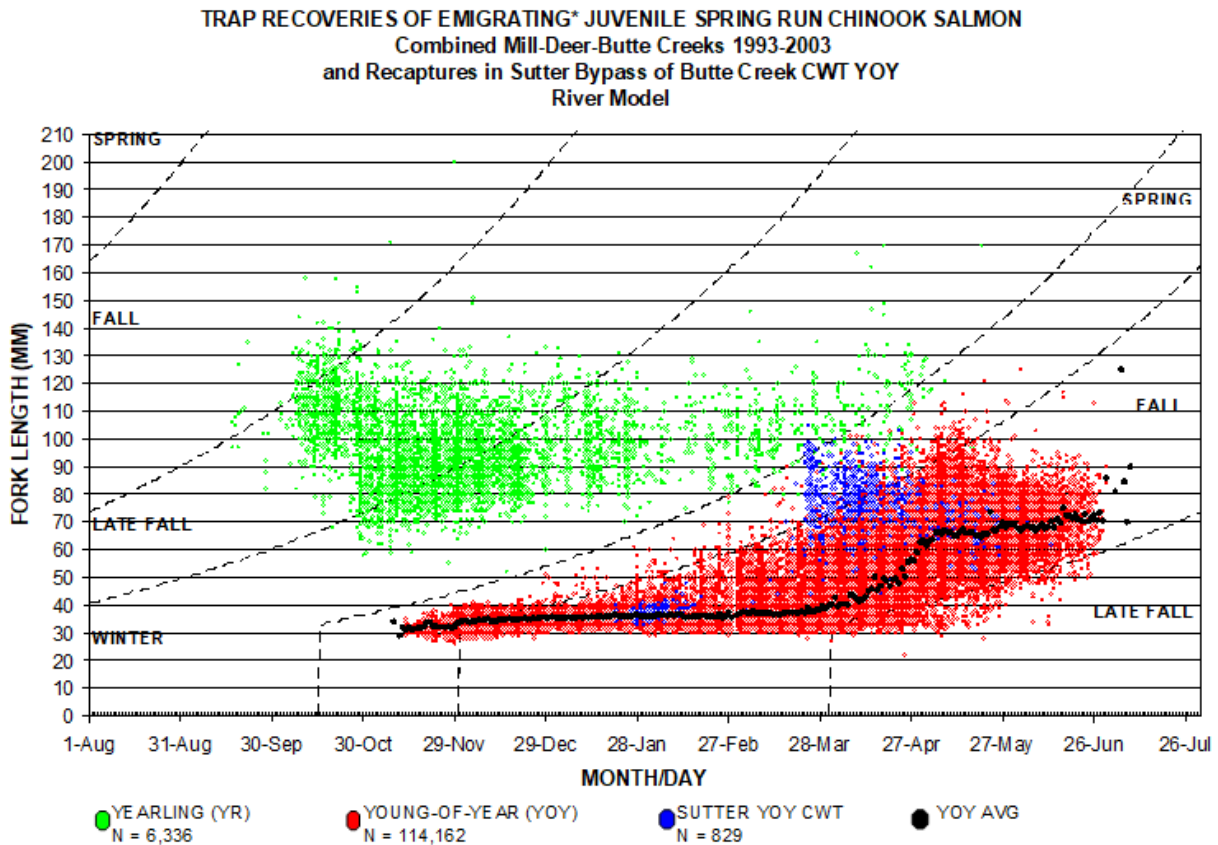


Figure 57. Combined Mill, Deer, and Butte Creek juvenile Chinook salmon RST catches August through June for years 1993-2003 plotted against Fisher (1992) growth curves, illustrating how the Fisher growth chart (LAD criteria) can incorrectly assign Butte Creek juvenile Chinook salmon by race (CDFW unpublished data).

CHNSR salvaged at the SWP and CVP export facilities cannot be definitively identified without genetic testing of all unclipped Chinook salmon observed. Conducting rapid genetic analyses on all observed unclipped juvenile Chinook salmon, which has historically peaked at 687 fish⁶ in one day, is not currently feasible. As shown above, due to size overlap of the four races, the LAD criteria can lead to both false negative and false positive CHNSR identification. For example, if minimization measures were implemented for CHNSR based on their presence in salvage using the LAD criteria rather than rapid genetics, measures could frequently be triggered by the presence of other runs (mainly CHNFR) that were falsely identified as CHNSR. Conversely, CHNSR may measure as a different run based on the LAD criteria and be falsely identified as another race (mainly CHNFR) and thus not trigger the minimization measure. In addition, unlike CHNWR, there is currently no methodology available to calculate a JPE for CHNSR, thus salvage or loss specific measures cannot be developed for CHNSR (as they as for CHNWR) based on estimated abundance of the species.

Hatchery practices currently time in-river releases of CHNSR and CHNFR production groups with favorable emigration conditions, such as rain events, that lead to increased turbidity and river flow. The

⁶ Observed on April 4, 2000. This is the highest number of unclipped Chinook salmon observed (i.e., prior to calculating an expanded salvage count) in one day at the SWP and CVP salvage facilities between January 1, 1993 and March 8, 2020 (CDFW 2020d).

timing of these production releases also spans the timing of natural origin CHNSR emigration which is triggered by these same environmental cues. Upstream monitoring sites including Tisdale and Knights Landing RSTs along with Sacramento River beach seines and trawls have demonstrated that CHNSR comingle with the hatchery release groups (along with naturally produced CHNFR) as they emigrate downstream (Jason Julienne personal communication 1/2020; CalFish 2019); however, their numbers are few in comparison. When these groups of emigrating and rearing fish are observed at the salvage facilities, only genetic analyses will distinguish CHNSR from natural and hatchery produced Chinook salmon of similar size. In the absence of rapid genetic testing of CHNFR observed at the salvage facilities, it is difficult to identify true CHNSR that fall outside of the CHNSR LAD range to implement protective measures. Both hatchery produced Chinook salmon and natural origin CHNSR emigrating into and through the Delta experience the same hydrology and effects from Project operations. As a result, in-river hatchery releases are suitable for use as surrogates to quantify loss and take of CHNSR as a result of Project operations.

Releases of CHNSR and CHNFR, that closely match the size and timing of natural CHNSR emigrating from the Sacramento River and its tributaries through the Delta, can be utilized as surrogates for emigration and presence of Sacramento Basin natural CHNSR at the fish salvage facilities. As shown in Figures 55-57, YOY CHNSR from Deer, Mill, and Butte Creeks are most often classified as CHNFR using the LAD criteria. Data collected from Coleman National Fish Hatchery (CNFH) CHNFR production releases occurring in late March show that the average FL of these releases are similar to that of the CHNSR exiting Deer, Mill, and Butte Creeks. Additionally, the average fork length of CHNFR releases from FRFH and Nimbus Fish Hatchery (NFH) are of similar size to that of CHNFR releases from CNFH (Jason Julienne personal communication 3/2020). Natural YOY CHNSR generally enter the Delta during the April/May period when federal and State hatcheries are conducting in-river production releases.

The presence of CHNSR hatchery surrogates in salvage will be used to make adjustments to exports and OMR flows to reduce subsequent entrainment and salvage at the export facilities per Condition of Approval 8.6.4 in the ITP. Specifically, Conditions of Approval 8.6.4 and 8.6.5 require Permittee to support the release of CWT CHNSR hatchery surrogate in-river releases from the FRFH, NFH, and CNFH. If cumulative loss of any in-river surrogate release group exceeds 0.25%, Permittee is required to restrict exports to maintain an OMR of -3,500 cfs for five consecutive days. This minimization measure is consistent with the use of CNFH CHNFR releases as surrogates for older juvenile Chinook salmon under Action IV.2.3 of the 2009 NMFS BiOp, which required OMR flow reductions when 0.5% loss of surrogate groups was observed at the salvage facilities. The 0.25% threshold in Condition of Approval 8.6.4 was developed considering the yearling CHNSR surrogate minimization measure established at 0.5% in NMFS 2009 and the associated CDFW Consistency Determination and incorporating reach-specific survival estimates for YOY CHNSR in the upper Sacramento River and Feather River. The intent was to establish a loss threshold and minimization measure based on the number of fish estimated to be entering the Delta and not solely on the release group size. Studies have indicated estimated loss of juvenile salmon is 40% in the upper Sacramento River (Notch et al. 2020) and 6-70% in the Feather River prior to Delta entry (Colin Purdy personal communication 3/2020). By assuming the same take limit for YOY CHNSR surrogates as for yearling CHNSR surrogates (1%), as was relied upon in the NMFS 2009 BiOp and CDFW Consistency Determination, and incorporating estimated survival between release sites and Delta entry (estimated at 50%), the threshold for YOY CHNSR surrogates was established at 0.25%. In the absence of a CHNSR JPE, the use of CHNSR hatchery surrogates along with enhanced juvenile monitoring (see

Condition of Approval 7.5.2 in the ITP and discussed in Section 8.23 of this Effects Analysis) can be used to minimize take of natural Sacramento Basin CHNSR.

