Long-Term Operation – Biological Assessment

Chapter 6 – Spring-Run Chinook Salmon

October 2024

Contents

Tables

Figures

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Chapter 6 Spring-Run Chinook Salmon

The federally listed Evolutionarily Significant Unit (ESU) of Central Valley (CV) spring-run Chinook salmon (*Oncorhynchus tshawytscha*,) and designated critical habitat occurs in the action area and may be affected by the Proposed Action. Adult spring-run Chinook salmon return to their natal tributary in the spring and spawn during the summer and fall months. Juvenile spring-run Chinook salmon uniquely exhibit two life history strategies whereby some juveniles migrate to the ocean after spawning as “young of year” and some over-summer in their natal tributary and migrate the following year as “yearlings.” Spring-run Chinook salmon primarily spawn on the mainstem Sacramento River and Butte, Mill, and Deer creeks with a reintroduction program on the San Joaquin River below Friant Dam.

6.1 Status of Species

National Marine Fisheries Service (NMFS) first listed CV spring-run Chinook salmon as threatened on September 16, 1999 (64 *Federal Register* (FR) 50394); reaffirmed as threatened on June 28, 2005 (70 FR 37160). NMFS designated critical habitat for CV spring-run Chinook salmon on September 2, 2005 (70 FR 52488).

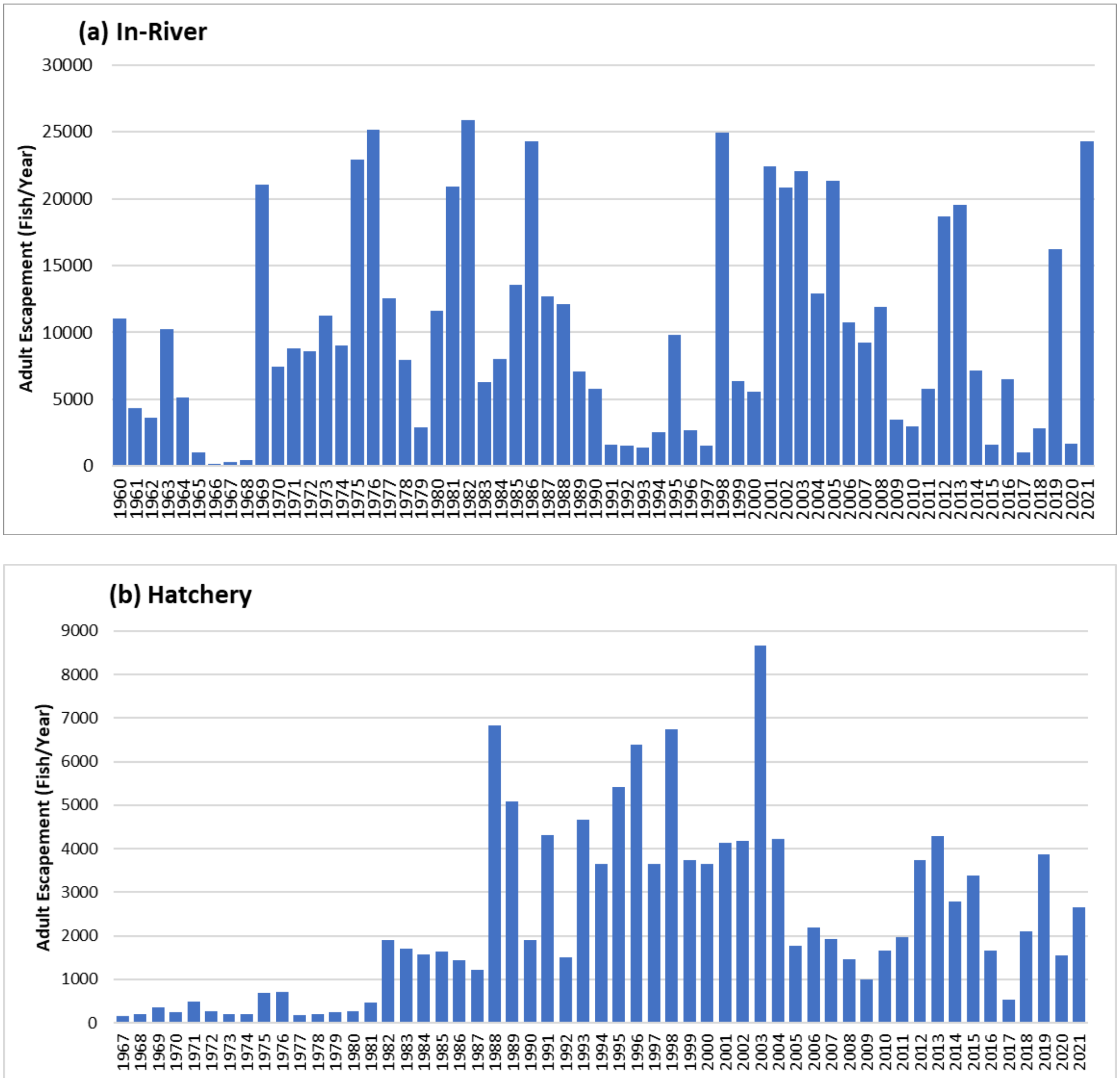
6.1.1 Distribution and Abundance

Historically, spring-run Chinook salmon occupied the headwaters of all major river systems in the Central Valley where natural barriers to migration were absent. The Sacramento River was used as a migratory corridor to spawning areas in tributaries and headwater streams (California Department of Fish and Game 1998). Beginning in the 1880s, harvest, habitat degradation, water development, and the construction of dams substantially reduced the number and range of spring-run Chinook salmon. Construction of the Shasta Dam in 1945 and Keswick Dams in 1950 blocked passage on the Sacramento River and limited potential spawning habitat to downstream areas. Similar water resource development and construction of dams occurred across the Central Valley. Current spawning is restricted to limited areas in a few select tributaries in mainstem reaches below the lowermost impassable dams.

The Central Valley drainage as a whole is estimated to have supported annual runs of spring-run Chinook salmon as large as 600,000 fish between the late 1880s and 1940s (California Department of Fish and Game 1998). Annual runs were estimated to be no more than 26,000 fish in the 1950s and 1960s (Yoshiyama et al. 1998; Azat 2022) after the construction of most dams. Since 1970, spring-run Chinook salmon in-river escapement estimates (excluding in-river spawners in the Yuba and Feather rivers, which are considered of hatchery origin) have been highly variable, ranging from 1,059 in 2017 to 25,890 in 1976 (Azat 2022, Source: Azat 2022.

Note: Axis scales differ between upper and lower panels; data from 2009-2021 are preliminary.

Figure 6-1). Hatchery escapement increased in the 1980s and has remained higher than during the 1960s-1970s.



Source: Azat 2022.
Note: Axis scales differ between upper and lower panels; data from 2009-2021 are preliminary.

Figure 6-1. Spring-Run Chinook Salmon Adult (a) In-River (excluding Yuba and Feather rivers), 1960-2021, and (b) Hatchery Annual Escapement in the Central Valley, 1967–2021.

The only known streams that currently support self-sustaining populations of non-hybridized spring-run Chinook salmon in the Central Valley are Mill, Battle, Deer, and Butte creeks (Nelson et al. 2022). Since 1995, spring-run Chinook salmon annual run size estimates typically have been dominated by Butte Creek returns. Of the three tributaries producing naturally spawned spring-run Chinook salmon (Mill, Deer, and Butte creeks), Butte Creek has produced an average of two-thirds of the total production over the past 10 years (California Department of Water

Resources and Reclamation 2017; California Department of Fish and Wildlife 2018). The populations use the mainstem Sacramento River as a migration corridor though there is evidence of spawning occurring. It is difficult to distinguish spring-run Chinook salmon from fall-run Chinook salmon; however, aerial redd surveys have reported spring-run Chinook salmon redds in the Sacramento in reaches above the confluence of the Sacramento River with Clear Creek (e.g., Anderson-Cottonwood Irrigation District (ACID). to the Highway 44 Bridge). Appendix C, *Species Spatial-Temporal Domains*, presents information on spawner adult abundance (Section 3.5) and redds (Section 3.7). The Central Valley Project (CVP) supports populations of spring-run Chinook salmon on Clear Creek which migrate through the Sacramento River. The State Water Project (SWP) supports a hatchery on the Feather River, the only hatchery that produces spring-run Chinook salmon for ocean harvest. Populations hybridized with fall-run Chinook salmon occur on the Feather and Yuba rivers.

Currently there are only nonessential experimental populations of CV spring-run Chinook salmon in the San Joaquin River. An experimental population of spring-run Chinook salmon has been designated under section 10(j) of the Endangered Species Act (ESA) in in the San Joaquin River from Friant Dam downstream to its confluence with the Merced River (78 FR 79622 2013), and spring-run Chinook salmon are currently being reintroduced to the San Joaquin River. The broodstock for the spring-run Chinook salmon experimental population came from the Sacramento River Basin (Feather River Fish Hatchery spring-run Chinook salmon). There is evidence of Chinook salmon occurring in the Stanislaus and Tuolumne rivers that may represent residual populations of spring-run Chinook salmon or individuals that have strayed from other river basins and use the Stanislaus and Tuolumne rivers for spawning. Evidence is based on run timing and the presence of fry and juveniles that show traits characteristic of spring-run Chinook salmon populations such as hatching dates and seasonal sizes (Franks 2014; National Marine Fisheries Service 2016).

6.1.2 Life History and Habitat Requirements

The Salmon and Sturgeon Assessment of Indicators by Life Stage (SAIL) conceptual model (Windell et al. 2017) describes life stages and geographic locations for winter-run Chinook salmon, and has been adapted for spring-run Chinook salmon (Figure 6-2).

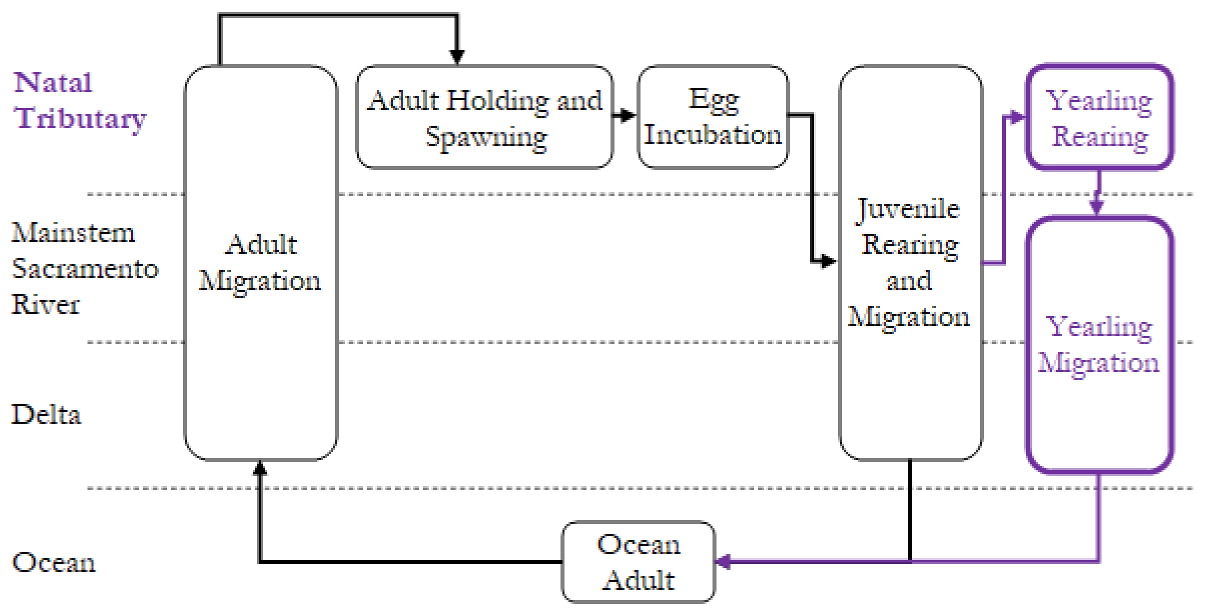


Figure 6-2. Geographic Life Stage Domains for Spring-Run Chinook Salmon (adapted from Windell et al. 2017, Figure 2).

The habitat requirements for spring-run Chinook salmon are similar to those for winter-run Chinook salmon. The primary differences in the habitat requirements between the two runs are the duration and the time of year that the different life stages of the species utilize the habitat. Adult spring-run Chinook salmon use the Bay-Delta and mainstem Sacramento River primarily for migration. Spring-run Chinook salmon generally enter rivers as sexually immature fish. While maturing, adults hold in deep pools with cold water for several months before spawning (Moyle 2002). The length of time required for embryo incubation and emergence from the gravel is dependent on water temperature. Juveniles migrate to the ocean as young-of-the-year in the winter or spring months within eight months of hatching while some may reside in freshwater for 12 to 16 months (CALFED 2000b).

Once in the ocean, juvenile spring-run Chinook salmon tend to stay along the California coast (Moyle 2002). This behavior is likely due to the high productivity caused by the upwelling of the California current. These food-rich waters are important to ocean survival, as indicated by a decline in survival during years when the current does not flow as strongly and upwelling decreases (Lindley et al. 2009; Moyle 2002). After entering the ocean, juveniles become voracious predators on small fish and crustaceans and invertebrates such as crab larvae and amphipods. As spring-run Chinook salmon grow larger, their diet shifts towards whatever pelagic fish are most abundant, usually herring, anchovies, juvenile rockfish, and sardines. The ocean stage of the Chinook salmon life cycle lasts one to five years.

Monitoring data from snorkeling, carcass surveys, redd surveys, rotary screw traps, trawls, and beach seines describe the timing of spring-run Chinook salmon presence (Figure 6-3) (Appendix C).

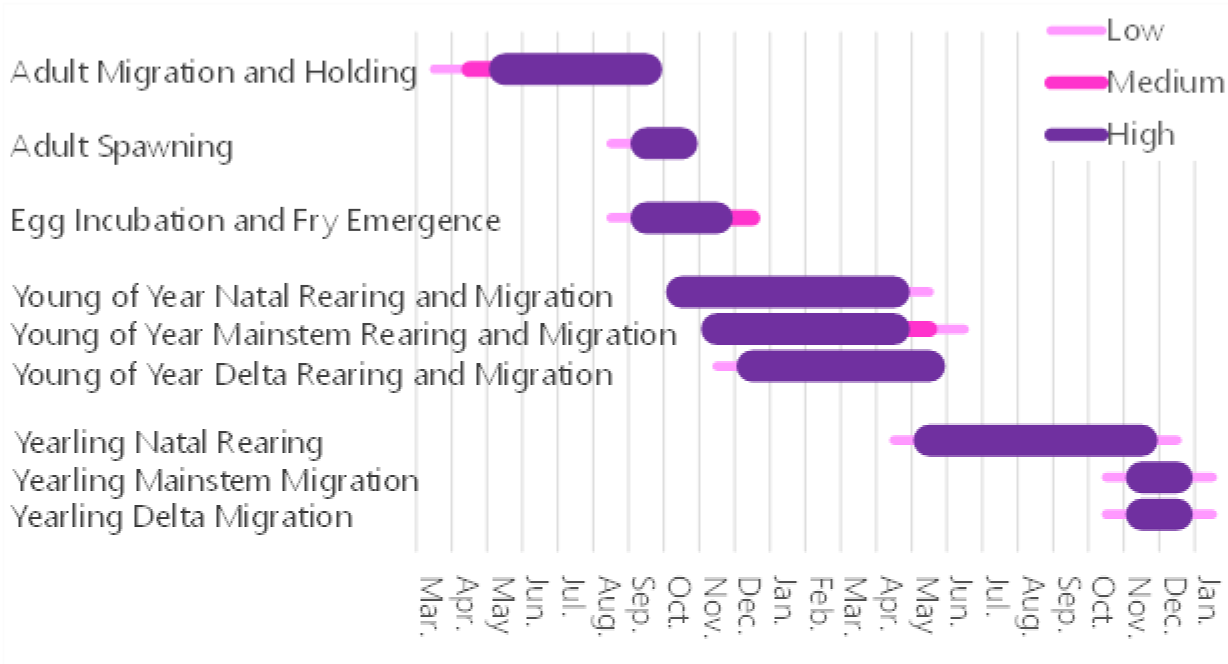


Figure 6-3. Temporal Life Stage Domains for Spring-Run Chinook Salmon from Appendix C.