8.17. Condition of Approval 8.6.5 - Funding for Spring-run Hatchery Surrogates

Committing funds to secure the annual production, tagging and release of the CHNSR hatchery surrogates is necessary to ensure that the Condition of Approval 8.6.4 is implemented. Condition of Approval 8.6.5 requires DWR to work with CDFW to increase its annual hatchery production to provide juveniles designated for the sole purpose of being CHNSR surrogates. Costs associated with propagating juveniles and uniquely marking each surrogate release group must be guaranteed before the production of additional stock can be considered. Securing the funds annually will secure the production of juvenile salmon for Condition of Approval 8.6.4.

8.18. Condition of Approval 8.7 - OMR Flexibility During Delta Excess Conditions

As described in the Project Description in the ITP, Permittee may increase exports to capture excess flows in the Delta (hereafter referred to as “OMR Flex”) during the OMR Management period of January 1 through June 30⁷. Condition of Approval 8.7 limits the times when Permittee may conduct OMR Flex operations to specific hydrologic conditions and in response to species-specific restrictions. During OMR Flex operations, Condition of Approval 8.7 requires Permittee to maintain an OMR flow no more negative than -6,250 cfs on a 5-day average.

Permittee will continue to monitor fish in real-time and operate in accordance with additional real-time OMR restrictions described in Conditions of Approval 8.3.1, 8.3.3, 8.4.1, 8.4.2, 8.5.1, 8.5.2, 8.6.1, 8.6.2, 8.6.3, and 8.6.4, which include those measures that trigger the Onset of OMR Management, such as Integrated Early Winter Pulse Protection, Adult Longfin Smelt Entrainment Protection, Salmonid Presence, and other species protection measures such as Turbidity Bridge Avoidance, larval and juvenile DS and LFS protections, salmonid single-year loss thresholds, and salmonid daily loss thresholds.

Exports, and corresponding changes in OMR flows, impact juvenile salmonid migration and reduce overall survival by routing fish into the interior and south Delta and increasing entrainment into the CCF and the salvage facilities. Based on PTM simulation of particles injected at the confluence of the Mokelumne River and the San Joaquin River conducted to support the 2009 NMFS BiOp, the risk of particle entrainment nearly doubles from 10% to 20% as net OMR flows increases southward from -2,500 cfs to -3,500 cfs, and quadruples to 40% at -5,000 cfs. At flows more negative than -5,000 cfs, the risk of entrainment increases at an even greater rate, reaching approximately 90% at -7,000 cfs. Even if salmonids do not behave exactly as neutrally buoyant particles, the risk of entrainment increases considerably with increasing exports, as represented by net OMR flows. Thus, the risk of entrainment into the south Delta channels is increased when OMR flows are more negative (NMFS 2009).

⁷OMR Management may start earlier than January 1 if an Integrated Early Winter Pulse Protection action occurs during December (see Condition of Approval 8.3.1) or Adult Longfin Smelt Entrainment Protections (see Condition of Approval 8.3.3) are initiated after December 1. OMR Management may end earlier in June if specific off-ramps occur (see Condition of Approval 8.8).

If fish are present in the vicinity of the export facilities in the south Delta when exports are increased during OMR Flex operations, it is likely there will be an increase in the number of fish entrained into the salvage facilities. Furthermore, since listed salmonids tend to start migrating downstream in response to elevated flows in the Sacramento River Basin and San Joaquin River Basin waterways (see Sections 4.1.8 and 4.2.10 above), there is a high probability that more fish will be present in the Delta when precipitation events occur in the Central Valley and flows in the Delta peak. In addition to the fish entering the Delta on the elevated storm flows, listed salmonids (especially CHNWR) may already be present in the Delta due to migration earlier in the year.

The hydrologic conditions created by high export rates during OMR Flex operations may create more adverse conditions in south Delta waterways than are currently observed for migrating fish. The 2019 USFWS and NMFS BiOps evaluate exports based on maximum capacity at the Banks and Jones Pumping Plants (14,900 cfs) during OMR Flex operations, not OMR flows. The severity of these conditions would depend on whether high storm flows are originating from the Sacramento River or San Joaquin River Basins, and to what extent exports are increased. Assuming the extreme scenario of combined increased exports at both SWP and CVP facilities with flows originating only in the Sacramento River Basin, the footprint of the export effects would encompass much of the south and interior Delta up to and including the mainstem San Joaquin River downstream to at least Jersey Point. If the storms are present only in the Sacramento River Basin and river flows are increased only for that Basin, then elevated exports will exaggerate the effects of OMR as water is predominately coming from the north across the Delta to supply the high exports. Low flows in the San Joaquin River basin at the same time would exacerbate this condition, as they would not offset the source of export water being diverted by the pumps. Conversely, if storms are centered over the San Joaquin River Basin and high Delta inflows are confined to the mainstem of the San Joaquin River, the high export rates will primarily pull in water from this source. Flow through Old River via the Head of Old River (HOR) will offset the effects of exports on OMR flows to some extent, depending on the magnitude of combined exports, and the volume of flow coming through the HOR. Because there is less unregulated flow in the San Joaquin River compared to the Sacramento River, “storm” events that trigger OMR flexibility operations are more likely to be dominated by Sacramento River flow.

SST (2017) concluded, “...route selection is generally proportional to the flow split at channel junctions, and the effect of exports on route selection is strongest at the junction leading directly to the export facilities (i.e., HOR).” Any fish that originates in the San Joaquin River basin will be at a high risk of entrainment due to the routing of fish through Old River from the HOR. The fish that stay within the mainstem San Joaquin River channel at the HOR may enter the interior Delta at other junctions and be exposed to the increased footprint of the altered hydrodynamics created by the high level of exports in the channels leading to the pumps.

Other key conclusions from SST (2017) include:

- For junctions on both the Sacramento River and San Joaquin River, “...a -5,000 cfs OMR reverse flow limit provides protection compared to more negative OMR reverse flow levels that would exert a larger influence on flow routing at tributary junctions and, thus, on juvenile routing and survival”.
- Within the interior channels of the south Delta, “...the -5,000 cfs OMR flow is predicted to be less effective at preventing or minimizing export effects on juvenile routing at junctions and

residence times within the interior channels of the South Delta than in the mainstems of the Sacramento River and San Joaquin River... because the export-driven influence on hydrodynamic conditions at a given OMR flow level increase with proximity to the export facilities.”

- There is “inadequate empirical evidence from fish tracking studies to more precisely evaluate junction-specific relationship between distributary flow changes and changes in fish routing and survival. As a result, there is uncertainty in relating specific OMR reverse flow thresholds to overall through-Delta survival.”

Management of OMR flows is recognized to help reduce negative effects of exports on CHNWR and CHNSR, as stated in SST (2017):

Export effects that incrementally increase the routing of juvenile salmonids (either from the Sacramento River or from the San Joaquin River) into the Interior Delta will incrementally reduce overall survival...In addition to the predicted effects of export on routing, the conceptual model predicts that OMR reverse flow management will decrease mortality by increasing the probability that juveniles that enter the South Delta (San Joaquin River mainstem and channels to the south and west of the San Joaquin River mainstem) will successfully migrate out of the South Delta to Chipps Island. Mechanisms by which this might occur include: 1) reducing entrainment at the export facilities...; 2) reducing confusing navigational cues caused by OMR reverse flow; and 3) increasing the duration and magnitude of ebb tide flows and velocities, relative to flood tides, which is expected to reduce the residence time of juveniles in the South Delta and, therefore, reduce exposure time to agents of mortality.

Per Condition of Approval 8.7 of the ITP, Permittee can only operate to OMR flex if all of the following requirements are met:

- The Delta is in excess conditions,
- QWEST is greater than 0,
- A measurable precipitation event has occurred in the Central Valley,
- Permittee, in coordination with Reclamation, determines that the Delta outflow index indicates a higher level of outflow available for diversion due to peak storm flows,
- Conditions of Approval 8.3.1, 8.3.3, 8.4.1, 8.4.2, 8.5.1, 8.5.2, 8.6.1, 8.6.2, 8.6.3, and 8.6.4 are not controlling,
- Risk assessments conducted by the Salmon and Smelt Monitoring Teams indicate that an OMR more negative than -5,000 cfs is not likely to trigger an additional real-time OMR restriction,
- Cumulative salvage of yearling CNFH CHNLFR (as yearling CHNSR surrogates) is less than 0.5% within any of the release groups, and
- Risk assessments conducted by the Salmon and Smelt Monitoring Teams determine that no changes in spawning, rearing, foraging, sheltering, or migration behavior as a result of OMR Flex operations beyond those anticipated to occur through operations described in Conditions of Approval 8.3.1, 8.3.3, 8.4.1, 8.4.2, 8.5.1, 8.5.2, 8.6.1, 8.6.2, 8.6.3, and 8.6.4 are likely to occur.