Water quality requirements and physical habitat characteristics are similar to those for winter-run Chinook salmon.

6.1.3 Limiting Factors, Threats, and Stressors

Loss of historic spawning habitat for spring-run Chinook salmon remains a major threat, as most of that habitat continues to be blocked by the direct or indirect effects of dams. Since spring-run Chinook salmon were originally listed as threatened in 1999, spawning habitat for those fish has been expanded very little compared to the hundreds of miles of habitat blocked by dams.

Currently there are only experimental populations of spring-run Chinook salmon in the San Joaquin River. Efforts to reintroduce spring-run Chinook salmon to historic habitat are underway in the San Joaquin River. The San Joaquin River Restoration Program calls for a combination of channel and structural modifications along the San Joaquin River below Friant Dam, releases of water from Friant Dam to the confluence of the Merced River, and the reintroduction of spring-run Chinook salmon.

Status reviews for spring-run Chinook salmon (Myers et al. 1998, Good et al. 2005, NMFS 2011) have indicated that the remaining spawning and rearing habitat for this species is severely degraded. Threats to spring-run Chinook salmon habitat include, but are not limited to: (1) operation of antiquated fish screens, fish ladders, diversion dams, and inadequate flows on streams throughout the Sacramento River Basin including on Deer, Mill, and Antelope creeks; (2) levee construction and maintenance projects that have greatly simplified riverine habitat and have disconnected rivers from the floodplain; and (3) water delivery and hydroelectric operation on Butte Creek, Battle Creek, the mainstem Sacramento River (CVP), and the Feather River

(SWP). The degradation and simplification of aquatic habitat in the Central Valley has greatly reduced the resiliency of spring-run Chinook salmon to respond to additional stressors, such as an extended drought. The Sacramento Valley and San Joaquin Valley Water Year Hydrologic Classification Indices have been designated as Critical or Dry 6 and 7, respectively, out of the previous 10 years (2013–2022). The impacts of the extended drought will unfold over the next several years as fish return from the ocean.

The available information indicates that the fishery impacts on the spring-run Chinook salmon ESU have not changed appreciably since the 2010 status review (National Marine Fisheries Service 2011; 2016). Attempts have been made (Grover et al. 2004) to estimate spring-run Chinook salmon ocean fishery exploitation rates using coded-wire tag recoveries from natural origin Butte Creek fish, but due to the low number of recoveries the uncertainty of these estimates is too high for them to be of value.

Naturally occurring pathogens may pose a threat to the spring-run Chinook salmon ESU because artificially propagated spring-run Chinook salmon are susceptible to disease outbreaks such as the Infectious Hematopoietic Necrosis Virus and Bacterial Kidney Disease. For example, the parasite *Ceratonova shasta* (*C. shasta*) is hypothesized to limit Chinook salmon recruitment in the Feather River (Foott et al. 2023).

Predation is a threat to spring-run Chinook salmon, especially in the lower Feather River, the Sacramento River, and in the Delta where there are high densities of non-native fish (e.g., striped bass, small-mouth bass and large-mouth bass) and native species (e.g., pikeminnow) that prey on outmigrating salmon juveniles.

Overall trends for water quality show improvements in water quality across the Central Valley. Many surface waters are polluted as water is discharged from agricultural operations, urban/suburban areas, and industrial sites. These discharges transport pollutants such as pesticides, sediment, nutrients, salts, pathogens, and metals into surface waters. Although conditions in most streams, rivers, and estuaries, throughout the State are much improved from 40 years ago, the rate of improvements have slowed overtime (San Francisco Estuary Partnership 2015). Contaminants such as Polybrominated diphenyl ethers, and copper have declined over time, however many potentially harmful chemicals and contaminants of emerging concern (pharmaceuticals) have yet to be addressed. Legacy pollutants such as mercury and Polychlorinated biphenyls limit consumption of most fish, and directly and indirectly affect endangered fish populations, as well as their designated critical habitat.

Climate experts predict physical changes to ocean, river and stream environments along the West Coast that include warmer atmospheric temperatures resulting in more precipitation falling as rain rather than snow, diminished snow pack resulting in altered stream flow volume and timing, increased winter flooding, lower late summer flows, a continued rise in stream temperatures, increased sea-surface temperatures, increased ocean acidity, sea-level rise, altered estuary dynamics, changes in the timing, duration and strength of nearshore upwelling, and altered marine and freshwater food-chain dynamics (see Williams et al. 2016 for a more detailed discussion of these and other projected long-term impacts due to climate change). These long-term climate, environmental and ecosystem changes are expected to, in turn, cause changes in salmon and steelhead distribution, behavior, growth, and survival.

To understand the CVP and SWP stressors on fish, SAIL models describe linkages between landscape attributes and environmental drivers to habitat attributes that may affect fish (stressors) based on life stage. The SAIL models provide life stages and stressors of adult migration, adult holding and spawning, egg incubation to fry emergence, and juvenile rearing to outmigrating. In addition to the winter-run Chinook salmon life stages and stressors identified in Chapter 5, *Winter-Run Chinook Salmon,* the proposed conceptual lifecycle framework for spring-run Chinook salmon considers two additional life stages that include stressors from the winter-run Chinook salmon Juvenile Rearing to Outmigration hypotheses. Each additional stressor is briefly summarized from Windell et al. (2017).

6.1.3.1 Yearling Rearing

- Toxicity and contaminants: Urban stormwater and agricultural runoff may be contaminated with pesticides, herbicides, oil, grease, heavy metals, polycyclic aromatic hydrocarbons, and other organics and nutrients that potentially have direct lethal and sub-lethal physiological and behavioral effects on fry and destroy the aquatic life necessary for salmonid growth and survival. Acid mine drainage still escapes untreated from waste piles and seepage on the north side of Iron Mountain, which eventually flows into the Sacramento River. There remains uncertainty associated with determining the impacts of operations on the toxicity from contaminants stressor, particularly for impacts in the Delta.
- Stranding risk: Significant flow reductions present a stranding risk to juveniles.
- Outmigration cues: Storage of unimpeded runoff by Shasta and Keswick dams and the use of stored water for irrigation and export have altered the natural hydrograph by which spring-run Chinook salmon base their migrations.
- Water temperature and dissolved oxygen (DO): Fry are confined to the low-elevation habitats on the Sacramento River that are dependent on coldwater releases from Shasta Dam to sustain the remnant population.
- Pathogens and disease: Specific diseases are known to affect juvenile spring-run Chinook salmon survival.
- Entrainment risk: Unscreened or poorly screened water diversions lead to direct entrainment and mortality and can also reduce river flow.
- Refuge habitat: Altered flows have resulted in diminished natural channel formation, and slower regeneration of riparian vegetation. Channelized, leveed, and riprapped reaches typically have low habitat complexity.
- Food availability and quality: Altered flows have resulted in altered food web processes. Channelized, leveed, and riprapped reaches typically have low abundance of food organisms.
- Predation and competition: Channelized, leveed, and riprapped reaches typically offer little protection from predators. Water-diversion infrastructures, provide in-river structure that support predation on spring-run Chinook salmon fry by native and non-native fishes.

6.1.3.2 Yearling Migration

- Toxicity and contaminants: Urban stormwater and agricultural runoff may be contaminated with pesticides, herbicides, oil, grease, heavy metals, polycyclic aromatic hydrocarbons, and other organics and nutrients that potentially have direct lethal and sub-lethal physiological and behavioral effects on fry and destroy the aquatic life necessary for salmonid growth and survival. Acid mine drainage still escapes untreated from waste piles and seepage on the north side of Iron Mountain, which eventually flows into the Sacramento River. There remains uncertainty associated with determining the impacts of operations on the toxicity from contaminants stressor, particularly for impacts in the Delta.
- Stranding risk: Significant flow reductions present a stranding risk to juveniles.
- Outmigration cues: Storage of unimpeded runoff by Shasta and Keswick dams and the use of stored water for irrigation and export have altered the natural hydrograph by which spring-run Chinook salmon base their migrations.
- Water temperature and DO: Fry are confined to the low-elevation habitats on the Sacramento River that are dependent on coldwater releases from Shasta Dam to sustain the remnant population.
- Pathogens and disease: Specific diseases are known to affect juvenile spring-run Chinook salmon survival.
- Entrainment risk: Unscreened or poorly screened water diversions lead to direct entrainment and mortality and can also reduce river flow.
- Refuge habitat: Altered flows have resulted in diminished natural channel formation, and slower regeneration of riparian vegetation. Channelized, leveed, and riprapped reaches typically have low habitat complexity.
- Food availability and quality: Altered flows have resulted in altered food web processes. Channelized, leveed, and riprapped reaches typically have low abundance of food organisms.
- Predation and competition: Channelized, leveed, and riprapped reaches typically offer little protection from predators. Water-diversion infrastructures, provide in-river structure that support predation on spring-run Chinook salmon fry by native and non-native fishes.

6.1.4 Management Activities

In 2014, NMFS published the *Recovery Plan for the Evolutionary Significant Units of Sacramento River Winter-run Chinook Salmon and Central Valley Spring-run Chinook Salmon and the Distinct Population Segment of California Central Valley Steelhead*. The Recovery Plan identifies recovery goals, objectives, and criteria for delisting these Central Valley salmonids. Recovery actions include locations in the Pacific Ocean, San Francisco, San Pablo, and Suisun Bays, the Delta, the Central Valley, the Sacramento River, and Battle Creek. The Recovery Plan serves as a guide of voluntary management activities that can be pursued to enhance listed species and designated critical habitat condition.

6.1.4.1 Recovery Plan Activities Related to the Long-Term Operation of the Central Valley Project and State Water Project

Recovery and research focused management activities identified in the 2014 Recovery Plan that applied to winter-run Chinook salmon, spring-run Chinook salmon and steelhead are described in Chapter 5, Section 5.1.4, *Management Activities.*

The following recovery and research focused management activities, identified in the 2014 Recovery Plan, are focused on spring-run Chinook salmon, and are associated with the operation of the CVP and SWP or related facilities. Actions involving spring-run Chinook salmon are listed below by watershed.

- **Delta**
    - *Continue to evaluate head of Old River barrier operations to identify and then implement the best alternative for maximizing survival of juvenile steelhead and spring-run Chinook salmon emigrating from the San Joaquin River.* This activity is complete. *See Appendix R – Head of Old River Barrier.*
- **Clear Creek**
    - *Manage releases from Whiskeytown Dam with instream flow schedules and criteria to provide suitable water temperatures for all life stages, reduce stranding and isolation, protect incubating eggs from being dewatered, and promote habitat quality and availability as described in RPA action I.1.6 of the 2009 Biological Opinion for the long-term operations of the CVP and SWP (NMFS 2009b).* This activity is ongoing as part of operations and addressed in this consultation.
    - *Develop water temperature models to improve Clear Creek water temperature management as described in RPA action I.1.5 of the 2009 Biological Opinion for the long-term operations of the CVP and SWP (NMFS 2009b).* The Sacramento - Trinity Water Temperature Modeling Platform has been recently completed.
    - *Implement channel maintenance flows in Clear Creek called for in the CVP/SWP biological opinion (NMFS 2009b, Action I.1.2).* This activity is ongoing as part of operations and addressed in this consultation.
    - *Implement the Clear Creek pulse flows called for in the CVP/SWP Biological Opinion (NMFS 2009b, Action I.1.1), utilizing adaptive management to adjust pulse timing, magnitude, and/or duration, as needed, to be most effective at attracting adult spring-run Chinook salmon.* This activity is ongoing as part of operations and addressed in this consultation.
    - *Operate the Clear Creek segregation weir to create reproductive isolation between fall-run Chinook salmon and spring-run Chinook salmon.* This activity is ongoing as part of operations and addressed in this consultation.
    - *Develop a long-term operation and maintenance agreement for the segregation weir in Clear Creek.* Completed in 2020.

- **San Joaquin River**
    - *Develop and implement an ecologically based San Joaquin River flow regime to help restore natural river processes and support all life stages of steelhead and spring-run Chinook salmon (Poff et al. 1997).* This activity is ongoing as a separate program (San Joaquin River Restoration Program [SJRRP]) and not addressed in this consultation.
    - *Implement channel modifications as outlined in the San Joaquin River Stipulation of Settlement, including increasing the channel capacity to accommodate restoration flows up to 4,500 cfs (available at http://restoresjr.net/).* This activity is ongoing as a separate program (SJRRP), and not addressed in this consultation.
    - *Provide fish passage at existing structures as outlined in the San Joaquin River Stipulation of Settlement (available at http://restoresjr.net/) including: (1) modifications to the Sand Slough Control Structure; (2) modification of the Reach 4B head gate; (3) reconstruction of Sack Dam to ensure unimpeded fish passage; (4) construction of a Mendota Pool Bypass; (5) modifications to structures in the Eastside and Mariposa Bypasses channels; and (6) fixing other passage impediments including road crossings, drop structures, and others as identified in the DWR Passage Report (DWR 2012) for the San Joaquin River Restoration Area.* This activity is ongoing as a separate program (San Joaquin River Restoration Program), and not addressed in this consultation.
    - *Minimize entrainment and fish losses to both adult and juvenile life stages to non-viable migration pathways as outlined in the San Joaquin River Stipulation of Settlement, including, placing temporary barriers at Mud and Salt Sloughs and other potential sources of adult entrainment, screening Arroyo Canal and other riparian diversions as they are identified, and modifying and screening the Chowchilla Bypass Bifurcation Structure (available at http://www.restoresjr.net/).* This activity is ongoing as a separate program (SJRRP), and not addressed in this consultation.

6.1.4.2 Other Recovery Plan Activities

Additional recovery and research focused management activities identified in the 2014 Recovery Plan do not involve the operation of the CVP, SWP, nor related facilities. Some of these actions fall within additional United States Department of the Interior, Bureau of Reclamation (Reclamation) and California Department of Water Resources (DWR) authorities to contribute to the recovery of listed species as projects and programs with their own administration and consultation processes.

- **Delta**
    - *Identify and implement projects designed to improve passage and habitat conditions in the Stockton Deep Water Ship Channel.*
- **Clear Creek**

- *Develop programs and implement projects for Clear Creek that promote natural river processes, including projects that restore floodplain habitat (e.g., Cloverview project and Paige Bar floodplain lowering project), add riparian habitat and instream cover, and control non-native invasive plant species.*

- *Implement floodplain restoration projects, potentially including the Lower Clear Creek Floodway Rehabilitation Project (Phase 3C).*

- *Develop a new spawning gravel budget and implement a long-term gravel augmentation plan in Clear Creek, including acquisition of a long-term gravel supply (per Central Valley Project Improvement Act (CVPIA) and RPA action I.1.3 of the 2009 Biological Opinion for the long-term operations of the CVP and SWP (NMFS 2009).*

- **San Joaquin River**

  - *Develop education and outreach programs and coordinate with local governments, communities, and conservation districts to encourage river stewardship in the San Joaquin River Basin.*

  - *Develop and implement a spring-run Chinook salmon reintroduction strategy as outlined in paragraph 14 of the San Joaquin River Stipulation of Settlement (available at http://www.restoresjr.net/).*

  - *Develop information to better understand the interaction between surface water and groundwater in the San Joaquin watershed in order to evaluate the potential impacts of water management options (e.g., groundwater sales; conjunctive use) in the watershed on San Joaquin River flows.*

  - *Conduct studies to evaluate whether predator control actions (e.g., fishery management or directed removal programs) can be effective at minimizing predation on steelhead and spring-run Chinook salmon in the San Joaquin River; continue implementation if effective.*

  - *Develop and implement design criteria and projects to minimize predation at weirs, diversion dams, and related structures in the San Joaquin River.*

  - *Manage juvenile salmonid predation risk by filling and/or isolating high priority gravel pits as identified in paragraph 11(b) of the San Joaquin River Stipulation of Settlement (available at http://www.restoresjr.net/).*

6.1.4.3 Monitoring

Sacramento River tributary populations in Mill, Deer, and Butte creeks are likely the best trend indicators for the spring-run Chinook salmon ESU. Generally, these streams have shown a positive escapement trend since 1991, displaying broad fluctuations in adult abundance. The Feather River Fish Hatchery spring-run Chinook salmon population represents the only remaining evolutionary legacy of the spring-run Chinook salmon populations that once spawned above Oroville Dam, and has been included in the ESU based on its genetic linkage to the natural spawning population and the potential development of a conservation strategy for the hatchery program (70 FR 37160 [June 28, 2005]).

Counts of Chinook salmon redds in September are typically used as an indicator of the spring-run Chinook salmon population abundance. Less than 15 Chinook salmon redds per year were observed in the Sacramento River from 1989 to 1993, during September aerial redd counts. Redd surveys conducted in September from 2001 to 2011 have observed an average of 36 Chinook salmon redds from Keswick Dam downstream to the Red Bluff Diversion Dam, ranging from 3 to 105 redds; from 2012 to 2015, redds observed were close to zero except in 2013, when 57 redds were observed in September (California Department of Fish and Wildlife 2017). Currently, Clear Creek is the only tributary within this diversity group that has an independent population of spring-run Chinook salmon. Juvenile production as estimated from rotary traps at Red Bluff Diversion Dam indicates that juvenile outmigration of spring-run Chinook salmon from Clear Creek and the upper Sacramento River has fluctuated since 2013. Estimates of outmigrants ranged from over 120,000 to 1.7 million between 2013 and 2015 brood years, declining more recently to just under one million in brood year 2016 and just over 300,000 in brood year 2017, and then jumping back up to over 3.3 million juveniles outmigrating for brood year 2018 (Voss and Poytress 2022).

Below are summaries of spring-run Chinook salmon take and mortality by life stage for 2020 (Table 6-1), 2021 (Table 6-2), and 2022 (Table 6-3).

Table 6-1. Summary of spring-run Chinook salmon take and mortality by life stage, 2020.

Spring-Run Chinook Salmon – 2020	Sum of Expected Take	Sum of Actual Take	Sum of Indirect Mortality	Sum of Actual Mortality
Adult	173035	12066	4304	157
Egg	2500	0	0	0
Fry	4	0	0	0
Juvenile	265783	8918	7396	80
Smolt	4470	508	77	0
Spawned Adult/Carcass	2497	35	0	0
Not Specified	0	1004	0	712
Grand Total	**448289**	**22531**	**11777**	**949**

Table 6-2. Summary of spring-run Chinook salmon take and mortality by life stage, 2021.

Spring-Run Chinook Salmon – 2021	Sum of Expected Take	Sum of Actual Take	Sum of Indirect Mortality	Sum of Actual Mortality
Adult	28924	1502	12	6
Egg	2500	0	0	0
Juvenile	487841	17657	11754	264
Smolt	4650	779	82	8

Spring-Run Chinook Salmon – 2021	Sum of Expected Take	Sum of Actual Take	Sum of Indirect Mortality	Sum of Actual Mortality
Spawned Adult/Carcass	2362	6192	0	0
Not Specified	0	504	0	420
Grand Total	**526277**	**26634**	**11848**	**698**

Table 6-3. Summary of spring-run Chinook salmon take and mortality by life stage, 2022.

Spring-Run Chinook Salmon – 2022	Sum of Expected Take	Sum of Actual Take	Sum of Indirect Mortality	Sum of Actual Mortality
Adult	30184	4029	15	3
Egg	2500	0	0	0
Juvenile	490986	84084	11779	1310
Smolt	4650	5	98	0
Spawned Adult/Carcass	5417	13	0	0
Not Specified	0	192	0	159
Grand Total	**533737**	**88323**	**11892**	**1472**

6.1.5 Current Long-Term Operation Incidental Take Statement

Quantitative incidental take for the previous long-term operation of the CVP and SWP from the 2019 NMFS Biological Opinion are described below.

NMFS permitted incidental take as:

6.1.5.1 Adults

The anticipated level of take will be exceeded if the daily average temperature at the Igo gauge exceeds 60°F from June 1 through September 14 for longer than seven consecutive days or exceeds 61°F for any single day.

6.1.5.2 Eggs

- **Upper Sacramento (Shasta and Sacramento) Division**
    - Measures for winter-run Chinook salmon
    - Proportion of redds that are exposed to a daily average water temperature over 53.5°F measured between Keswick Dam and Balls Ferry
    - Three percent of redds are dewatered
- **Clear Creek (Trinity River Division)**
    - The ecological surrogate for the amount or extent of take of spring-run Chinook salmon egg to-fry life stage is the daily average temperature at the Igo gauge

when eggs are in the gravel incubating. This is expected to occur between September 15 and October 31.

  - Years in which Trinity Lake volume available is in excess of 2.0 million acre feet at the end of April and facilities are capable of functioning at capacity, average daily water temperature at the Igo gauge exceeds 56°F for longer than seven consecutive days or exceeds 57°F for any single day.

  - In years where Trinity Lake volume is less than 2.0 million acre-feet but greater than or equal to 1.5 million acre-feet at the end of April, average daily water temperature exceeds 57°F for longer than seven consecutive days.

  - Years when end of April volumes are less than 1.5 million acre-feet, or times when infrastructure is impaired, the anticipated level of take will be highly variable and interrelated with the Sacramento River expected take, average daily water temperature exceeds 59°F for longer than seven consecutive days.

- The ecological surrogate for the amount or extent of take during base flows for the spring-run Chinook salmon is flow lower than 200 cfs for all water year types (WYT) except critically dry years, which could go below 150 cfs depending on the available water supply between October 1 and May 31 and 150 cfs from June 1 to September 30.

6.1.5.3 Juveniles

- Incidental take of spring-run Chinook salmon was reasonably likely to occur due to Barker Slough Pumping Plant Sediment and Weed Control Operations. The anticipated level of take is more than five unclipped listed salmonids (cumulative) are entrained per year through any combination of Sacramento River winter-run Chinook salmon, spring-run Chinook salmon, and CV steelhead.

- Incidental take of spring-run Chinook salmon was reasonably expected to occur due to Clifton Court Predator Management: Predator Reduction Electrofishing Study. Based on results of previous years of studies, the anticipated level of take for spring-run Chinook salmon will be exceeded if the two-year take for the combined predator reduction electrofishing study and the predatory fish relocation study within Clifton Court Forebay is higher than 50 for the two-year non-lethal incidental take (juveniles and adults) and five for lethal incidental take (juveniles).

- Incidental take of spring-run Chinook salmon was reasonably expected to occur due to Barker Slough Pumping Plant and the North Bay Aqueduct Intake: The ecological surrogate for take of listed winter-run Chinook salmon, spring-run Chinook salmon, steelhead, and southern distinct population segment green sturgeon will be the maximum diversion rate of 175 cfs. If the Barker Slough Pumping Plant and the North Bay Aqueduct intakes are operated in a manner not consistent with the Proposed Action, then the anticipated level of take of listed salmonids and southern distinct population segment green sturgeon will have been exceeded.

- Incidental take of spring-run Chinook salmon was reasonably expected to occur due to Delta Cross Channel (DCC) Gates: The ecological surrogate is the frequency and duration of opening the DCC Gates in the October through January time period. Because of the causal relationship of gate opening to exposure of increased stressors within and between life stages, frequency and duration of opening may be used as a surrogate for the amount or extent of take for listed salmonids. The anticipated level of take will be exceeded if the number or duration of openings exceed those described in the Proposed Action.

6.1.5.4 Yearlings

- 1% of the estimated number of late fall-run Chinook salmon released from Coleman National Fish Hatchery (CNFH) in each surrogate release group released into Battle Creek

The 2019 NMFS Biological Opinion additionally included elements of the Proposed Action as ecological surrogates but did not quantify the effects by life stage.

6.2 Effects Analysis

The following sections summarize potential effects of the Proposed Action to spring-run Chinook salmon by life stage and stressors identified in the winter-run Chinook salmon Salmon SAIL conceptual model (Windell et al. 2017) as adapted to spring-run Chinook salmon. Appendix B, *Water Operations and Ecosystem Analyses,* shows how the seasonal operation of the CVP and SWP change river flows, water temperatures, and water quality parameters in different locations and under different hydrologic conditions. Appendix C summarizes when fish may be present in different locations based on historical monitoring in the Central Valley and, in many cases, these data were used to craft a proportion determination.

Appendix D, *Seasonal Operations Deconstruction,* analyzes potential stressors for the seasonal operation of the CVP and SWP. Deconstruction of the seasonal operation systematically evaluated how each stressor identified by the SAIL conceptual models may or may not change with the Proposed Action to store, release, divert, route, or blend water. Stressors not linked to the operation of the CVP and SWP were identified as "not anticipated to change." Stressors that may change to an extent insignificant or discountable were documented. Insignificant effects relate to the size of the impact and should never reach the scale where take occurs. Based on best judgment, a person would not be able to meaningfully measure, detect, or evaluate insignificant effects. Discountable effects are extremely unlikely to occur. Based on best judgment, a person would not be able to expect discountable effects to occur.

Stressors that may result in effects to listed species were documented and proposed conservation measures identified. Appendix G, *Specific Facility and Water Operations Deconstruction*, analyzes potential stressors due to facility specific operations, and analyses of conservation measures to minimize or compensate for adverse effects are found in Appendix H, *Conservation Measures Deconstruction*, Appendix I, *Old and Middle River Flow Management*, Appendix J, *Winter and Spring Pulses and Delta Outflow - Smelt, Chinook Salmon, and Steelhead Migration and Survival*, Appendix K, *Summer and Fall Delta Outflow and Habitat*, Appendix L, *Shasta*

Coldwater Pool Management, Appendix M, *Folsom Reservoir Flow and Temperature Management*, Appendix N, *New Melones Stepped Release Plan*, Appendix O, *Tributary Habitat Restoration*, Appendix P, *Delta Habitat*, Appendix Q, *Georgiana Slough Non-Physical Barrier*, Appendix R, *Head of Old River Barrier*.

6.2.1 Adult Migration

Adult spring-run Chinook salmon enter the San Francisco Estuary from the Pacific Ocean to begin their upstream spawning migration in late January and early February (California Department of Fish and Game 1998). Adult spring-run Chinook salmon are expected to migrate upstream through the Bay-Delta region from January to June with a peak presence from February through April. The Delta and Sacramento River provide a critical migration corridor for adults to their spawning grounds upstream. Adult spring-run Chinook salmon may use the portion of the lower San Joaquin River within the Delta as a migratory pathway.

Spring-run Chinook salmon adults enter the Sacramento River from March to September, primarily in May and June (Moyle 2002; Yoshiyama et al. 1998).

Adult spring-run Chinook salmon migrate into Clear Creek from April to August, and peak passage occurs in May and June (Clear Creek Technical Team 2018; Giovannetti and Brown 2013).

The stressors that influence spring-run Chinook salmon adult migration are *In-river Fishery and Poaching, Toxicity from Contaminants, Stranding Risk, Water Temperature, Dissolved Oxygen, and Pathogens*.

The Proposed Action is not anticipated to change the stressors: *In-River Fishery and Poaching, nor Stranding Risk*

Stressors that may change at a level that is insignificant or discountable include the following:

- The Proposed Action may decrease the *water temperature* stressor. During the adult migration period, the Proposed Action will release water resulting in increased flows. Evidence suggests that optimal water temperatures between 37.9°F and 60.8°F for Pacific Northwest Chinook salmon migrating and between 42.8°F and 57.2°F for hatchery Chinook salmon holding (Reiser and Bjornn 1979, McCullough 1999). Studies on Pacific Northwest salmon showed migration halting and pre-spawn mortality occurring at temperatures greater than 68°F (Goneia et al. 2006, Bowerman et al. 2018).

  Delta water temperature is positively correlated with Delta inflow in the winter, Delta water temperature is negatively correlated with Delta inflow in the spring (Bashevkin and Mahardja 2022). On the Sacramento River at Emmaton, historic January through June water temperatures (2006–2022) were less than 68°F in all years before middle of May and only less than 60.8°F in most years January through end of March. The range of potential reservoir operations under the Proposed Action is unlikely to have a measurable effect on Delta water temperatures as Bay-Delta water temperature is mainly driven by timing of snowmelt (Knowles and Cayan 2002), air temperature, solar radiation, and meteorology (Vroom et al. 2017, Daniels and Danner 2020). There is uncertainty about whether the decreased inflow from reservoir operations increases Delta water temperatures; however, the correlations include wet years with flood operations. Thus, the stressor is not anticipated to change in the Delta because the volume of water required to provide sufficient thermal mass to deviate from ambient air temperatures is substantially larger than releases outside of flood operations.

- The Proposed Action may increase or may decrease the *pathogens and disease* stressor. During the adult migration period, the Proposed Action will release water resulting in changes to water temperatures which may influence pathogens. McCullough (1999) reported a 59.9°F water temperature threshold as the threshold above which diseases affecting Chinook salmon become highly virulent. The same rational for temperature applies to this stressor and conditions are likely below the threshold.

- The Proposed Action may decrease the DO stressor. During the adult migration period, the Proposed Action will release water resulting in increased flows that may provide a higher DO saturation potential. Spring-run Chinook salmon wait to migrate until DO is at least 5.0 milligrams per liter (mg/l) (Carter 2005) Additionally, higher levels of DO have been shown as preferable for migrating Chinook salmon (Bjornn and Reiser 1991).

  On the Sacramento River at Prisoner's Point in the Delta, historic January through June daily water DO levels (2006–2022) fluctuate, typically recorded around 10 mg/L. Levels were recorded at or below 5.0 mg/L in 2012 and 2015 for short periods of time during April and May. However, generally the DO stressor is not anticipated to change because it is unlikely the Proposed Action operations changes in flows will cause changes to DO in the Delta.

  On the Sacramento River above Clear Creek and at Red Bluff Diversion Dam (2006–2022), March to September daily DO levels fluctuate but on average recorded above 10 mg/L in the majority of years.

  Upper Clear Creek is steep and there is often white water. In the spring and summer on Clear Creek, DO is likely at saturation due to the facilitation of gas exchange in white water conditions.