The first four requirements for OMR Flex require elevated flows in the Sacramento River or San Joaquin River basins. Positive values of QWEST represent a net positive flow at Jersey Point, indicating a positive inflow westward to the Delta. Negative values of QWEST indicate greater potential for fish entrainment

at the export facilities due to lower inflow into the Delta (see Appendix D in ITP Attachment 7, CDFW Smelt Effects Analysis for more detail). During wet periods, the San Joaquin River and eastern Delta tributaries (Mokelumne, Consumnes, and Calaveras rivers) may provide sufficient flow to maintain a net positive flow in the lower San Joaquin River (i.e., positive Qwest) despite high exports at the SWP and CVP facilities. Such flows would tend to transport pelagic organisms in the main San Joaquin River channel toward Suisun Bay. By restricting OMR Flex only when there are elevated flows in the Delta, Condition of Approval 8.7 minimizes the risk of juvenile CHNWR and CHNSR entraining into the south Delta and experiencing loss at the export facilities.

Juvenile CHNWR and CHNSR migrate downstream in response to elevated flows in the Sacramento River and San Joaquin River Basins. Therefore, there is a high probability that juvenile CHNWR and CHNSR will be present in the Delta when SWP increases exports under OMR Flex. This overlap in fish presence and increase in export operations may lead to increases in entrainment. However, if any of last four requirements for OMR Flex have not been met, OMR Flex cannot occur. Specifically, if a risk assessment, conducted by the Salmon Monitoring Team, determines that CHNWR and CHNSR are more likely to become entrained above thresholds established under Condition of Approval 8.6, OMR Flex cannot be implemented.

Additionally, per Condition of Approval 8.7, if during OMR Flex, any of the last four biological requirements are no longer being met, Permittee must off-ramp OMR Flex to provide protections to listed species by reducing exports to achieve an average OMR index no more negative than -5,000 cfs on a 14-day average, unless further reduction in exports is required by a specific Condition of Approval. Off-ramp of OMR Flex operations, again driven by analyses and recommendations of the Salmon and Smelt Monitoring Teams, is essential to reducing take of listed salmonids when real-time data indicate fish are present in the zone of entrainment and when salvage/loss data indicates fish are being entrained at the facilities.

Together, these eight requirements will minimize loss of CHNWR and CHNSR by only allowing OMR Flex during times when there is positive Delta inflow from both the Sacramento River and the San Joaquin River basins, there are no controlling Conditions of Approval⁸, and the risk of entrainment is low based on risk assessments conducted by the Salmon Monitoring Team.

8.19. Condition of Approval 8.8 – End of OMR Management

Condition of Approval 8.8 requires the OMR Management season to end June 30 or prior if smelt and salmonid specific off-ramps occur. For salmonids, off-ramps from OMR Management include all of the following conditions:

- More than 95% of CHNWR and CHNSR have migrated past Chipps Island as determined by the Salmon Monitoring Team (Condition of Approval 8.1.2), AND
- Daily average water temperature at Mossdale exceeds 22.2°C for 7 non-consecutive days in June, AND

⁸ Controlling Conditions of Approval include 8.3.1, 8.3.3, 8.4.1, 8.4.2, 8.5.1, 8.5.2, 8.6.1, 8.6.2, 8.6.3, and 8.6.4. These conditions includes all Conditions of Approval from 8.3-8.6 with the exception of Conditions of Approval 8.3.2 (Salmonid Presence), 8.4.3 (High Flow Off-ramp for Longfin Smelt OMR Restrictions), 8.6.5 (Funding for CHNSR Hatchery Surrogates), and 8.6.6 (Evaluate Proactive Salmon Entrainment Minimization During Real-time Operations).

- Daily average water temperature at Prisoner’s Point exceeds 22.2°C for 7 non-consecutive days in June.

8.20. Condition of Approval 8.8 – End of OMR Management: 95% Salmon Migration Past Chipps Island

8.20.1. Introduction

This section examines historical presence of YOY CHNWR and CHNSR emigrating from the Delta to determine when 95% of CHNWR and CHNSR have migrated past Chipps Island prior to June 30.

8.20.2. Methods

Salvage and estimated loss at the SWP and CVP were summarized for CHNWR and CHNSR and compared to DOSS and SacPAS data to evaluate the timing of natural YOY CHNWR and CHNSR emigration from the Delta.

8.20.2.1. Loss Analysis

Salvage data for the SWP and CVP export facilities were collected from the CDFW Bay-Delta Region salvage database (CDFW 2019c). Loss was calculated from salvage data using the loss equation (CDFW 2018 and Attachment 6 to the ITP). The database identified salmon runs based on the Delta LAD Model (USFWS 1997) and included specimen information pertaining to fork length and presence of an adipose fin (as an indication of natural versus hatchery fish).

Salvage and loss data available included water years 1993 until 2019; however, analyses were limited to water years 1995 through 2019 for consistency with available monitoring data reported in SacPAS. For natural YOY CHNWR and CHNSR, loss data were analyzed to determine the date that last loss occurred at each facility and the percent of total annual loss that occurred at each facility by June 30. Two yearling CHNSR were salvaged (10/15/1997 and 9/26/2000) at the SWP and were omitted from this analysis since the time period of consideration was June.

8.20.2.2. DOSS Analysis

DOSS develops weekly and annual reports during each water year starting in October and ending the second week in June. In water year 2014, DOSS began estimating the percent of natural YOY CHNWR and CHNSR exiting the Delta.

8.20.2.3. SacPAS Analysis

SacPAS reports juvenile exit from the Delta using Chipps Island trawl catch data (RM 18) as an indicator of salmonid exit from the Delta. The USFWS conducts monitoring at Chipps Island three days a week year-round, except during December, January, May, June, and sometimes April when sampling is conducted daily. SacPAS reports the percent cumulative catch in increments at Chipps Island at the end of the monitoring season. This cumulative catch does not represent the percentage of fish passing through the river, nor does it include sampling efficiency like the RBDD RST used to develop the CHNWR JPI.

For CHNWR and CHNSR off-ramp analyses, the 95% annual cumulative catch for each run was calculated for water years 1995 through 2019. Data were also analyzed to determine the percent of the annual cumulative catch on June 30 for each water year.

8.20.3. Results

8.20.3.1. Winter-run Chinook Salmon

8.20.3.1.1. Loss Analysis

For water years 1995 through 2019, the average last date of loss for natural YOY CHNWR combined at the SWP and CVP export facilities was April 10 (Table 29). Across the 25 years of analysis, loss was only observed through June in water year 2003. Otherwise, loss ended prior to June 30 for all other water years.

Brood Year	Water Year	SWP	CVP	SWP/CVP	SWP	CVP	SWP/CVP
		Natural CHNWR	Natural CHNWR	Natural CHNWR	Natural CHNWR	Natural CHNWR	Natural CHNWR
		Date of Last Loss			% Loss by June 30		
Average		14-Apr	24-Mar	10-Apr	100.00	100.00	100.00
Median		19-Apr	10-Apr	20-Apr	100.00	100.00	100.00
1994	1995	3/3/1995	5/6/1995	5/6/1995	100.00	100.00	100.00
1995	1996	4/2/1996	4/18/1996	4/18/1996	100.00	100.00	100.00
1996	1997	4/19/1997	3/30/1997	4/19/1997	100.00	100.00	100.00
1997	1998	3/3/1998	3/27/1998	3/27/1998	100.00	100.00	100.00
1998	1999	4/26/1999	4/17/1999	4/26/1999	100.00	100.00	100.00
1999	2000	4/12/2000	4/14/2000	4/14/2000	100.00	100.00	100.00
2000	2001	4/23/2001	4/12/2001	4/23/2001	100.00	100.00	100.00
2001	2002	4/27/2002	4/17/2002	4/27/2002	100.00	100.00	100.00
2002	2003	4/9/2003	6/27/2003	6/27/2003	100.00	100.00	100.00
2003	2004	5/19/2004	3/30/2004	5/19/2004	100.00	100.00	100.00
2004	2005	4/20/2005	3/22/2005	4/20/2005	100.00	100.00	100.00
2005	2006	5/3/2006	3/21/2006	5/3/2006	100.00	100.00	100.00
2006	2007	4/21/2007	4/22/2007	4/22/2007	100.00	100.00	100.00
2007	2008	4/29/2008	4/1/2008	4/29/2008	100.00	100.00	100.00
2008	2009	4/17/2009	4/11/2009	4/17/2009	100.00	100.00	100.00
2009	2010	4/14/2010	4/20/2010	4/20/2010	100.00	100.00	100.00
2010	2011	4/8/2011	4/13/2011	4/13/2011	100.00	100.00	100.00
2011	2012	5/29/2012	4/18/2012	5/29/2012	100.00	100.00	100.00
2012	2013	4/6/2013	4/1/2013	4/6/2013	100.00	100.00	100.00
2013	2014	3/21/2014	4/14/2014	4/14/2014	100.00	100.00	100.00
2014	2015	3/31/2015	1/21/2015	3/31/2015	100.00	100.00	100.00
2015	2016	2/2/2016	3/22/2016	3/22/2016	100.00	100.00	100.00
2016	2017	5/5/2017	4/5/2017	5/5/2017	100.00	100.00	100.00
2017	2018	5/15/2018	4/10/2018	5/15/2018	100.00	100.00	100.00
2018	2019	4/20/2019	3/13/2019	4/20/2019	100.00	100.00	100.00

Table 29. Date of last loss and percent of annual loss by June 30 for natural YOY CHNWR at the SWP and CVP export facilities for water years 1995 through 2019.