- The Proposed Action may decrease or may increase the *toxicity from contaminants* stressor. During the adult migration period, the Proposed Action will release water resulting in increased flows in the Sacramento River below Keswick Dam and in Clear Creek. The Proposed Action will also decrease inflow into the Delta. Increased flows may dilute contaminants if and when contaminants are present while decreased inflow may concentrate contaminants. However, increased flows and pulses can mobilize suspended sediments consisting of contaminants in river systems (van Vliet et al. 2023). The timing of snowmelt may also play a role in this stressor though studies on contaminants present in snowmelt and rainfall runoff have reported differing results (Parajulee et al. 2017; Chen et al. 2018).

  Water quality in the Central Valley is regulated by the U.S. Environmental Protection Agency. Contaminants are commonly found on floodplains (e.g., methylmercury, selenium); however, releases as part of seasonal operations would be below the bankfull flows that would mobilize these contaminants. During migration, adults do not eat, which reduces their exposure to contaminants in prey during this life stage. Monitoring has not shown fish kills that may be indicative of contaminants at levels likely to affect adult salmon. Levels safe for human consumption are assumed not likely to impact fish health and (Murphy et al. 2022) identifies Chinook salmon as safe to eat.

There are no changes in stressors likely to harm, harass, or kill individuals during adult migration. The Proposed Action is not expected to result in incidental take during this life stage.

6.2.2 Adult Holding and Spawning

Spring-run Chinook salmon generally enter rivers as sexually immature fish and must hold in freshwater for up to several months before spawning (Moyle 2002). While maturing, adults hold in deep pools with cold water. Documentation of holding locations on the Sacramento River was not identified.

Adults distribute throughout Clear Creek and hold in deep pools throughout the summer from Whiskeytown Dam (river mile 18.3) as far downstream as river mile four. Spawning occurs in gravel substrate in relatively fast-moving, moderately shallow riffles or along banks with relatively high water velocities to promote higher oxygen levels and eliminate fines in the substrate. Spawning normally occurs between mid-August and early October, peaking in September (Moyle 2002).

The stressors that influence the holding and spawning of adult spring-run Chinook salmon are *In-river Fishery and Poaching, Toxicity from Contaminants, Stranding Risk, Water Temperature, Pathogens and Disease, Dissolved Oxygen, Spawning Habitat, and Competition, Introgression, and Broodstock Removal* and are described in Section 6.1.3, *Limiting Factors, Threats, and Stressors.*

The Proposed Action is not anticipated to change the stressors: *In-River Fishery and Poaching, nor Competition, Introgression, and Broodstock Removal.*

Stressors that may change at a level that is discountable or insignificant include:

- The Proposed Action may decrease the *toxicity from contaminants* stressor. During the adult holding and spawning period, the Proposed Action will release water and increase flows into the Sacramento River below Keswick Dam. Increased flows may dilute contaminants if and when contaminants are present.

  Monitoring of adults on the Sacramento River has not shown fish kills that may be indicative of contaminants at levels likely to affect adult salmon. Evidence presented in the toxicity and contaminants section for Section 6.2.1, *Adult Migration* is applicable for the toxicity and contaminants under Adult Holding and Spawning.

  Monitoring of adults on Clear Creek has not shown fish kills that may be indicative of contaminants at levels likely to affect adult salmon. Evidence presented in the toxicity and contaminants section for Section 6.2.1, *Adult Migration* is applicable for the toxicity and contaminants section under Adult Holding and Spawning.

- The Proposed Action may decrease the DO stressor. During the adult holding and spawning period, the Proposed Action will release water and increase flows into the Sacramento River below Keswick Dam. Releases may result in cooler water temperatures and higher flows that may provide a higher DO saturation potential. Evidence presented for Section 6.2.1, *Adult Migration* is applicable for the DO stressor under Adult Holding and Spawning.

  On the Sacramento River, daily levels of DO fluctuate; however, historic records were on average recorded around 10 mg/L between the months of August and October (2006–2022).

  On Clear Creek, daily levels of DO fluctuate; however, historic records were on average recorded around 10 mg/L between the months of August and October (2006–2022).

Described below are stressors exacerbated by the Proposed Action, potentially resulting in incidental take. Also described below are conservation measures included as part of the Proposed Action to avoid or compensate for adverse effects. Finally, the Proposed Action may also ameliorate certain stressors in the environmental baseline, and below a description of these beneficial effects is included.

6.2.2.1 Spawning Habitat

The proposed release of water may increase the spawning habitat stressor. During the adult holding and spawning period, releases from Whiskeytown and Shasta reservoirs associated with the Proposed Action will increase flows and modify water temperature in Clear Creek and the Sacramento River below Keswick Dam, respectively, during the spawning season. Habitat suitability curves show higher flows reduce areas of spawning habitat quantity and quality (2020 TSC Sacramento River Gravel Augmentation Study). Dudley et al. (2019) shows higher flows result in higher velocities and the potential increase of superimposition. Appendix O, presents analysis of effects of proposed releases on spawning habitat based on suitable depths, velocities, and substrate.

The increase in spawning habitat stressors is expected to be **lethal**. Although a lack of sufficient spawning habitat can result in incomplete egg expression and redd superimposition that exposes previously deposited eggs to damage and predation, further analysis revealed that spawning habitat may not be limiting in Clear Creek. In addition, only a remnant spawning population of spring-run Chinook salmon spawn in the Sacramento River as consequence of the existence of dams and other factors in the environmental baseline and spawning habitat is not expected to be materially limited by the Proposed Action.

Changes in spawning habitat for spring-run Chinook salmon exist in the **environmental baseline** (without the Proposed Action). Hydrology, which then influences the available erodible sediment supply, the bathymetry of the river, and downstream flows drives spawning habitat quantity and quality.

Spawning is also affected by the presence of Shasta and Keswick dams. Spring-run Chinook salmon have been excluded from historical spawning habitat since the construction of Shasta and Keswick dams (NMFS 2011). Dams also influence the depth, quality, and distribution of spawning habitat. Generally, dams reduce or block the recruitment of spawning gravel, resulting in the winnowing and armoring of downstream substrates. Gravel sources from riverbanks and floodplains can also be reduced by levee and bank protection measures. Levee and bank protection measures restrict the meandering of the river, which would normally release gravel into the river through natural erosion and deposition processes. Flood control of storage further reduces peak flows that could mobilize gravels on the riverbed.

On Clear Creek, water users constructed, and historically diverted water at, the McKormick-Saeltzer Dam. In 1963, Reclamation completed construction of Whiskeytown Dam above the McKormick-Saeltzer Dam. In 2000, Reclamation removed the McKormick-Saeltzer Dam, which opened approximately 12 miles of lower Clear Creek to salmon and steelhead spawning. Since 2000, Whiskeytown Dam has been the only remaining dam on Clear Creek, which provides cold water to sustain spring-run Chinook salmon spawning and rearing.

Efforts have been made to restore parts of lower Clear Creek. For example, the Lower Clear Creek Floodway Restoration Project restored the natural form and function of a 1.8-mile channel and floodplain along lower Clear Creek to benefit salmon and steelhead. As part of that project, gravel was added to areas of Clear Creek that are high priority for Chinook salmon and steelhead. Gravel augmentations on Clear Creek have occurred in most years since 1996. The current project is managed under the Lower Clear Creek Anadromous Fish Habitat Restoration and Management Project biological assessment and the associated Biological Opinion (WCR-2014-955). Gravel augmentations in Clear Creek are summarized below in Table 6-4.

Additionally, each year the USFWS installs and operates a segregation weir to separate spring-run Chinook salmon and fall-run Chinook salmon during spawning to minimize hybridization. Before the arrival of fall-run Chinook salmon and just prior to the onset of spring-run Chinook salmon spawning, USFWS installs and operates a temporary weir each year to physically separate the two runs during spawning to minimize hybridization and redd superimposition. The segregation weir is placed at river mile 7.5 or 8.2 in late August and left in place until early November after the peak of fall-run Chinook salmon spawning.

Table 6-4. Gravel Placement in the Sacramento River and Clear Creek and percent of the 10,000 ton Target. Clear Creek does not have established annual gravel injection targets.

Year	Sacramento River: Tons	Sacramento River: % Target	Clear Creek: Tons	Clear Creek: % Target
1997	31,000	310%	3,500	100%
1998	23,000	230%	8,999	100%
1999	25,000	250%	8,001	100%
2000	32,000	320%	11,001	100%
2001	0	0%	12,501	100%
2002	15,000	150%	13,125	100%
2003	8,800	88%	10,248	100%
2004	8,500	85%	12,258	100%
2005	7,200	72%	9,735	100%

Year	Sacramento River: Tons	Sacramento River: % Target	Clear Creek: Tons	Clear Creek: % Target
2006	6,000	60%	2,601	100%
2007	6,000	60%	10,000	100%
2008	8,300	83%	8,485	100%
2009	9,900	99%	5,767	100%
2010	5,500	55%	8,290	100%
2011	5,000	50%	10,000	100%
2012	15,000	150%	9,974	100%
2013	14,000	140%	0	0%
2014	0	0%	7915	100%
2015	0	0%	0	0%
2016	32,000	320%	11,013	100%
2017	14,000	140%	9,010	100%
2018	0	0%	10,000	100%
2019	32,000	320%	8,389	100%
2020	2,000	20%	6,407	100%
2021	38,000	380%	5,011	100%
2022	20,000	200%	0	0%
Total	**358,200**	**138%**	**189,105**	**88%**

Source: Graham Matthews and Associates 2013.

The **proportion** of the population affected by the Proposed Action depends, in part, on the depths, velocities, and water temperature in areas with suitable substrate. Increased releases may reduce the quality and quantity of spawning habitat; however, early in the spawning period, spawning habitat is not saturated. In Clear Creek, spawning habitat may not be limiting for adult spring-run Chinook salmon and would be **low**. For example, 2021 saw record numbers (2,250) of spring-run Chinook salmon in Clear Creek and even then, spawning habitat was not likely limiting as the fish distribute widely and ample habitat was available.

On the Sacramento River, during summer and fall months when Shasta Reservoir has a sufficient coldwater pool to operate to suitable water temperatures downstream of the Clear Creek confluence, there is sufficient cold water and water temperature management is not required. Only a remnant population of spring-run Chinook salmon spawn in the Sacramento River and redd superimposition has not been documented for this very small population. The figure below shows the habitat provided at different flows and the habitat need from the CVPIA SIT (Science Integration Team).

Literature does not uniquely inform the proportion of the population.

Datasets use historical conditions and observation to inform how spring-run Chinook salmon may respond to the Proposed Action. Historical monitoring may support or refute hypotheses and inform the reasonableness of information generated by models. A review of carcass and redd surveys does not identify redd superimposition. Reports on the Sacramento River describe pre-spawn mortality as a potential issue in some years; however, no attribution has occurred to a lack of available spawning habitat.

Models provide quantitative estimates of future conditions under the Proposed Action. Reclamation evaluated multiple lines of evidence, with different assumptions and complexity, to narrow the likely range of potential effects. Two models estimate the acres of suitable spawning habitat available. The Sacramento weighted usable area (WUA) analysis is a method for estimating the availability of suitable habitat in rivers, streams, and floodplains under different flow conditions (Bovee et al. 1998). The CVPIA SIT DSM are based on flow to suitable habitat area relationships used to estimate Chinook salmon spawning and rearing habitat in all CVP tributaries.

Attachment O.3, *Sacramento River Weighted Usable Area Analysis* provides context for the WUA available for spring-run Chinook salmon spawning downstream of Keswick releases. Spawning WUA for spring-run Chinook salmon, which was estimated from the fall-run WUA curve, peaks at approximately 5,000 cfs upstream of Cow Creek, where most spring-run Chinook salmon spawn. The expected WUA habitat value under the Proposed Action phases range from 2,061 to 2,532 (Figure 6-4). Overall, these WUA habitat values are lowest in wet and above normal water years and highest in the drier WYT. This difference is attributable to the relatively low flows at which spring-run spawning WUA in the Sacramento River peaks.

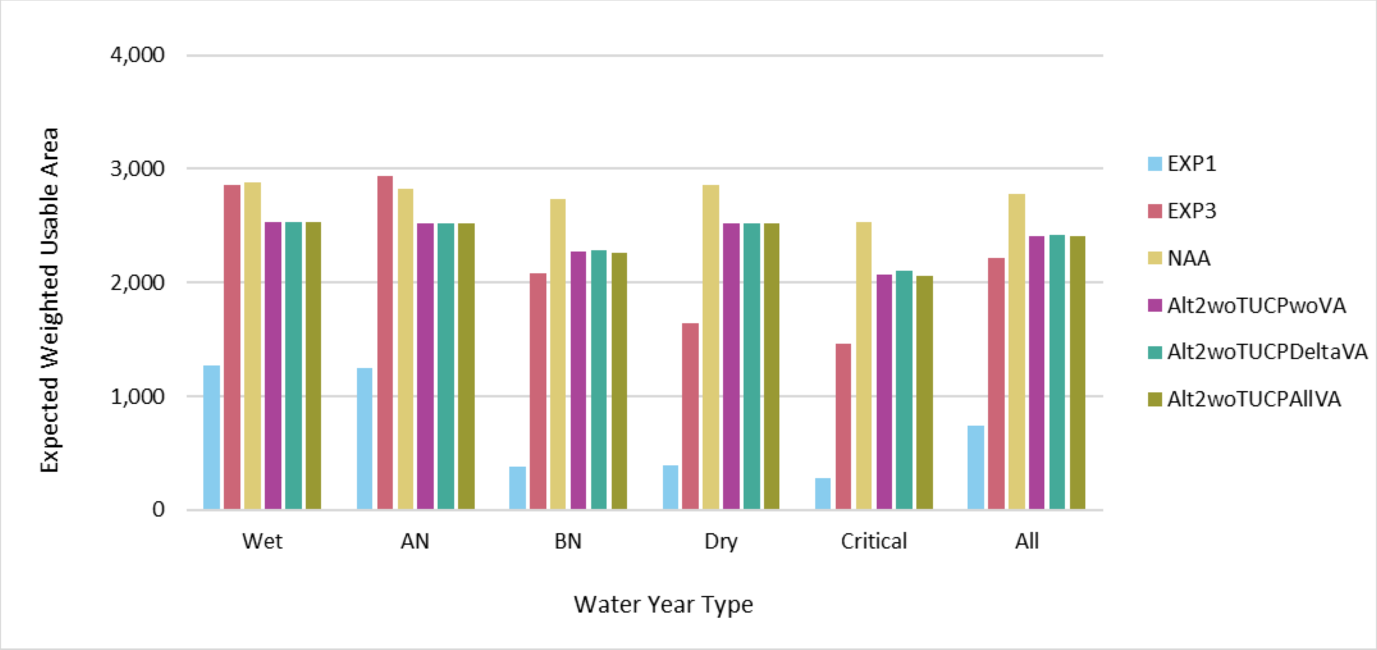


Figure 6-4. Expected Weighted Usable Area for Segments 5+6 by Water Year Type, Spring-run Spawning in the Sacramento River

Attachment O.1, *CWP Clear Creek Weighted Usable Area Analysis* provides context for the WUA available for spring-run Chinook salmon spawning between Whiskeytown Reservoir and Clear Creek's confluence with the Sacramento River. Spawning WUA for spring-run Chinook salmon, peaks at approximately 700–900 cfs. The WUA habitat value under the Proposed Action phases range from 342,214 to 448,282 (Figure 6-5). Overall, these WUA habitat values are lowest in critical water years and highest in the wet WYT.