8.20.3.1.2. DOSS & SacPAS Analyses

Based on water years 2014 to 2019, DOSS estimated on average that 95% of the natural YOY CHNWR population had exited the Delta by April 27 (Figure 58). By June 30, DOSS estimated on average that 100% of natural YOY CHNWR had exited the Delta.

Using empirical data from SacPAS for water years 1995 through 2019, on average 95% of the natural YOY CHNWR catch at the exit of the Delta occurred by April 16, eleven days earlier than estimated by DOSS (Figure 58). By May 3, on average, 100% of the natural YOY CHNWR catch was observed. However, it is important to note that DOSS typically estimates a range of percentages of CHNWR passage out of the Delta. The date when DOSS estimated 95% as having exited the Delta in this analysis is based on the first date when DOSS ranges included 95%.

DOSS and SacPAS indicate that on average 95% of the natural YOY CHNWR population (or catch) exit the Delta prior to June 30. On average, 1.66% of the annual loss of natural YOY CHNWR would be lost to the export facilities after 95% are estimated to have emigrated from the Delta.

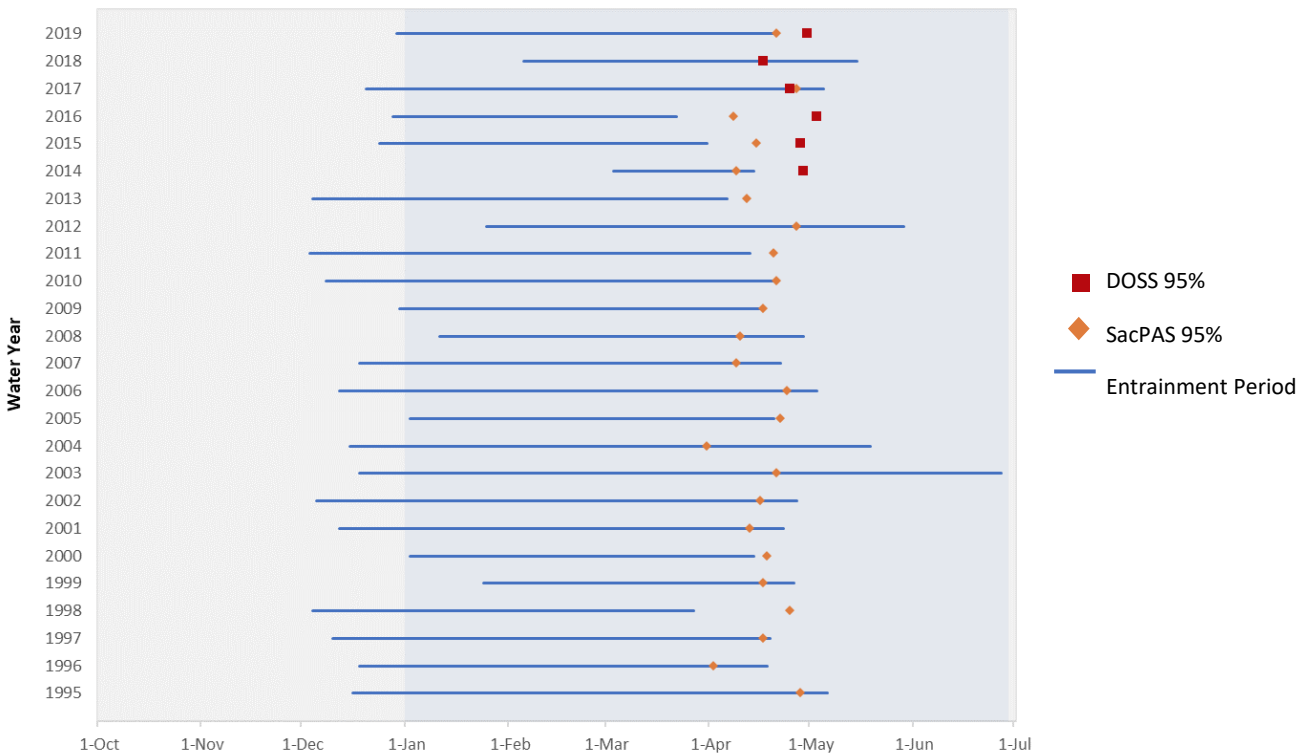


Figure 58. Natural YOY CHNWR entrainment periods at the SWP and CVP export facilities for water years 1995 to 2019. The red box and orange diamond indicate the date that 95% of the CHNWR population exited the Delta for each water year as indicated by DOSS and SacPAS, respectively. The shaded blue box indicates the January 1 through June 30 time period each year.

8.20.3.2. Spring-run Chinook Salmon

8.20.3.2.1. Loss Analysis

For water years 1995 through 2019, the average last date of loss for natural YOY CHNSR combined at the SWP and CVP export facilities was June 5 (Table 30). Across the 25 years of analysis, loss ended on or prior to June 30 in all water years, with loss in six water years extending through late June.

Brood Year	Water Year	SWP	CVP	SWP/CVP	SWP	CVP	SWP/CVP
		Natural CHNSR	Natural CHNSR	Natural CHNSR	Natural CHNSR	Natural CHNSR	Natural CHNSR
		Date of Last Loss			% Loss by June 30		
Average		28-May	2-Jun	5-Jun	100.00	100.00	100.00
Median		30-May	5-Jun	5-Jun	100.00	100.00	100.00
1994	1995	6/20/1995	6/30/1995	6/30/1995	100.00	100.00	100.00
1995	1996	6/9/1996	6/12/1996	6/12/1996	100.00	100.00	100.00
1996	1997	5/26/1997	6/5/1997	6/5/1997	100.00	100.00	100.00
1997	1998	6/25/1998	6/13/1998	6/25/1998	100.00	100.00	100.00
1998	1999	5/30/1999	6/4/1999	6/4/1999	100.00	100.00	100.00
1999	2000	6/1/2000	5/28/2000	6/1/2000	100.00	100.00	100.00
2000	2001	5/14/2001	5/12/2001	5/14/2001	100.00	100.00	100.00
2001	2002	5/15/2002	6/3/2002	6/3/2002	100.00	100.00	100.00
2002	2003	5/29/2003	5/20/2003	5/29/2003	100.00	100.00	100.00
2003	2004	5/18/2004	5/26/2004	5/26/2004	100.00	100.00	100.00
2004	2005	6/7/2005	6/11/2005	6/11/2005	100.00	100.00	100.00
2005	2006	6/19/2006	6/15/2006	6/19/2006	100.00	100.00	100.00
2006	2007	5/30/2007	5/3/2007	5/30/2007	100.00	100.00	100.00
2007	2008	6/2/2008	6/5/2008	6/5/2008	100.00	100.00	100.00
2008	2009	5/27/2009	6/15/2009	6/15/2009	100.00	100.00	100.00
2009	2010	6/3/2010	6/5/2010	6/5/2010	100.00	100.00	100.00
2010	2011	6/24/2011	6/18/2011	6/24/2011	100.00	100.00	100.00
2011	2012	5/11/2012	6/8/2012	6/8/2012	100.00	100.00	100.00
2012	2013	5/25/2013	5/17/2013	5/25/2013	100.00	100.00	100.00
2013	2014	3/19/2014	5/10/2014	5/10/2014	100.00	100.00	100.00
2014	2015	5/4/2015	5/18/2015	5/18/2015	100.00	100.00	100.00
2015	2016	5/14/2016	5/19/2016	5/19/2016	100.00	100.00	100.00
2016	2017	6/29/2017	6/19/2017	6/29/2017	100.00	100.00	100.00
2017	2018	5/21/2018	5/23/2018	5/23/2018	100.00	100.00	100.00
2018	2019	5/30/2019	6/25/2019	6/25/2019	100.00	100.00	100.00

Table 30. Date of last loss and percent of annual loss by June 30 for natural YOY CHNSR at the SWP and CVP export facilities for water years 1995 through 2019.

8.20.3.2.2. DOSS & SacPAS Analyses

Based on water years 2014 to 2019, DOSS estimated on average that 95% of the natural YOY CHNSR population exited the Delta by May 20 (Figure 59). By June 30, DOSS estimated on average that 100% of natural YOY CHNSR had exited the Delta.

Using empirical data from SacPAS for water years 1995 through 2019, on average 95% of the natural YOY CHNSR catch at the exit of the Delta occurred by May 9, eleven days earlier than estimated by DOSS (Figure 59). By June 18, on average 100% of the natural YOY CHNSR catch was observed. On average, 14.62% of the annual loss of natural YOY CHNSR occurs after DOSS and SacPAS estimate 95% have emigrated from the Delta.