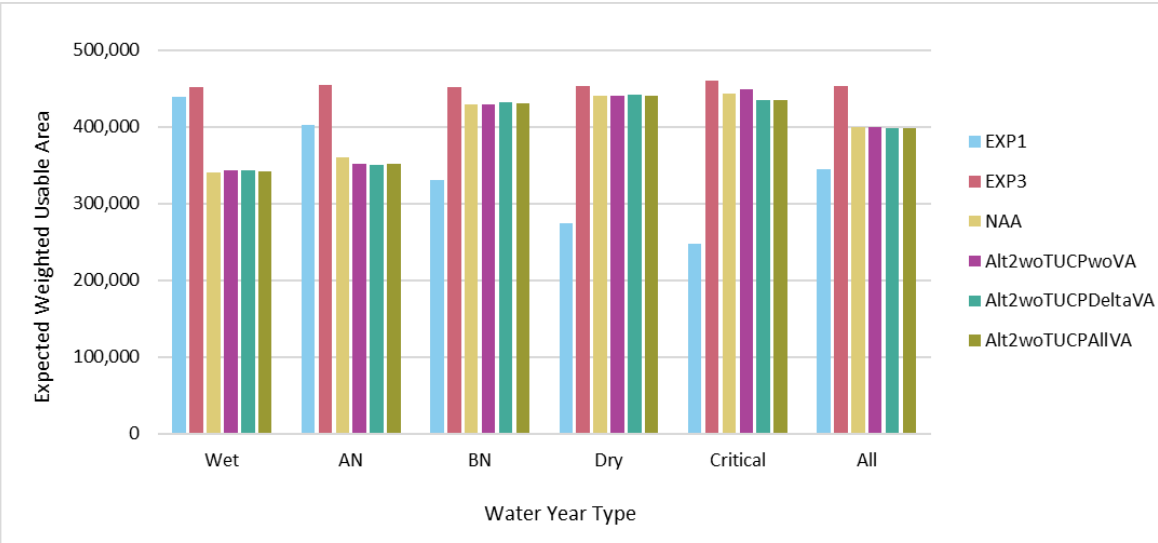


Figure 6-5. Expected Weighted Usable Area for Combined Upper Alluvial and Canyon Segments by Water Year Type, Spring-run Spawning in Clear Creek

The SIT Lifecycle Model (LCM) Habitat Estimates (Attachment O.2, *SIT LCM Habitat Estimates*) provide context for the habitat area available for spring-run Chinook salmon spawning in the Sacramento River. The monthly habitat value under the Proposed Action phases ranges from approximately 31 to 68 acres (Figure 6-6). Spawning WUA for fall-run Chinook salmon (used as a proxy for Spring-Run WUA) peaks at approximately 5,000 cfs in the upper Sacramento River. Overall, the habitat values are higher in October than in September and are especially low in Wet WYT and in September of Above Normal WYT. The lowest habitat values occurred in Proposed Action phases in September. Habitat values were relatively consistent across other WYT for all Proposed Action phases.

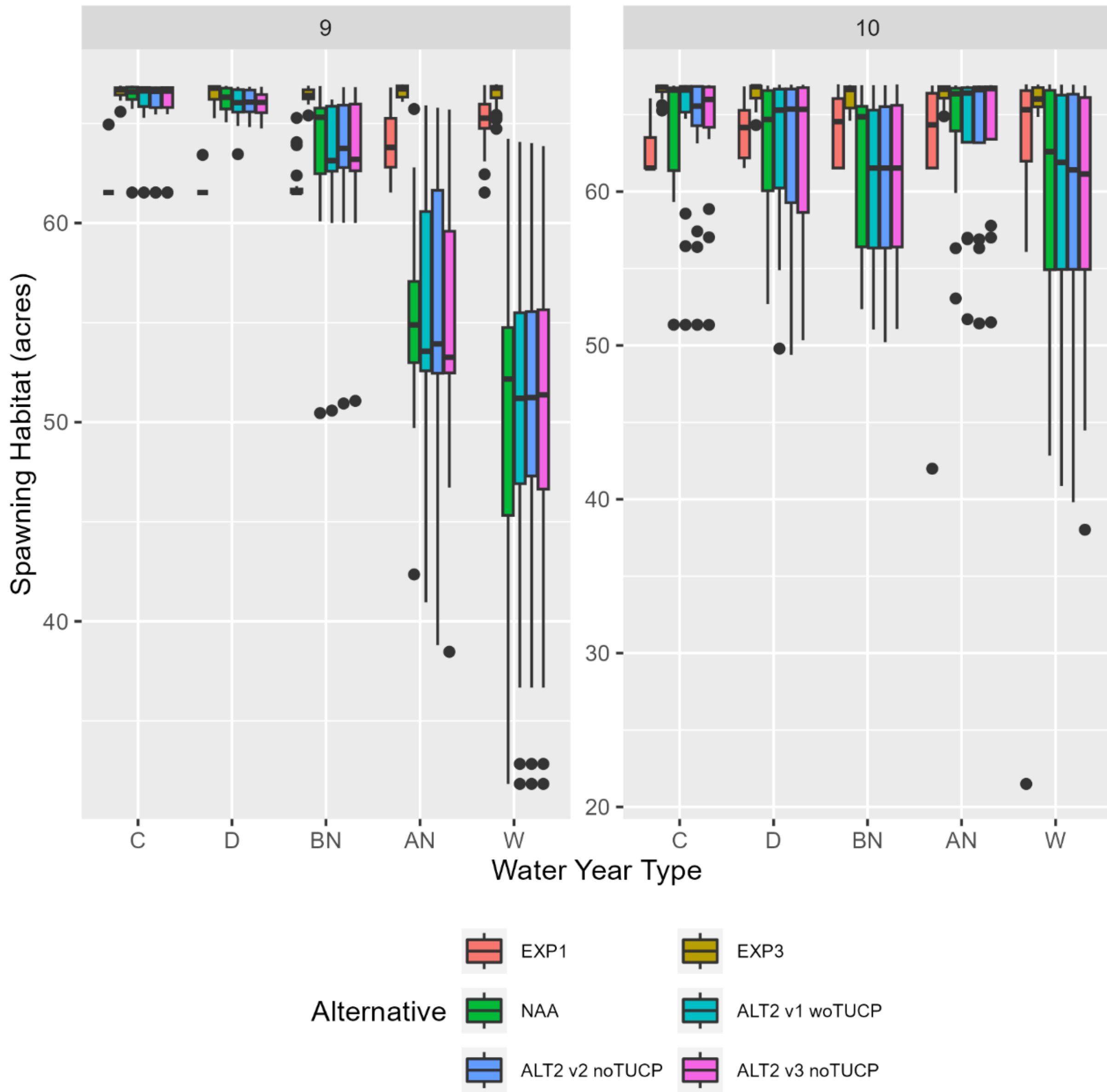


Figure 6-6. Estimated spawning habitat for spring-run adults in the upper Sacramento River across spawning months. Variability within each month-watershed combination reflects variation across CalSim WYs.

Attachment O.2, *SIT LCM Habitat Estimates* provides context for the habitat area available for spring-run Chinook salmon spawning in Clear Creek. The monthly habitat value under the Proposed Action phases is extremely limited and ranges from approximately 0.04 to 0.48 acres (Figure 6-7). Spawning WUA for fall-run Chinook salmon (used as a proxy for Spring-run Chinook salmon WUA) peaks at approximately 5,000 cfs in Clear Creek. Generally, the habitat values are higher in October than in September and are consistently between 0.2 and 0.3 acres across WYT for all Proposed Action phases.

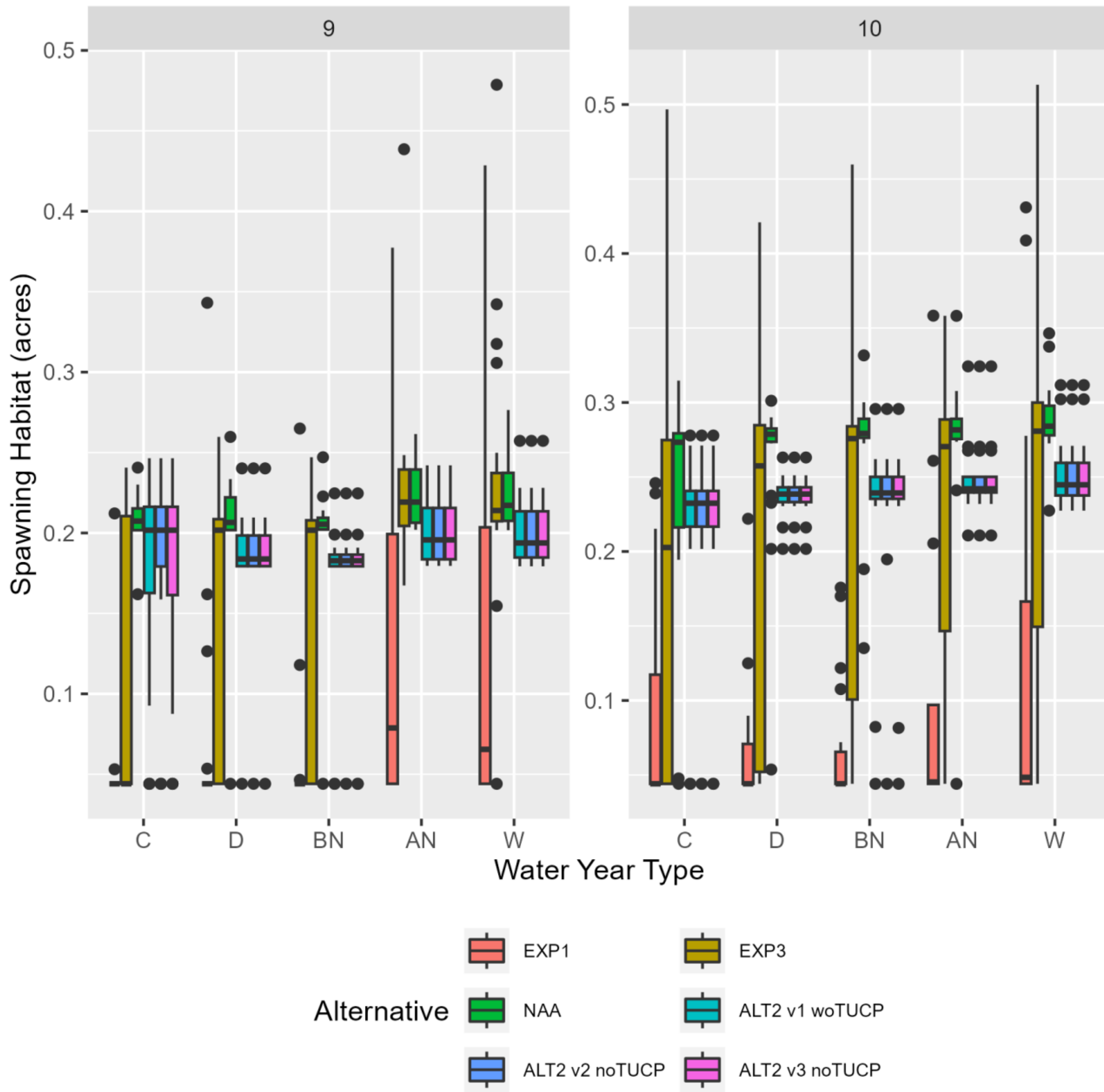


Figure 6-7. Estimated spawning habitat for spring-run Chinook salmon adults in Clear Creek across spawning months. Variability within each month and water year type combination reflects variation across CalSim WYs.

While the area of suitable habitat is affected in all years, the **frequency** when habitat impacts occur from limited cold water, particularly in Critical and Dry WYT, is **low** based on historical hydrology and the frequency of water temperature constraints. The number of recent spawners has not affected redd superimposition.

To evaluate the **weight of evidence** for the spawning habitat stressor, USFWS (2003) includes habitat suitability curves from the upper Sacramento River for Chinook salmon spawning habitat quantity and quality. Since 2003, habitat use and location of spawning has changed and additional spawning habitat restoration has occurred, so there is uncertainty in these relationships. Additionally, there is a CVPIA SIT DSM that is species specific, location specific, and quantitative while relying on multiple experts and peer review (Peterson and Duarte 2020).

- Literature, Dudley: quantitative, species-specific, location-specific, both 2018 and 2019 published as peer-reviewed literature in multiple publications, individual-based model using multiple environmental parameters and inclusion of biological processes.
- Historic superimposition observations, Sac + Clear Creek: quantitative, species-specific, location-specific, available through multiple sources and QA/QCed data from a long timeseries, published in technical memos and annual reports from technical teams, not expected to have statistical power.
- The CVPIA SIT DSM, similarly uses habitat suitability curves that are species specific, location specific, and quantitative while relying on multiple experts and peer review (Peterson and Duarte 2020).
- Sacramento WUA analysis is quantitative and species-specific but not location-specific to the Sacramento River (see Assumption 3 in Attachment O.3). WUA analyses are widely used and recognized analytical tools for assessing effects of flow on fish populations (Reiser and Hilgert 2018).
- Clear Creek WUA analysis is quantitative, species-specific, and location-specific to Clear Creek. RIVER2D was the principal hydraulic habitat model used in the USFWS analyses (2007, 2011a, 2011b, 2013) to develop the Clear Creek WUA curves used in this analysis.

Conservation measures in the Proposed Action that minimize or compensate for effects of the operation of the CVP and SWP on this stressor include:

- Sacramento River
  - Minimum Instream Flows
  - Fall and Winter Base Flows for Redd Maintenance
  - Sacramento River Settlement Contractors Rice Decomposition Smoothing
- Clear Creek
  - Minimum Instream Flows
  - Segregation Weir

Conservation measures in the Proposed Action for other species, life stages and/or stressors that may exacerbate this stressor include:

- Sacramento River
  - Fall and Winter Base Flows for Shasta Refill

6.2.2.2 Water Temperature

The proposed blending of water may generally decrease the water temperature stressor. During the adult holding and spawning period, imports from Trinity Reservoir and operation of a Temperature Control Device (TCD) on Shasta Reservoir under the Proposed Action are expected to maintain cooler water temperatures. Cooler water temperatures may diminish stress on adults taxed from upstream migration and spawning and the benefits are enhanced from late summer into the fall in both Clear Creek and the Sacramento River.

The decrease in water temperature stressor is expected to be **beneficial**; however, the operation of the TCD to release warmer water and preserve the coldwater pool during a drought may have **sub-lethal** effects. As part of the drought toolkit, Reclamation may operate the TCD to release warmer water temperatures during this period to preserve water for egg incubation later in the year. These warmer temperatures may increase stress on adults taxed from upstream migration and spawning. Appendix L, presents analysis of the water temperature management conservation measure for adult holding and spawning.

Although the Proposed Action may, at times, increase the water temperature stressor, unsuitable water temperatures for adult spring-run Chinook salmon holding and spawning exists in the **environmental baseline** (without the Proposed Action). The amount of precipitation, local ambient air temperatures and solar radiation drives the water temperature stressor (Windell et al. 2017). It is expected that climate change will result in warmer air temperature and shift in forms of precipitation, with more precipitation falling as rain, which will exacerbate water temperatures in the reservoirs.

In 1997, Reclamation completed the TCD at Shasta Reservoir, which can be used to effectively blend water from the warmer upper reservoir levels and, thereby, extend the period in which cold water can be provided downstream. Reclamation's past operation of Shasta Reservoir has influenced the flow of water in the Sacramento River. Reclamation has operated the CVP to reduce the water temperature stressor during adult holding and spawning by using the TCD. Different approaches have targeted different water temperatures and locations throughout the years including warmwater bypasses to conserve limited coldwater pools. Currently, the Sacramento River does not support spring-run Chinook salmon spawning or juvenile production.