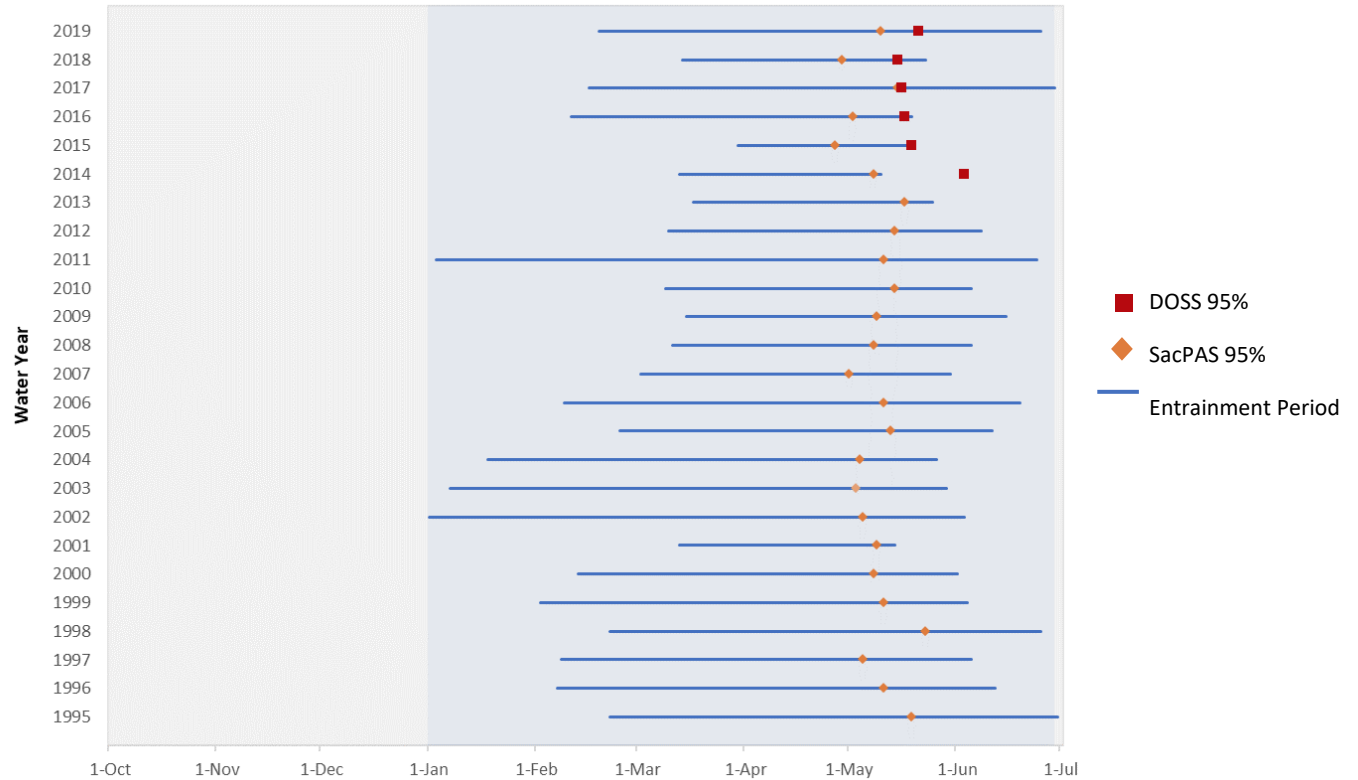


Figure 59. Natural YOY CHNSR entrainment periods at the SWP and CVP export facilities for water years 1995 to 2019. The red box and orange diamond indicate the date that 95% of the CHNSR population exited the Delta for each water year as indicated by DOSS and SacPAS, respectively. The shaded blue box indicates the proposed period, January 1 through June 30, of OMR Management for salmonids in the Delta.

8.20.4. Discussion

DOSS predictions for salmonid exit from the Delta are generally later than what empirical data supports. Therefore, DOSS provides a conservative estimate for salmonid exit from the Delta. CHNSR consistently exit the Delta after CHNWR, as indicated by Chipps Island trawl catch data. Based on Chipps Island Trawl data from water years 1995 through 2019, on average, 95% of CHNSR catch occurs by May 9. However, CHNSR salvage persists through June with up to 14.62% of the annual loss of CHNSR occurring after 95% of the CHNSR catch has occurred at Chipps Island. It is also important to note that DOSS typically estimates a range of percentages of CHNSR passage out of the Delta. The date when DOSS estimated 95% as having exited the Delta in this analysis is based on the first date when DOSS ranges included 95%.

Disproportionate take of CHNWR migration strategies (early, peak, and late) can lead to a decrease in life history diversity (Sturrock et al. 2019b). It is important to preserve all migrants of salmonid populations to maintain the portfolio effect of each species. This portfolio effect contributes to population sustainability and abundance by distributing risk throughout the run and reducing intraspecific competition (Sturrock et al. 2015; Carlson and Satterthwaite 2011; Greene et al. 2010; Healey 1991).

As described in Section 8.19 above, the End of OMR Management (Condition of Approval 8.8) includes three requirements to allow OMR Management for juvenile CHNWR and CHNSR to off-ramp prior to June 30. The requirements include migration of more than 95% of juvenile CHNWR and CHNSR past Chipps Island and daily average water temperature exceedances of 22.2°C for 7 non-consecutive days in June at both Mosssdale and Prisoner’s Point. Together, all three of these requirements will minimize take of late migrant juvenile CHNWR and CHNSR by preventing the End of OMR Management when the risk of entrainment is still high. Prior to the End of OMR Management, the Salmon Monitoring Team will review entrainment data and survey data of juvenile CHNWR and CHNSR upstream of the Delta, within the Delta (as determined by Sherwood Harbor trawl), and downstream of the Delta (as determined by Chipps Island). This analysis will help determine what proportion of the population of juvenile CHNWR and CHNSR remains at risk of being entrained into the export facilities. The two temperature requirements (discussed in more detail in Section 8.21 below) further minimize the risk of entrainment of juvenile CHNWR and CHNSR by limiting the End of OMR management to no earlier than June and only after temperatures have exceeded core and non-core rearing temperatures as documented by USEPA (2003). When temperatures at Mosssdale and Prisoner’s Point exceed the UESPA (2003) approved rearing temperatures, it is unlikely that juvenile CHNWR and CHNSR are using this area to rear, indicating that juveniles are at low risk of being entrained at the export facilities.

8.21. Condition of Approval 8.8 – End of OMR Management: Salmon Temperature Off-ramps

8.21.1. Introduction

The following analysis evaluates entrainment minimization achieved as a result of the salmon temperature off-ramps from OMR Management, which must be met in addition to the 95% salmon migration off-ramp described in the preceding Section 8.20, for OMR Management to off-ramp prior to June 30.

8.21.2. Methods

To evaluate the effectiveness of the End of OMR Management salmon temperature off-ramps in reducing entrainment, this analysis included a historical review of estimates of CHNWR and CHNSR exit from the Delta, historical entrainment of CHNWR and CHNSR, evaluation of when the specified temperature stations would have historically off-ramped OMR, and historic temperature variability across the interior Delta.

8.21.2.1. Salmonid Presence and Entrainment

To determine the historical presence of CHNWR and CHNSR in the interior Delta when the temperature off-ramps may occur, the dates in which 95% of CHNWR and CHNSR exited the Delta based on SacPAS data and DOSS estimates (see Section 8.20) were reviewed for water years 2010-2019. Additionally, to determine the presence of each species in salvage during the OMR Management period, salvage data for both species was obtained from the CDFW Bay-Delta Region salvage database (CDFW 2019c) and loss was calculated using the loss equation (CDFW 2018 and Attachment 6 to the ITP).

8.21.2.2. Temperature Station Off-Ramps

Daily mean temperature data for the month of June in water years 2010-2019 was obtained from CDEC (DWR 2019b) for the two OMR Management salmon temperature off-ramp stations: Mosssdale and

Prisoner’s Point. Data from each station was filtered to only include the specific day in June of each water year in which OMR Management was off-ramped at that station based on the temperature criteria.

8.21.2.3. Temperature Variability Across the Delta

Using CDEC, thirteen temperature stations were selected to represent the southern, central, and northern regions of the interior Delta. These stations included: MSD, CLC, BDT, MHO, OH4, SJG, OBI, TRN, HLT, ORQ, BET, PRI, and BLP (Table 31 and Figure 60).

Temperature Station (south to north)	Location
MSD	San Joaquin River at Mossdale Bridge
CLC	Clifton Court Forebay
BDT	San Joaquin River at Brandt Bridge
MHO	Middle River near Howard Road Bridge
OH4	Old River at Highway 4
SJG	San Joaquin River at Garwood Bridge
OBI	Old River at Bacon Island
TRN	Turner Cut near Holt
HLT	Middle River near Holt
ORQ	Old River at Quimbly Island Near Bethel Island
BET	Bethel Island
PRI	San Joaquin River at Prisoner’s Point near Termino
BLP	Blind Point

Table 31. Temperature stations in the interior Delta listed south to north by location.