On Clear Creek, spring-run Chinook salmon spawn below Whiskeytown Dam, and releases from Whiskeytown Dam support Chinook salmon spawning. In 1992, Reclamation installed two temperature curtains in Whiskeytown Reservoir in an effort to improve passage of cold water through the reservoir during the warm months of the year for downstream coldwater needs. Both curtains were recently replaced.

Since 1999, Reclamation has managed Whiskeytown Dam releases to meet a daily average water temperature of: (1) 60°F from June 1 through September 14: and (2) 56°F or less from September 15 to October 31 at the Igo Stream Gauging Station, located at river mile 11.0 on Clear Creek (U.S. Geological Survey 2019). By September, the coldwater pool in Whiskeytown becomes limited, and in some cases may result in less cold water available for Clear Creek during the spring-run Chinook salmon spawning. period. Since 2009, Reclamation has operated Whiskeytown Dam to provide pulse flows to lower Clear Creek in May and June in most years to encourage spring-run Chinook salmon holding in the Sacramento River to move into Clear Creek to spawn where temperatures are more favorable.

The **proportion** of the population affected by the Proposed Action is **likely large** for Sacramento River but depends on water temperature management. The **proportion** of the population affected by the Proposed Action is **likely large** for Clear Creek.

Literature does not uniquely inform the proportion of the population.

Datasets use historical conditions and observation to inform how spring-run Chinook salmon may respond to the Proposed Action. Historical monitoring may support or refute hypotheses and inform the reasonableness of information generated by models. Figure 6-8 shows historic water temperatures on the Sacramento River above Clear Creek (CCR) during the adult spawning period. Water temperatures were elevated during 2015 and 2021, when coldwater pool volume was diminished, and there was little available cold water left to release from Shasta Reservoir. Figure 6-8 shows historic water temperatures on the Sacramento River above Clear Creek (CCR) during the adult holding and spawning period. Water temperatures were elevated during two dry periods (2015 and 2020/2021), when coldwater pool volume was diminished and there was little available cold water left to release from Shasta Reservoir. Source: SacPAS, CDEC.

Figure 6-9 shows historic water temperatures on Clear Creek at Igo during the adult spawning period. Water temperatures on Clear Creek generally decreased through the adult holding and spawning period.

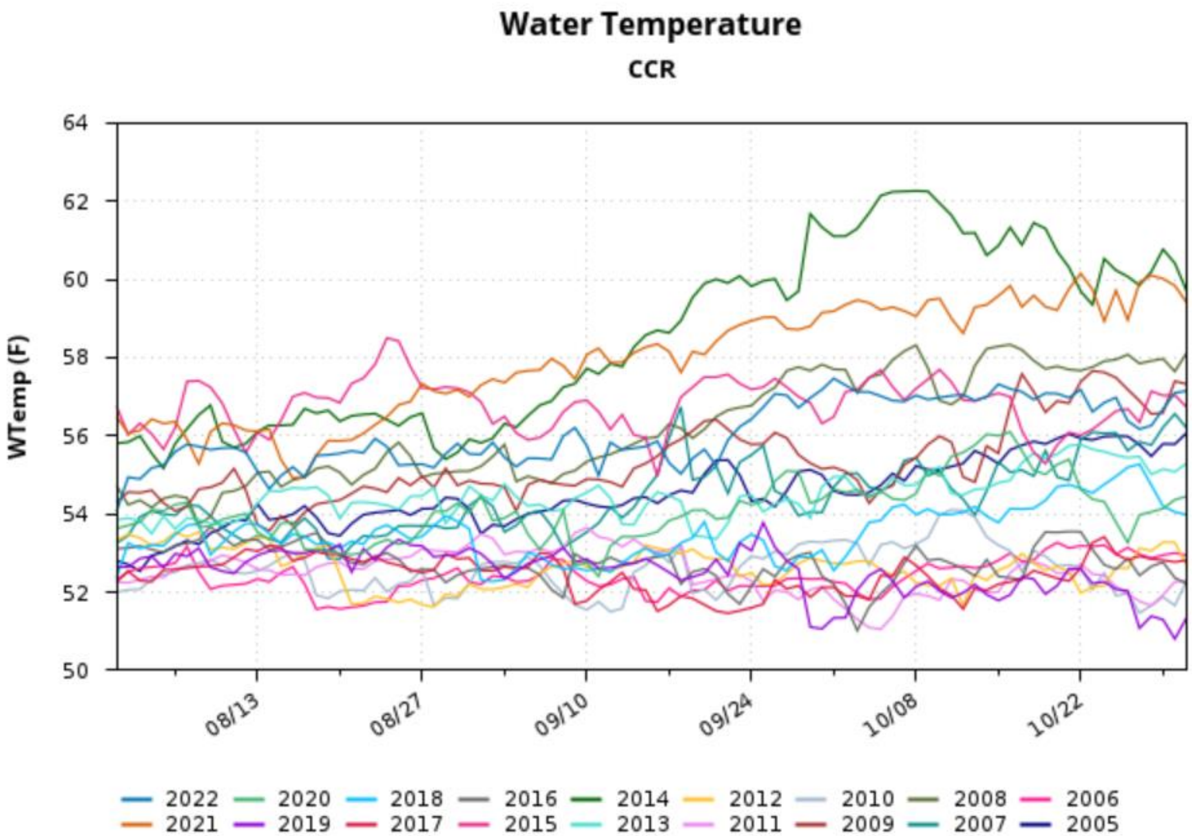
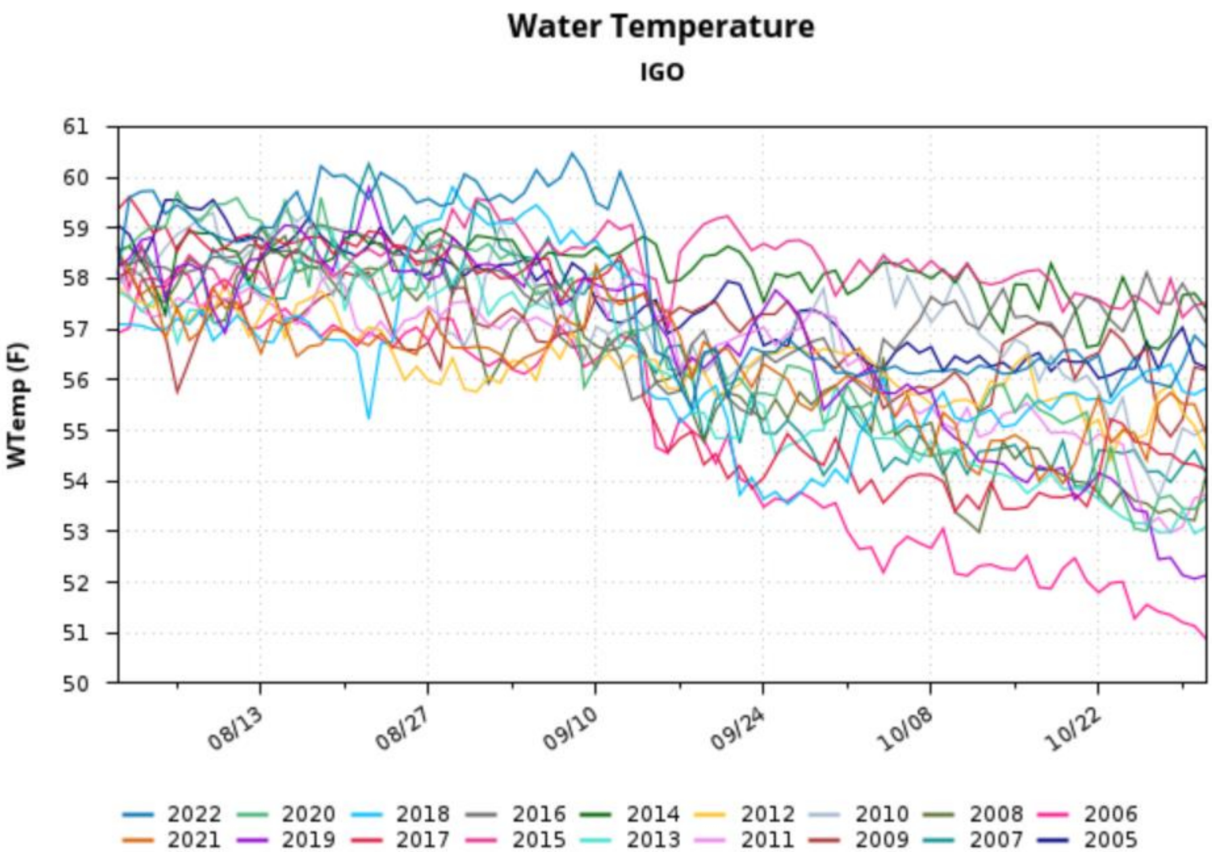


Figure 6-8. August through October water temperatures on the Sacramento River above Clear Creek, 2005 – 2022. Water temperatures are symbolized by year. Source: SacPAS, CDEC.



Source: SacPAS, CDEC.

Figure 6-9. August through October water temperatures on Clear Creek at Igo, 2005 – 2022. Water temperatures are symbolized by year.

In the Sacramento Basin, four independent populations of spring-run Chinook salmon remain from 19 historic independent populations (McElhany et al. 2000). These populations – Battle, Mill, Deer, and Butte creeks – feed into the Sacramento River. However, there is little information for adult spring-run Chinook salmon spawning mortality or carcasses in the Sacramento River and on Clear Creek. Adult spring-run Chinook salmon otoliths (2003 – 2018) have been collected during sampling on Deer (snorkel surveys, n = 59), Mill (redd surveys, n = 60), and Butte (carcass surveys, n = 286) creeks (Goertler et al. 2020). Table 6-5 shows spring-run Chinook salmon carcasses in Clear Creek including percent female and percent clipped 2003 – 2018 (USFWS 2019). Hatcheries clip 25% of release groups so the percentages may be underestimated. In Clear Creek, the percent of carcasses recovered varied widely from 0% (2018) to 61% (2003). There is not a similar table or record for carcasses on the Sacramento River. Table 6-6 shows pre-spawn mortality for female spring-run Chinook salmon on Clear Creek.

Table 6-5. Spring-run Chinook salmon carcasses recovered upstream of the segregation weir during monitoring in Clear Creek, 2003 – 2018. Weir breaches occurred in several years, numbers in parentheses represent potential fall-run Chinook salmon run as opposed to spring-run Chinook salmon.

Year	Carcass Total	% Female	% Gender Unknown	% Clip	% Adipose Status Unknown
2003	25	61%	28%	4%	16%
2004	43 (21)	23% (6%)	30% (14%)	2% (0%)	7% (0%)
2005	67	35%	18%	0%	9%
2006	62	61%	20%	0%	0%
2007	72	32%	26%	3%	6%
2008	77	39%	16%	0%	1%
2009	41 (51)	36% (4%)	5% (0%)	0% (5%)	2% (0%)
2010	12 (41)	17% (2%)	0% (12%)	8% (5%)	0% (0%)
2011	38	18%	11%	5%	5%
2012	21 (19)	14% (0%)	5% (11%)	10% (16%)	0% (5%)
2013	71 (1)	41%	25%	5%	16%
2014	65	24%	6%	23%	6%
2015	33	8%	19%	30%	11%
2016	10	37%	26%	11%	26%
2017	8	25%	8%	33%	8%
2018	10	0%	20%	0%	10%

Source: USFWS 2019.

Table 6-6. Pre-spawn mortality for female spring-run Chinook salmon on Clear Creek.

Return Year	Natural Origin Total Carcasses	Natural Origin Number Not Spawned	Natural Origin Percent Not Spawned
2008	24	4	16.67%
2009	9	0	0.00%
2010	2	0	0.00%
2011	2	0	0.00%
2012	1	0	0.00%
2013	27	1	3.70%
2014	11	0	0.00%
2015	2	0	0.00%

Return Year	Natural Origin Total Carcasses	Natural Origin Number Not Spawned	Natural Origin Percent Not Spawned
2016	1	0	0.00%
2017	0	NA	NA
2018	0	NA	NA
2019	1	0	0.00%
2020	0	NA	NA
2021	71	4	5.63%
2022	10	3	30.00%

Models provide quantitative estimates of future conditions under the Proposed Action.

HEC-5Q modeling analysis enumerates the frequency at which mean monthly simulated water temperatures exceed water temperature criteria obtained from scientific literature. Modeled water temperatures (Hec-5Q) during adult spring-run Chinook salmon holding and spawning are as follows.

Results for the 42.1 °F to 55 °F range are presented in Table 6-7 for Clear Creek below Whiskeytown, Table 6-8 for the Sacramento River at Keswick, and Table 6-9 for the Sacramento River at the Red Bluff Diversion Dam. At Clear Creek, Percentages outside the range during the period of April to October under the Proposed Action phases ranged from 14.4% in Critical water years to 1.0% for Above Normal WYT. In Critical water years, the percentage of months outside the optimal range was notably higher. During Dry WYT, water temperatures were within the range 100% of the time for each phase of the Proposed Action. Overall, the percentage of months outside of the optimal temperature range was similar for all WYT, with the exception of Critical water years, under all three phases of the Proposed Action.

Table 6-7. Percent of months outside the 42.1 °F to 55 °F water temperature range for minimal adult spring-run Chinook salmon migration impairment by water year type and for all years combined, Clear Creek below Whiskeytown, April through October.

WYT	EXP1	EXP3	NAA	Alt2woTUCPwoVA	Alt2woTUCPDeltaVA	Alt2woTUCPAllVA
W	84.7	0.0	2.6	1.0	2.0	2.0
AN	85.7	0.0	1.1	1.1	1.1	1.1
BN	86.5	7.9	0.8	1.6	1.6	1.6
D	83.9	20.2	0.0	0.0	0.0	0.0
C	85.6	26.1	3.6	14.4	13.5	13.5
All	85.1	10.5	1.6	3.0	3.2	3.2

At the Sacramento River at Keswick, the percent of months outside the 42.1°F to 55 °F range under the Proposed Action phases range from 29.7% during Critical water years to 3.2% of months during Below Normal WYT. During Wet and Above Normal WYT the percentage of months outside of the optimal range was 0% for all three phases of the proposed action during the period of April through October.

Table 6-8. Percent of months outside the 42.1 °F to 55 °F water temperature range for minimal adult spring-run Chinook salmon migration impairment by water year type and for all years combined, Sacramento River at Keswick, April through October.

WYT	EXP1	EXP3	NAA	Alt2woTUCPwoVA	Alt2woTUCPDeltaVA	Alt2woTUCPAllVA
W	74.5	2.6	2.0	0.0	0.0	0.0
AN	79.1	3.3	2.2	0.0	0.0	0.0
BN	86.5	4.8	7.1	3.2	4.0	3.2
D	87.5	4.2	11.3	5.4	5.4	6.0
C	91.0	18.9	27.9	29.7	27.0	27.0
All	83.1	6.1	9.4	6.6	6.4	6.4

At the Sacramento River at the Red Bluff Diversion Dam, the percent of months outside the 42.1°F to 55 °F had a range from 100.0% for Critical to 88.8% for Wet WYT. Overall, the percentage of months outside of the optimal range increased from wetter to drier, but within a narrow range with all phases of the Proposed Action performing similarly for all WYT during the period of April to October.

Table 6-9. Percent of months outside the 42.1 °F to 55 °F water temperature range for minimal adult spring-run Chinook salmon migration impairment by water year type and for all years combined, Sacramento River at the Red Bluff Diversion Dam, April through October.