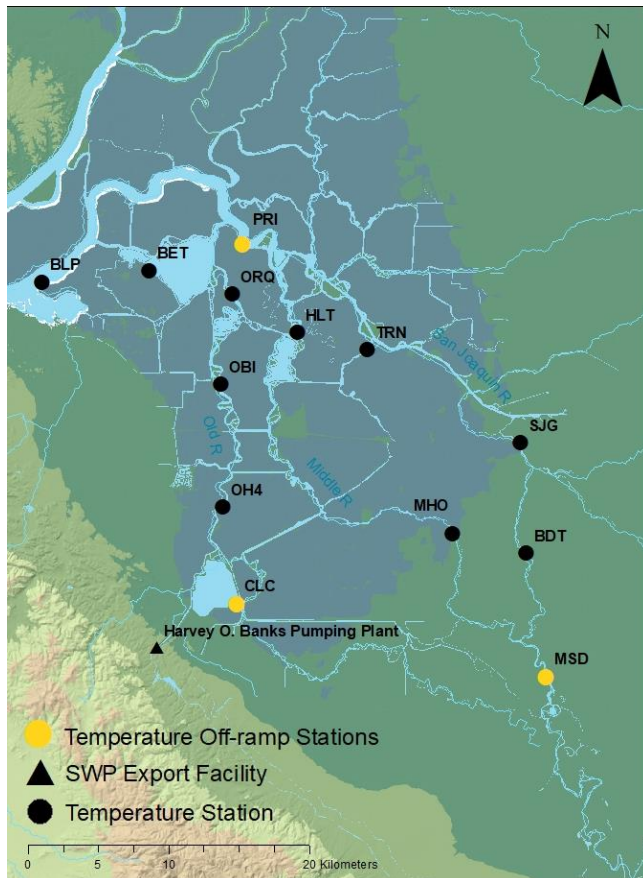


Figure 60. Map of the interior Delta showing the locations of the thirteen temperature stations. Temperature stations that off-ramp OMR Management as described in Condition of Approval 8.8 are indicated with a yellow dot.

The temperature stations specific to End of OMR Management for salmon are MSD and PRI. Daily mean temperature data for the month of June was downloaded from CDEC for each station for water years 2010 to 2019. Temperature data for all stations was filtered to only include dates with daily mean temperatures of 22.2°C or greater in June to determine the dates in which the temperature off-ramps were met. The date of the seventh non-consecutive day of temperatures exceeding 22.2°F at Mossdale and Prisoner’s Point were identified as the off-ramp dates for salmon for years 2010-2019. The June temperature dataset was visually analyzed by plotting individual box plots for each station within each year.

8.21.3. Results/Discussion

8.21.3.1. Salmonids Presence and Entrainment

As described above in Section 7.3.4.1 – Historical Loss of Juvenile Winter-run Chinook Salmon, CHNWR have been observed in the salvage facilities from December through June with most of the salvage and loss occurring from December through April. Salvage and loss of juvenile CHNWR in May and June is generally very low. No salvage of juvenile CHNWR occurred in June during water years 2010 through 2019; the most recent salvage in June was in 2003. Additionally, as shown in Section 8.20, on average 95% of CHNWR have exited the Delta by April 27 as estimated by DOSS (April 16 as estimated by SacPAS). Thus, CHNWR are likely not present (or present in very small numbers) in the zone of entrainment in June and take of CHNWR due to the End of OMR Management is minimal.

Historically, salvage of CHNSR has occurred from January through June with peak salvage and loss occurring March through May (see Section 7.3.4.2 – Historical Loss of Juvenile Spring-run Chinook Salmon above). Loss in June is normally low, however there were three years in this time-period where loss surpassed 5,000 fish (1995, 2011, and 2017). On average, SacPAS and DOSS estimate 95% of CHNSR have exited the Delta in May while salvage is ongoing into June. We presume that fish are still present in the interior Delta during that time if they are observed in salvage. Thus, it is important to understand the relationship between an early off-ramp from OMR Management and the potential for subsequent entrainment of CHNSR.

8.21.3.2. Temperature Station Off-Ramp

Table 32 provides a summary of the dates in June during each water year (2010-2019) in which the OMR Management species-specific temperature off-ramps established in Condition of Approval 8.8 would have occurred.

Water Year	Mossdale (22.2°C for 7 consecutive days)	Prisoner’s Point (22.2°C for 7 consecutive days)
2010	June 30*	June 30
2011	June 30*	June 30*
2012	June 15	June 30*
2013	June 7	June 30*
2014	June 7	June 10
2015	June 7	June 13
2016	June 7	June 5
2017	June 30*	June 22
2018	June 24	June 25
2019	June 30*	June 30*

Table 32. OMR temperature off-ramps occurring in June during water years 2010-2019 for each temperature station. The green highlights indicate which temperature station would have off-ramped OMR Management for salmon prior to June 30. The asterisk (*) indicates years in which OMR Management ended on June 30 because a temperature off-ramp did not occur.

The Mossdale temperature station would have off-ramped OMR Management for CHNWR and CHNSR in 1 of the 10 water years. The Prisoner’s Point temperature station would have off-ramped OMR Management for CHNWR and CHNSR in 3 of the 10 years. In the remaining 6 years, the End of OMR Management date of June 30 would have off-ramped OMR Management for salmon prior to temperatures exceeding 22.2°C for 7 consecutive days at both Mossdale and Prisoner’s Point. Figure 61 provides the entrainment period of CHNSR overlaid with SacPAS and DOSS estimates of 95% exit from the Delta along with the dates in which OMR Management would have been off-ramped due to temperature exceedances at the Mossdale and Prisoner’s Point temperature stations.

SWP/CVP - Natural and Hatchery YOY Spring-run Entrainment Period by WY

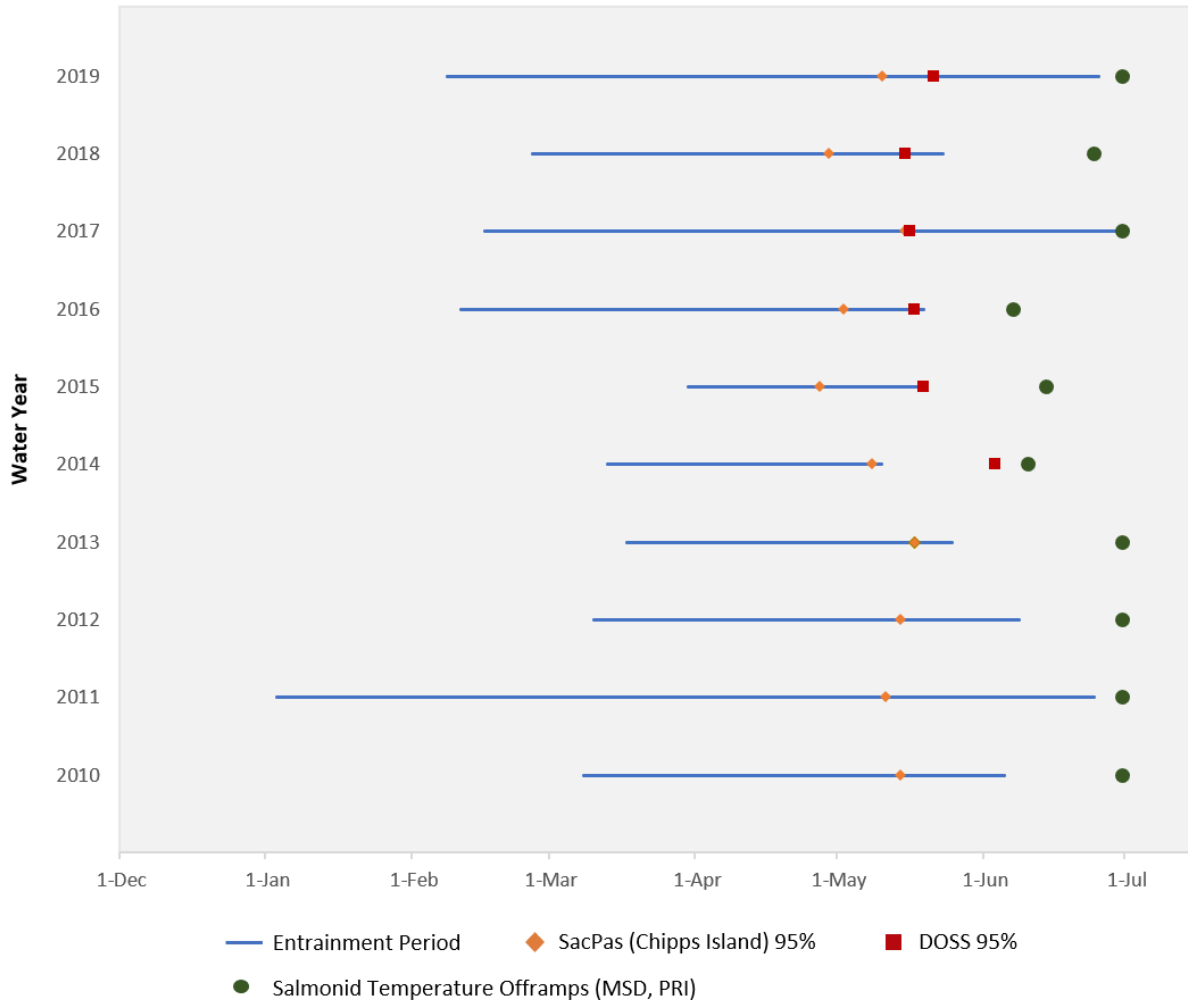


Figure 61. Natural and Hatchery CHNSR entrainment period at the CVP and SWP export facilities for water years 2010-2019. The orange diamond and red box indicate the date that 95% of the CHNWR population were estimated to have exited the Delta for each water year as indicated by SacPAS and DOSS, respectively. The green dot indicates when the temperature stations (Mossdale and Prisoner’s Point) would have off-ramped OMR Management for salmonids.