WYT	EXP1	EXP3	NAA	Alt2woTUCPwoVA	Alt2woTUCPDeltaVA	Alt2woTUCPAllVA
W	89.8	95.9	91.3	89.3	88.8	89.3
AN	96.7	98.9	96.7	96.7	96.7	96.7
BN	97.6	100.0	97.6	98.4	98.4	98.4
D	98.8	99.4	98.8	97.6	98.8	98.8
C	100.0	100.0	100.0	100.0	100.0	100.0
All	96.0	98.6	96.4	95.7	95.8	96.0

Water temperature management occurs in all years and water temperatures downstream of Shasta Reservoir are dependent on hydrology and meteorology. The **frequency** of when the Proposed Action would provide benefits to adult spring-run Chinook salmon is **high**. Historic August through October temperatures on the Sacramento River above Clear Creek (2005 – 2022) and on Clear Creek at Igo (2005 – 2022) were lower than 65°F in all years.

As an exception to the Proposed Action providing benefits is a warmwater bypass action taken as part of the drought toolkit. This action is assumed to occur only when the coldwater pool volume is limited, preventing water temperature management for egg incubation and the temperature target is limited to 60°F on the Sacramento River above Clear Creek. The **frequency** of this occurring is **low** and likely only occurs in the second or more years of consecutive drought years. In this instance the **proportion** of the population negatively impacted would be **small**, the **frequency** would be **low**, and the action would not occur without coordination through the Shasta Operations Team (SHOT).

To evaluate the **weight of evidence** for the water temperature stressor, there are temperature thresholds from a synthesis document for Chinook salmon but are not specific to spring-run Chinook salmon nor to the Sacramento River. There is a ten-year quantitative historical record of spring-run Chinook salmon monitoring and seasonal releases specific to the Sacramento River and Clear Creek.

- Historic temperatures, Sac River + Clear Creek: quantitative, not species-specific (but not expected to be, environmental variable), location-specific, available through multiple sources and QA/QCed data from long time-series, published in technical memos and annual reports from technical teams, not expected to have statistical power
- Historic spawn-timing observations, Sac River + Clear Creek: quantitative, species-specific, location-specific, available through multiple sources and QA/QCed data from long time-series, published in technical memos and annual reports from technical teams, not expected to have statistical power
- Historic pre-spawn mortality observations, Sac River + Clear Creek: quantitative, species-specific, location-specific, available through multiple sources and QA/QCed data from long time series, published in technical memos and annual reports from technical teams, not expected to have statistical power
- Hec-5Q water temperature modeling Line of Evidence (LOE): quantitative, not species-specific (but not expected to be, environmental variable, location-specific, model developed to evaluate reservoir system using control points, widely accepted as water temperature modeling system for use in the Central Valley upper watershed

Conservation measures in the Proposed Action that minimize or compensate for effects of the operation of the CVP and SWP on this stressor include:

- Sacramento River
    - Adult Migration and Holding Water Temperature Objectives
    - Shasta Reservoir Water Temperature and Storage Management
- Clear Creek
    - Water Temperature Management

Conservation measures in the Proposed Action for other species, life stages and/or stressors that may exacerbate this stressor include:

- Sacramento River
    - Voluntary Agreement Pulse Flows
    - Sacramento River Pulse Flows
    - Drought Tool Kit Shasta Warmwater Bypass
    - SHOT Determination on Temperature Shoulders (requiring too cold releases too early and exhausting the coldwater pool)

6.2.2.3 Pathogens and Disease

The proposed blending and releasing of water to reduce water temperatures may generally decrease the pathogens and disease stressor. During the adult spawning period, imports from Trinity Reservoir and operation of a TCD on Shasta Reservoirs associated with the Proposed Action are expected to result in cooler water temperatures. The occurrence of pathogen virulence is diminished in cooler waters. Appendix L presents analysis of this stressor.

The decrease in the pathogens and disease stressor is expected to be **beneficial**; however, the operation of the TCD to release warmer water and preserve the coldwater pool during a drought may have **sub-lethal** effects.

Although the Proposed Action may, at limited times, increase the pathogens and disease stressor, pathogens and disease that may affect adult winter-run Chinook salmon spawning exists in the **environmental baseline** (without the Proposed Action). Pathogens and disease have been present in the ambient environment since before construction of the CVP and SWP. The amount of precipitation, local ambient air temperatures and solar radiation drives the water temperature stressor, which then influences the pathogens and disease stressors (Windell et al. 2017). It is expected that climate change will result in warmer air temperature and shift in forms of precipitation, with more precipitation falling as rain, which will exacerbate water temperatures in the reservoirs. Low stream flows and higher water temperatures caused by drought can exacerbate disease (NMFS 1998).

Natural Chinook salmon may contract diseases that are spread through the water column (i.e., waterborne pathogens) (Buchanan et al. 1983). Infectious diseases and pathogens naturally affect adult salmonid survival. Salmonids are exposed to numerous bacterial, protozoan, viral, and parasitic organisms in spawning and rearing areas, hatcheries, migratory routes, and the marine environment (NMFS 1996, 1998, 2009). Specific diseases such as bacterial kidney disease, *Ceratomyxosis shasta*, columnaris, furunculosis, infectious hematopoietic necrosis, redmouth and black spot disease, whirling disease, and erythrocytic inclusion body syndrome are known, among others, to affect Chinook salmon and steelhead (NMFS 1996, 1998, 2009). However, very little current or historical information exists to quantify changes in infection levels and mortality rates attributable to these diseases for Chinook salmon.

Hatchery production and releases can influence disease and pathogens. While production and conservation hatcheries may increase this stressor from water discharges and the release of hatchery fish. Hatchery and Genetic Management Plans help to minimize effects.

The Water Temperature Modeling Platform developed by Reclamation in coordination with interested parties, helps inform the management of coldwater pool storage to reduce water temperatures. CVPIA Habitat and Facility Improvements help increase the available habitat, thus reducing crowding of fish and the spread of pathogens and disease.

The **proportion** of the population affected by Proposed Action depends on when temperature management starts, generally in May. Prior to water temperature management, water temperatures are generally colder than adult water temperature criteria and the threshold above which diseases affecting Chinook salmon become highly virulent (59.9°F, McCullough 1999). With all of spring-run Chinook salmon spawning occurring after May, the proportion of the population is **large**. See figures in Section 6.2.2.2*, Water Temperature Stressor* which show historic Sacramento River above Clear Creek and Clear Creek at Igo water temperatures during the adult spawning period (Figure 6-8 and Source: SacPAS, CDEC.

Figure 6-9, above).

Literature does not uniquely inform the proportion of the population.

For datasets, please see figures in "Water Temperature Stressor" section above.

Models provide quantitative estimates of future conditions under the Proposed Action. HEC-5Q modeling analysis enumerates the frequency at which mean monthly simulated water temperatures exceed water temperature criteria obtained from scientific literature.

Results for the exceedance of the 59.9 °F pathogen virulence temperature threshold are presented in Table 6-10 for Clear Creek below Whiskeytown and Table 6-11 for the Sacramento River at Keswick. At Clear Creek, the percent of months outside the range was from 10.8% in Critical water years to 0.5% in Wet WYT. In Critical WYT, the percent of months exceeding the pathogen virulence threshold was notably higher than all other WYT. During Dry and Above Normal WYT, the percentage of months that exceeded the temperature threshold remained at 0% for all phases of the Proposed Action during the period of April through October.

Table 6-10. Percent of months above the 59.9 °F pathogen virulence water temperature threshold for adult spring-run Chinook salmon migration by water year type and for all years combined, Clear Creek below Whiskeytown, April through October.

WYT	EXP1	EXP3	NAA	Alt2woTUCPwoVA	Alt2woTUCPDeltaVA	Alt2woTUCPAllVA
W	60.7	0.0	0.0	0.5	0.5	1.0
AN	57.1	0.0	0.0	0.0	0.0	0.0
BN	65.1	7.1	0.8	1.6	1.6	1.6
D	66.1	18.5	0.0	0.0	0.0	0.0

WYT	EXP1	EXP3	NAA	Alt2woTUCPwoVA	Alt2woTUCPDeltaVA	Alt2woTUCPAllVA
C	70.3	23.4	1.8	11.7	10.8	10.8
All	63.9	9.5	0.4	2.3	2.2	2.3

At the Sacramento River at Keswick, the percent of months that exceeded the 59.9 °F pathogen virulence temperature threshold under the Proposed Action phases remained at 0% for all WYT, except for Critical water years. For Critical WYT, the percentage of months above the temperature threshold was 17.1% for all three phases of the Proposed Action during the period of April to October.

Table 6-11. Percent of months above the 59.9 °F pathogen virulence water temperature threshold for adult spring-run Chinook salmon migration by water year type and for all years combined, Sacramento River at Keswick, April through October.

WYT	EXP1	EXP3	NAA	Alt2woTUCPwoVA	Alt2woTUCPDeltaVA	Alt2woTUCPAllVA
W	60.2	0.0	0.0	0.0	0.0	0.0
AN	61.5	0.0	0.0	0.0	0.0	0.0
BN	67.5	0.0	0.0	0.0	0.0	0.0
D	63.1	0.0	0.0	0.0	0.0	0.0
C	71.2	5.4	15.3	17.1	17.1	17.1
All	64.2	0.9	2.5	2.7	2.7	2.7

At the Sacramento River at the Red Bluff Diversion Dam, the percentage of months that exceeded the 59.9 °F pathogen virulence temperature threshold ranged from 59.45% for Critical water years to 13.18% for Above Normal WYT, Table 6-12. Overall, the percentage of months that exceeded the temperature threshold increased from wetter to drier WYT, with Critical WYT being notably higher under the three phases of the Proposed Action, during the period of April to October.

Table 6-12. Percent of months above the 59.9 °F pathogen virulence water temperature threshold for adult spring-run Chinook salmon migration by water year type and for all years combined, Sacramento River at the Red Bluff Diversion Dam, April through October.

WYT	EXP1	EXP3	NAA	Alt2woTUCPwoVA	Alt2woTUCPDeltaVA	Alt2woTUCPAllVA
W	78.57	46.43	22.96	15.31	15.31	15.31
AN	82.42	38.46	17.58	13.19	13.19	13.19
BN	80.95	36.51	25.40	15.87	16.67	17.46
D	82.74	34.52	27.98	19.05	18.45	22.02
C	92.79	70.27	68.47	59.46	57.66	55.86

WYT	EXP1	EXP3	NAA	Alt2woTUCPwoVA	Alt2woTUCPDeltaVA	Alt2woTUCPAllVA
All	82.80	44.51	31.21	23.12	22.83	23.55

Water temperature management occurs in all years and water temperatures downstream of Shasta Reservoir are dependent on hydrology and meteorology. Historical water temperatures on the Sacramento River above Clear Creek exceeded the 59.9°F threshold two out of 18 years (2014, 2021) between 2005 – 2022 and on Clear Creek at Igo exceeded the same threshold two out of 18 years (2014, 2022) during the same period. The **frequency** of when the Proposed Action would provide benefits to adult spring-run Chinook salmon is **high**.

To evaluate the **weight of evidence** for the pathogens and disease stressor, there are temperature criteria thresholds from published literature for pathogen and disease virulence specific to Chinook salmon. These thresholds, however, are not specific to spring-run Chinook salmon nor to the Sacramento River.

- Historic temperatures, Sac River + Clear Creek: quantitative, not species-specific (but not expected to be, environmental variable), location-specific, available through multiple sources and QA/QCed data from long time-series, published in technical memos and annual reports from technical teams, not expected to have statistical power.
- Hec-5Q water temperature modeling LOE: quantitative, not species-specific (but not expected to be, environmental variable, location-specific, model developed to evaluate reservoir system using control points, widely accepted as temperature modeling system for use in the Central Valley upper watershed.

Conservation measures in the Proposed Action that minimize or compensate for effects of the operation of the CVP and SWP on this stressor include:

- Sacramento River
    - Adult Migration and Holding Water Temperature Objectives
    - Shasta Reservoir Water Temperature and Storage Management
- Clear Creek
    - Water Temperature Management

Conservation measures in the Proposed Action for other species, life stages and/or stressors that may exacerbate this stressor include:

- Sacramento River
    - Allocation Reductions for Shasta Reservoir End of September Storage
    - Rebalancing between other CVP Reservoirs for Shasta Reservoir End of September Storage
    - Reduced Wilkins Slough Minimum Flows for Shasta Reservoir End of September Storage

- SRSC Diversion Spring Delays and Shifting
- Minimum Refuge Summer Deliveries North of Delta

6.2.3 Egg Incubation and Fry Emergence

Egg incubation occurs from September to early February based on redd timing. For maximum embryo survival, water temperatures reportedly must be between 41°F and 55.4°F and oxygen saturation levels must be close to maximum (Moyle 2002). Under those conditions, embryos hatch in 40 to 60 days and remain in the gravel as alevins (the life stage between hatching and egg sack absorption) for another four to six weeks before emerging as fry (Moyle 2002). Spring-run Chinook salmon fry emerge from the gravel from November to March (Moyle 2002). Based on juvenile passage indices from the USFWS rotary screw trap (river mile 8.4), fry emergence begins in early November, peak passage occurs from mid-November through January, and a small number of juveniles and smolts are captured throughout the remainder of the monitoring season, which generally ends on July 1 (Earley et al. 2009; Schraml et al. 2018). Fry emerge from the gravel from November to March (Moyle 2002), and can have highly variable emigration timing based on various environmental factors (NMFS 2009). Post-emergent fry inhabit calm, shallow waters with fine substrates and depend on fallen trees, undercut banks, and overhanging riparian vegetation for refuge (Healey 1991).

The stressors that influence spring-run Chinook salmon egg incubation and fry emergence are *In-River Fishery and Trampling, Toxicity and Contaminants, Stranding and Dewatering; Water Temperature, Dissolved Oxygen, Pathogens; Sedimentation and Gravel Quantity, Redd Quality; and Predation Risk.*

The Proposed Action is not anticipated to change the stressors: *In-River Fishery and Trampling* nor *Predation Risk.*

Stressors that may change at a level that is insignificant or discountable include:

- The Proposed Action may decrease the *toxicity from contaminants* stressor. During the egg incubation and fry emergence period, the Proposed Action will release water increasing flows in the Sacramento River below Keswick Dam and in Clear Creek below Whiskeytown. Increased flows may dilute contaminants if and when contaminants are present. However, increased flows and pulses can mobilize suspended sediments consisting of contaminants in river systems (van Vliet et al. 2023).

  Water quality monitoring on Clear Creek has not shown contaminants at levels likely to affect eggs and toxicity-related adverse effects have not been observed in fish monitoring. Moreover, eggs are not exposed to prey-derived contaminants until post exogenous feeding begins, which reduces their exposure to contaminants during this life stage.

  Water quality monitoring on the Sacramento River has not shown contaminants at levels likely to affect eggs and toxicity-related adverse effects have not been observed in fish monitoring. Moreover, eggs are not exposed to prey-derived contaminants until post exogenous feeding begins, which reduces their exposure to contaminants during this life stage.

- The Proposed Action may increase or may decrease the *pathogens and disease* stressor. During the egg incubation and fry emergence period, the Proposed Action will release water and increase flows in the Sacramento River below Keswick Dam and in Clear Creek below Whiskeytown and potentially influence pathogen and disease presence and virulence.

  Increased water temperatures have been hypothesized to be one of the factors that contributes to coagulated-yolk disease, or white-spot disease, in both eggs and fry along with other environmental conditions like gas supersaturation and low DO (Mazuranich and Nielson 1959). Monitoring in Clear Creek that not shown incidence of White Spot Disease in spring-run Chinook salmon. White Spot Disease has been observed in winter-run Chinook salmon in the Sacramento River (Foott 2016); however, not with high frequency, and not in spring-run Chinook salmon. There has been no evidence of White Spot Disease in the Sacramento River, and this disease appears to be more often observed at hatcheries than in rivers.