The entrainment period for CHNSR extends past the SacPAS and DOSS estimates of 95% exit of CHNSR from the Delta during all except 1 of the 10 years analyzed. Therefore, CHNSR are still present in the Delta when DOSS assumes that they have exited. The OMR off-ramp stations appear to effectively minimize take of CHNSR as the off-ramp extends beyond the 95% exit estimates and several days after the last date of observance of CHNSR in salvage during most water years. Thus, the temperature off-ramps for OMR Management minimize take of juvenile CHNSR during the OMR Management period and the off-ramp of OMR prior to June 30 due to the temperature exceedance does not appear to diminish the minimization of CHNSR entrainment and take.

8.21.3.3. Temperature Variability Across the Delta

As shown in Figure 62, most water years (2012-2016 and 2018) show a decreasing trend in water temperature from the southern Delta near Clifton Court Forebay to Prisoner’s Point on the San Joaquin

River. However, in wetter water years (2011, 2017, and 2019), the trend reverses and shows water temperatures increasing from Clifton Court Forebay to Prisoner's Point. This may be due to relatively low residence time on the San Joaquin River under higher flows, which would indicate that regional temperature stratification within the southern Delta is likely influenced by the magnitude of San Joaquin River inflow water temperatures across the Delta were relatively uniform in 2010.

Spatial Temperature Patterns of the South Delta in June

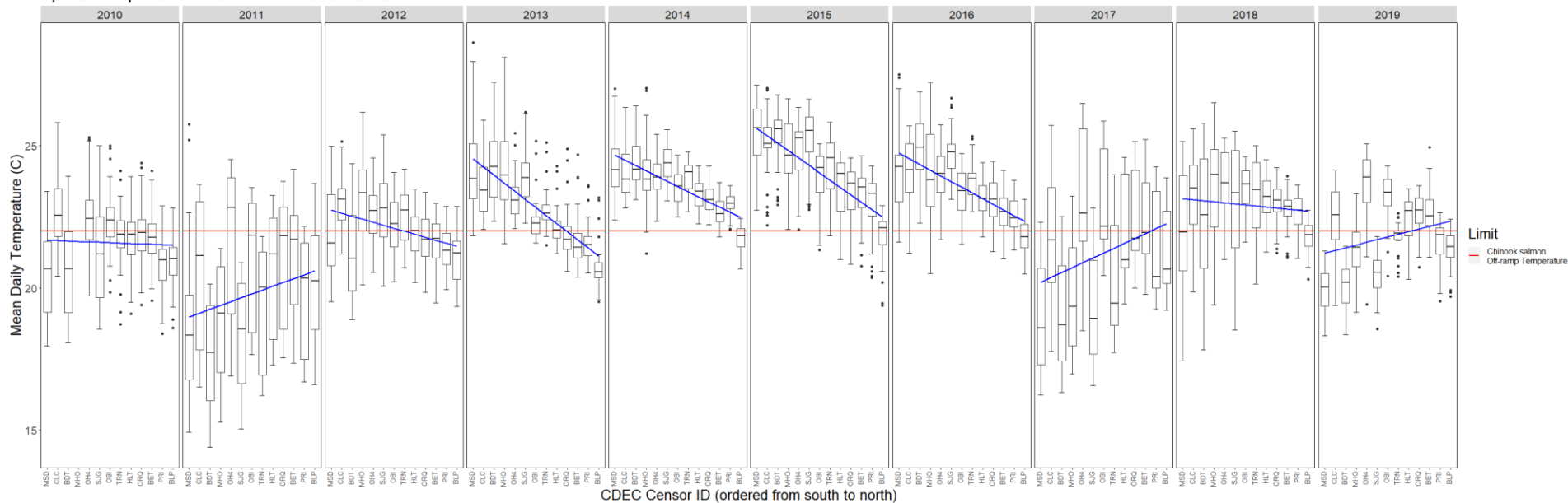


Figure 62. Box plots showing mean daily temperature trends in the month of June for each water year from 2010 through 2019. Temperature stations are listed on the x-axis in order from south (MSD; Mossdale) to north (BLP; Blind Point). The blue trendlines indicate the direction of temperature change across the interior Delta as represented by the temperature stations. The salmonid OMR Management temperature off-ramp of 22.2°C is represented by a solid red line.

The End of OMR Management salmon temperature station at MSD is located in the southern portion of the interior Delta and is assumed to be representative of conditions for salmon throughout the southern Delta. CHNWR are also not expected to be present in the interior Delta in June, while CHNSR may still be emigrating during this time. The End of OMR Management salmon temperature station PRI is located along the edge of the zone of entrainment and near the junctions of the San Joaquin River, Middle River, and Mokelumne River. Its location is significant because salmon entrained through Georgianna Slough and the DCC pass through this area during their juvenile emigration. PRI is also located in the interior Delta, which has different temperature patterns compared to the southern region in most years. To best represent thermal conditions experienced by salmon across the Delta it is important to equally represent temperatures from both MSD and PRI for the End of OMR Management salmon temperature off-ramp. As shown in Figure 62 above, even in drier water years (2013-2015), temperatures near PRI are still below the temperature off-ramp for salmon.

8.22. Conditions of Approval 7.4, 7.4.1, 7.4.2 and 8.15 – Skinner Fish Facility Operations and Staff

Duties of the CDFW staff at the Skinner Fish Facility include, but are not limited to: receive daily salvage data from the fish facilities, conduct QA/QC on salvage data, train salvage facility staff, oversee salvage facility operations, work with DWR to develop a revised Salvage Facility Protocol, and engage in real-time decision making to determine whether reduced count times are appropriate. The salvage process at the Skinner Fish Facility generates one of the largest data sources characterizing entrainment and take of CHNWR and CHNSR with a high amount of sampling effort. The duties performed by these staff members will ensure proper identification of state and federally listed salmonids at the Skinner Fish Facility, which allows for an accurate calculation of loss, which will trigger subsequent protections. These staff members will also maintain consistency in operating to the established protocols to ensure generation of a robust dataset with QA/QC data. This salvage data will be used in OMR Management to curtail exports during periods of high entrainment risk as identified by increased salvage.

8.23. Condition of Approval 7.5.2 – New and Ongoing Monitoring Required to Develop and Establish a Spring-run Chinook Salmon JPE

Condition of Approval 7.5.2 requires Permittee to convene a team to develop a monitoring plan to continue existing and conduct new monitoring to obtain the necessary data to inform development of a CHNSR JPE. This monitoring would be conducted in CHNSR natal tributaries upstream of the Delta and include adult passage and escapement surveys, juvenile emigration monitoring using screw traps and trap capture efficiency studies, juvenile tagging studies, and genetic identification of adult and juvenile Chinook salmon sampled during monitoring.

Once developed, the CHNSR JPE can provide a similar purpose for CHNSR as the current CHNWR JPEs provide for CHNWR. NMFS provides separate JPEs for both natural and hatchery CHNWR annually, which is used to determine the authorized level of incidental take for CHNWR under Section 7 of the ESA, for operation of the CVP/SWP pumping facilities in the south Delta. The CHNWR JPE is also used to inform the single-year loss threshold and mid- and late-season daily loss threshold for CHNWR (Conditions of Approval 8.6.1 and 8.6.3 in the ITP; see also Sections 8.14 and 8.15 in this Effect Analysis

document). These thresholds minimize take and related impacts of the taking of CHNWR entrained into the interior Delta and salvaged at the SWP and CVP export facilities. By using the annual JPEs to set loss thresholds, these Conditions of Approval incorporate population estimates based on all life stages. Population level scaling helps to inform how SWP and CVP operations impact the annual production of CHNSR. The development of a CHNSR JPE would allow similar thresholds to be established based on population estimates that incorporate all life stages, thus providing similar entrainment protections for CHNSR as are currently afforded to CHNWR. The CHNSR JPE is an important tool needed to facilitate the development of further protective measures for CHNSR related to the operation of the Project. To develop the JPE a technical team will guide implementation of monitoring and science to incorporate genetic run identification at key ecological and management relevant locations, bolster estimates of juvenile abundance and cohort strength across the freshwater landscape, expand and enhance real-time fish survival and movement monitoring, develop and collect life history diversity metrics at multiple life stages, as well as develop and collect metrics of fish condition, including disease prevalence.

8.24. Conditions of Approval 7.5, 7.5.1, 7.5.2, and 7.5.3 in combination with Conditions of Approval 8.6.6 and 8.16 and the Adaptive Management Plan

Together, Conditions of Approval 7.5, 7.5.1, 7.5.2, 7.5.3, 8.6.6, and 8.16 will support existing monitoring and science and develop new CHNSR and CHNWR monitoring and science to improve understanding of species ecology. These Conditions of Approval will serve to fill many of the information gaps noted in this Effects Analysis regarding CHNWR and CHNSR ecology and Project impacts on both species by:

- Continuing to build knowledge regarding the biology and life history of CHNWR and CHNSR
- Improving understanding of potential impacts of Project operations on CHNWR and CHNSR
- Continuing to refine the CHNWR JPE
- Developing a CHNSR JPE
- Developing a proactive CHNWR entrainment prediction tool to be evaluated as a measure to minimize take of CHNWR in the south Delta

When implemented, this suite of monitoring and science will better inform take and the related impacts of the taking as a result of Project operations and methods to proactively minimize take and related impacts of the taking. New science and monitoring will be synthesized and evaluated as a part of the Adaptive Management Plan (AMP) as described in Condition of Approval 8.16 and Attachment 3 to the ITP. Review and synthesis as a part of the AMP may result in recommendations regarding operational components of the ITP, and consequently Permittee may request an amendment of the ITP based on new information and science.

9. Mitigation of Take and Impacts of the Taking on Winter-run and Spring-run Chinook Salmon

9.1. Condition of Approval 9.2.1 – Mitigation for Impacts Associated with Project Operations

Condition of Approval 9.2.1 – Mitigation for Impacts Associated with Project Operations requires Permittee to provide \$20,000,000 over the term of the ITP for enhancement and restoration projects to benefit CHNWR and CHNSR in the Sacramento River watershed upstream of the Delta as compensatory mitigation for impacts associated with Project operations. This mitigation will benefit all life stages of CHNWR and CHNSR in upstream tributaries where spawning, egg incubation, rearing, and emigration occurs.

Improvements to juvenile upstream rearing habitat will serve as mitigation for unavoidable impacts to juvenile CHNWR and CHNSR due to SWP operations. In addition to the minimization measures identified under Conditions of Approval 6-8, there are remaining effects of SWP operations on juveniles and their habitat. At the Skinner Fish Facility and CCF, take associated with loss of juveniles due to export operations is known to occur and is estimated on a daily basis. However, loss of juvenile habitat is more difficult to quantify and impacts as a result of SWP operations cannot be fully avoided or substantially reduced through minimization measures. SWP operations result in low in-river survival of emigrating CHNWR and CHNSR that must pass through the Sacramento River and Delta during periods of low flow conditions resulting in part from SWP export operations. SWP operations cause delayed emigration and increased transit times related to Delta entrainment, which can increase the potential for mortality in juvenile CHNWR and CHNSR due to longer exposure periods coupled with poor in-Delta and through-Delta rearing and survival conditions. Improving juvenile rearing habitat will mitigate for adverse effects of SWP operations on CHNWR and CHNSR and their habitat. These habitat enhancements will increase habitat availability and improve the ecological function of the rearing and migratory corridor for juvenile CHNWR and CHNSR. CHNWR and CHNSR that utilize these habitats will experience increases in growth and survival rates. Increased growth in juveniles improves the likelihood of their survival as they migrate downstream and are exposed to SWP export operations. Improvement in growth and survival can also lead to increased population resiliency during times of increased temperatures and water demands.

Improvements to adult passage will serve as mitigation for unavoidable and unminimized impacts to adult CHNWR and CHNSR due to SWP operations. As indicated in Section 7.2.1 (Entrainment of Adult Chinook Salmon into Clifton Court Forebay) and Section 7.2.2 (Salvage of Adult Chinook Salmon), SWP operations cause reduced in-river flows and altered hydrology (e.g., reverse flows in Old and Middle rivers, false attraction towards export pumping) which can increase straying risk for adult CHNWR and CHNSR during immigration. Direct impacts to adult CHNWR and CHNSR are currently unquantified because data are not collected on the numbers of adults immigrating through the Delta and entrainment at the SWP export facilities (i.e., CCF, Skinner Fish Facility, California Aqueduct, Banks Pumping Plant). There are no minimization measures proposed for the loss of adult CHNWR and CHNSR at the SWP salvage facilities (i.e., CCF and Skinner Fish Facility). There are also no risk assessments conducted by the Salmon Monitoring Team that will propose minimization or OMR management when adults are present or at high risk of straying into the SWP salvage facilities. Minimization measures for juvenile CHNWR and CHNSR identified under Conditions of Approval 8.3.2, 8.6.1, 8.6.2, 8.6.3 and 8.6.4

may provide incidental benefits for adults present in the entrainment zone of the export facilities. Entrainment and loss of adults at the SWP export facilities can result in pre-spawn mortality due to stranding or physical injuries sustained during the salvage process. Pre-spawn mortality can lead to a reduction in genetic diversity of these populations and a decline in juvenile production. Providing improved upstream adult passage and spawning habitat improvements will allow access to habitat that was formerly limited due to either structural or flow impediments. Increasing the access of upstream habitat can allow for spatial diversity in spawning that can increase juvenile production, life history and genetic diversity as well as reduce the likelihood of redd superimposition. Improving fish passage throughout the Sacramento river basin will reduce migratory delays and loss of adult CHNWR and CHNSR at barriers and can enhance ecosystem function through improved habitat connectivity.

9.2. Condition of Approval 9.2.2 – Implement the Yolo Bypass Salmonid Habitat Restoration and Fish Passage Project

Condition of Approval 9.2.2 – Implement the Yolo Bypass Salmonid Habitat Restoration and Fish Passage Project (YBSHRFP Project) requires Permittee to enhance floodplain rearing habitat and fish passage in the Yolo Bypass, which will benefit CHNWR and CHNSR in addition to other species, including Central Valley steelhead and the Southern Distinct Population Segment (DPS) of North American green sturgeon (*Acipenser medirostris*).

The 2009 NMFS BiOp and CDFW Consistency Determination for CHNWR and CHNSR required DWR, in conjunction with Reclamation, to implement habitat enhancement projects to improve spawning and rearing habitat for Chinook salmon in the Sacramento River basin and Delta. Specifically, RPA Action I.6.1 required the restoration of floodplain rearing habitat for juvenile CHNWR and CHNSR in the lower Sacramento River basin (later identified as the YBSHRFP Project). The action required reinitiation of consultation if less than half of the total acreage identified in the restoration plan (later identified as the DWR and Reclamation 2012 Yolo Bypass Salmonid Habitat Restoration and Fish Passage Implementation Plan) was implemented by 2016. The Record of Decision/Notice of Determination for the YBSHRFP Project Environmental Impact Statement/Environmental Impact Report were signed on September 19, 2019, but State and federal environmental permits/consultations have not been issued and construction has not commenced. RPA Action I.7 required improvements to structures, including Fremont Weir, in the Yolo Bypass to reduce migratory delays and loss of adult and juvenile CHNWR and CHNSR. The action required improvements to Tule Canal and Toe Drain connectivity, including modification to existing road crossings and agricultural impoundments to reduce stranding and improve wetted habitat connectivity for emigrating and immigrating CHNWR and CHNSR. DWR and Reclamation completed improvements at Fremont Weir and Agricultural Road Crossings 2 and 3 under the Fremont Weir Adult Fish Passage Modification Project in 2018. The remaining road crossings, Agricultural Road Crossings 1 and 4, have not been addressed. However, Agricultural Road Crossing 1 improvements are included under the YBSHRFP Project EIS/EIR.

Impacts of SWP and CVP operations on CHNWR and CHNSR were assessed under the 2009 NMFS Biological Opinion and CDFW Consistency Determination, and RPA Actions I.6.1 and I.7 were required as mitigation for unavoidable loss and impacts to CHNWR and CHNSR and their critical habitat. RPA Actions I.6.1 and I.7 were required to fully mitigate, avoid jeopardizing the continued existence of the species,

and provide for the recovery of CHNWR and CHNSR under baseline conditions identified in the 2008 Reclamation Biological Assessment. There are temporal losses associated with delays in project implementation for habitat enhancements in the Yolo Bypass and Sacramento River. These temporal losses compounded by continued operations of the SWP have impeded the recovery of CHNWR and CHNSR, as evidenced by continued declines in population abundance (See Sections 4.1.2 and 4.2.2 for CHNWR and CHNSR Population Status and Trends and Sections 4.1.3 and 4.2.5 for CHNWR and CHNSR Extinction Risk). Therefore, in addition to DWR's commitment to implement the YBSHRFP Project required by Condition of Approval 9.2.1, Condition of Approval 9.2.2 requires DWR to make funding commitments to further enhance juvenile upstream rearing habitat, spawning habitat, and improve adult passage.

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