- The Proposed Action may decrease the DO stressor. During the egg incubation and fry emergence period, the Proposed Action will release water and increase flows in the Sacramento River below Keswick Dam and in Clear Creek below Whiskeytown Dam. Releases of storage associated with the Proposed Action may result in cooler water temperatures and higher flows that may provide a higher DO saturation potential. Chinook salmon egg and alevin survival decreases when DO levels are less than 5.5 mg/l (Del Rio et al. 2019).

  There is no DO sampling for Clear Creek. However, upper Clear Creek is very steep and monitoring shows white water which indicates high levels of gas exchange. On the Sacramento River above Clear Creek, historic DO levels were infrequently recorded below 5.5 mg/l, and values below that threshold occurred in a few years (e.g., 2014 – 2016).

- The Proposed Action may decrease the *sedimentation and gravel quantity* stressor. During the egg incubation and fry emergence period, the Proposed Action will release water and increase flows in the Sacramento River below Keswick Dam and in Clear Creek below Whiskeytown. Increased flows may provide environmental conditions favorable to redds and developing embryos.

  Increased surface flows may reduce sedimentation in the Sacramento River. Build-up of fine sediment can decrease permeability for embryos (Bjornn and Reiser 1991). Gravel quantity is addressed in the “Spawning Habitat” stressor of the “Adult holding and Spawning” section.

  The stressor is expected to similarly decrease in Clear Creek during the egg incubation and fry emergence period due to releases of water and increased flows.

Described below are stressors that will be exacerbated by the Proposed Action, potentially resulting in incidental take. Also described below are conservation measures included as part of the Proposed Action to avoid or compensate for adverse effects. Finally, the Proposed Action may also ameliorate certain stressors in the environmental baseline, and below a description of these beneficial effects is included.

6.2.3.1 Redd Stranding and Dewatering

The proposed storage and release of water may increase the stranding and dewatering stressor. The release of water from Whiskeytown Reservoir associated with Proposed Action results in higher flows in Clear Creek during the redd construction season. Higher flows do not increase the stranding and dewatering stressor. However, during part of the egg incubation and fry emergence period, the Proposed Action will store water from Shasta Reservoir resulting in lower flows on the Sacramento River. High elevation spring-run Chinook salmon redds that are still occupied by incubating eggs may be dewatered. Water temperature management targeting colder temperatures will delay emergence and, thus, increase the likelihood of occupied redds when flows are reduced. Multiple topic-specific appendices address aspects of redd stranding and dewatering in the Sacramento River.

- Appendix L, provides historical datasets and redd dewatering curves for relevant flows.
- Appendix H, presents analyses of “Minimum Instream Flows” and “Fall and Winter Minimum Flows” conservation measures.

The increase in stranding and dewatering stressors from the Proposed Action is expected to be **lethal**. Redds are defined as dewatered when any active redd has, at the minimum, its highest section (the tailspill mound) exposed to the air (Jarrett and Killam 2015). Eggs incubating in a redd that have been dewatered are no longer viable.

Although the Proposed Action may increase the redd stranding and dewatering stressor, spring-run Chinook salmon redd stranding and dewatering exists in the **environmental baseline** (without the Proposed Action). Physical attributes of the habitat and the magnitude of the change in flow drives the redd stranding and dewatering stressor (Windell et al. 2017). Historically, Chinook salmon in California rivers and streams, even before construction of CVP and SWP facilities, have been subject to redd stranding and dewatering. Flow fluctuations due to climate, hydrology and other factors contributed to the risk of redd stranding and dewatering. Chinook salmon may spawn in shallow water near a river’s edge where there is an increased likelihood of dewatering when river flows may be low. Natural flows would decrease through the summer without the release of water from Trinity Reservoir into Whiskeytown Reservoir. Reclamation’s past operation of Trinity Reservoir has influenced the flow of water in Clear Creek. Reclamation has implemented flow and temperature management actions in coordination with members of the Clear Creek Technical Team, a multi-agency group coordinating Clear Creek operations to reduce dewatering of spring-run Chinook salmon redds.

The **proportion** of the population affected by the Proposed Action depends on spawn timing, and duration of egg incubation, depth distribution of redds, and river stage and is likely **medium** for the Sacramento River and **medium** for Clear Creek. Currently, Clear Creek is the only tributary within the CV ESU that has an independent population of spring-run Chinook salmon (NMFS 2019 BiOp). Historically, peak spawning for the spring-run Chinook salmon population occurs in September with some portion of the population spawning earlier in mid-August and some spawning later in early October. Later spawned redds may be influenced by September to November flow reduction being potentially exposed. During higher flows, quality spawning gravel is below the water line and accessible to spawning adults. Data available from current monitoring programs are limited. Eggs are generally incubating between September and

November, with some as late as February. Redds observed from surveys in September are classified as spring-run Chinook salmon but those observed in October are classified as fall-run (Table 6-13). This may underestimate the number of spring-run Chinook salmon redds in the Sacramento River.

Literature does not uniquely inform the proportion of the population.

Datasets use historical conditions and observation to inform how spring-run Chinook salmon may respond to the Proposed Action. Historical monitoring may support or refute hypotheses and inform the reasonableness of information generated by models.

Spring-run and fall-run Chinook salmon redds are difficult to distinguish as adults can spawn concurrently in space and time. In October 2015, 16 fall-run Chinook salmon redds were dewatered and in November 2015, 112 fall-run Chinook salmon and one spring-run Chinook salmon redd were dewatered. In December 2015, reductions resulted in an additional 162 dewatered fall-run Chinook salmon redds for a total of 291 observed dewatered redds, 248 of which were located at or above Clear Creek, during the 2015/2016 season (Stompe et al. 2016). It is possible that one of the fall-run Chinook salmon redds was misclassified and was a spring-run Chinook salmon redd. The total dewatering percentage was estimated at 2.14% (using spring-run and fall-run Chinook salmon spawning females combined) (Stompe et al. 2016). Dewatering occurred more in 2015/2016 than in 2014/2015 but less than in 2013/2014, likely due to higher summer flows in 2013/2014 (Stompe et al. 2016). The number of spring-run Chinook salmon redds in Clear Creek is much smaller than the numbers found in the Sacramento River. Annually, the specific number depends on actions to conserve storage.

Table 6-13. Summary of dewatered redd information for mainstem Sacramento River for combined fall-run and spring-run Chinook salmon redds. Total redds pre-2010 were based on aerial redd counts, post-2010 based on post season estimate of all female spawners in the population for a given year (not including unspawned females).

Year	Shallow Redds Actively Monitored	Dewatered	Total Redds
2002	n/a	145	4,420
2003	n/a	9	3,832
2008	n/a	189	n/a
2009	n/a	92	205
2010	228	23	2,166
2011	83	25	1,900
2012	348	123	4,783
2013	743	538	17,368
2014	311	44	13,814
2015	774	291	13,771
2016	101	0	2,415

Year	Shallow Redds Actively Monitored	Dewatered	Total Redds
2017	36	15	772
2018	407	202	3,702
2019	433	35	10,557
2020	620	176	5,455

Source: Reclamation 2022.

Models provide quantitative estimates of future conditions under the Proposed Action.

The redd dewatering analyses for the Sacramento River (Attachment L.4 *Sacramento River Redd Dewatering Analysis*) are based on the maximum reduction in flow from the initial flow, or spawning flow, that occurs over the duration of an egg cohort. The duration of a cohort in a redd includes egg incubation and alevin development to emergence from the gravel. The minimum flow during the egg cohort period is referred to as the dewatering flow. If flows during the 3 months after spawning are all greater than the spawning flow, no dewatering is assumed to occur. This analysis uses the flow results from Upper Sacramento River Daily Operations Model (USRDOM).

The results for show modest and inconsistent variation in estimates of spring-run redd dewatering potential with water year type for EXP1 and EXP3 but under the No Action Alternative and the phases of Alternative 2, the variation among water year types is consistent, with the lowest estimates of redd dewatered potential in critical water years and highest estimates in wet and above normal water years (Table L.6-14). This pattern of variation is expected for spring-run Chinook because their spawning occurs in the fall, with incubation extending into early winter. During wet winters, periodic storms and high runoff increase flow fluctuations, which tends to result in greater estimates of redd dewatering potential. In drier winters, flow fluctuations are reduced and fewer redds are potentially dewatered.

Table L.6-14. Estimated percent of redd dewatering potential for Spring-run Chinook Egg Incubation in the Sacramento River from Keswick Dam to the Battle Creek Confluence for EXP1, EXP3, NAA, and Four Phases of Alternative 2

Water Year Type	EXP1	EXP3	NAA	Alt2wTUCP woVA	Alt2woTUCP woVA	Alt2woTUCP DeltaVA	Alt2woTUCP AllVA
Wet	3.3	8.6	25.7	24.6	24.7	24.8	25.0
AN	3.0	8.9	27.4	28.8	28.8	28.8	28.7
BN	2.8	10.6	14.4	13.2	12.6	12.8	14.4
Dry	2.5	11.5	12.7	13.1	12.8	12.1	12.5
Critical	1.4	11.2	9.5	8.2	8.1	7.9	7.9
All	2.7	10.1	18.2	17.8	17.6	17.5	17.9

The results for spring-run redd dewatering potential grouped by incubation period suggest that redd dewatering peaks in the September – December period and is generally similar under the No Action Alternative and phases of Alternative 2 (Figure 6-10). EXP1 has the lowest median percent of redds dewatered throughout spawning and incubation. The lowest median percent of redds dewatered for EXP3, the No Action Alternative, and phases of Alternative 2 occurs in October – January.

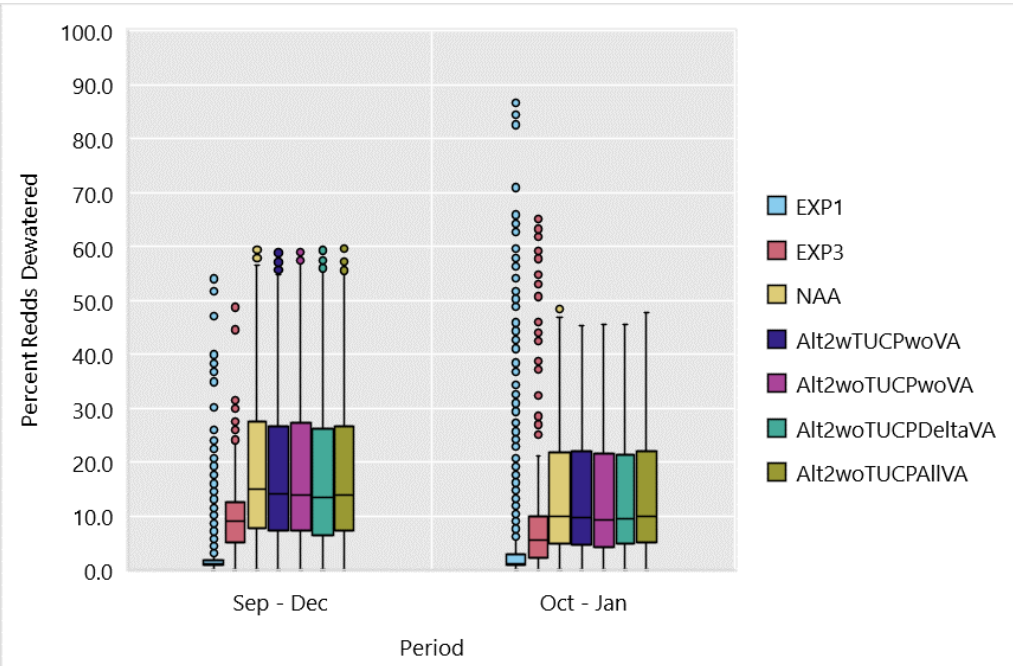


Figure 6-10. Estimated percent of redd dewatering potential for Spring-run Chinook Salmon in the Sacramento River from Keswick Dam to the Battle Creek Confluence for EXP1, EXP3, NAA, and four phases of Alternative 2, by Incubation Period

The **frequency** of occurrence is **high** and likely to occur annually. In the past 20 years, the frequency of lower releases in October and November than in September is high. After spring-run Chinook salmon construct their redds in months with higher flows, once flows are subsequently reduced in October, the result is dewatering of some of the redds with eggs still incubating in them. Eggs are generally incubating between September and February.

To evaluate the **weight of evidence** for the stranding and dewatering stressor, there is a quantitative historical record of spring-run Chinook salmon redd monitoring and seasonal releases specific to the Sacramento River and Clear Creek. However, current monitoring protocol and the inability to differentiate between spring-run and fall-run Chinook salmon with a high level of confidence indicates there is a data gap. There is limited literature regarding redd construction preference and utility are species specific and location specific. Additionally, the spatial and temporal overlap of fall-run and spring-run Chinook salmon and a lack of means to distinguish between adult spring- and fall-run Chinook salmon during the spawning makes reporting accurate estimates of difficult.

- Historic stranding and dewatering observations, Sac River + Clear Creek: quantitative, species-specific, location-specific, available through multiple sources and QA/QCed from a long time series, published in technical memos and annual reports from technical teams, not expected to have statistical power
- Historic flows associated with stranding and dewatering locations, Sacramento River + Clear Creek: quantitative, not species specific (but not expected to be, environmental variable), location-specific, available through multiple sources and QA/QCed from a long time series, published in technical memos and annual reports from technical teams, not expected to have statistical power
- Sacramento + Clear Creek Dewatering Analysis modeling LOE: quantitative, species specific, location specific, widely accepted in published literature
- USRDOM daily flow modeling LOE: quantitative, not species-specific (but not expected to be), environmental variable, location-specific, model developed to evaluate flows using multiple inputs, widely accepted as daily flow modeling system for use in the Central Valley upper watershed

Conservation measures in the Proposed Action that minimize or compensate for effects of the operation of the CVP and SWP on this stressor include:

- Sacramento River
    - Minimum Instream Flows
    - Fall and Winter Base Flows for Redd Maintenance
- Clear Creek
    - Minimum Instream Flows

Conservation measures in the Proposed Action for other species, life stages, and/or stressors that may exacerbate this stressor include:

- Sacramento River
    - Fall and Winter Base Flows for Shasta Refill
    - SRSC Transfer Delays

6.2.3.2 Redd Quality

The proposed release of water in the fall may decrease the redd quality stressor. During the egg incubation and fry emergence period, the Proposed Action will release water from Shasta Reservoir into the Sacramento River and release water from Whiskeytown Reservoir into Clear Creek increasing flows in the Sacramento River and Clear Creek, respectively. Increased surface flows are likely to increase hyporheic flows that improve DO and additionally may reduce sedimentation improving egg and alevin essential functions and development (Bennett et al. 2003). Build-up of fine sediment can decrease permeability, decrease interstitial flow, and reduce oxygen availability for embryos (Bjornn and Reiser 1991). Oxygen levels can be variable due to random packing within the cluster and may become depleted as water flows through egg clusters

(Martin et al. 2020). Eggs in the downstream half of a cluster can experience lower oxygen levels (Martin et al. 2020). Appendix L provides analysis regarding the effects on egg incubation from water temperature and flow.

The decrease in the redd quality stressor is expected to be **beneficial**. In lab studies, Utz et al. (2013) found a statistically significant, positive relationship between mean interstitial flow velocity and survivorship for fall-run Chinook salmon embryos in a uniform porous substratum.

The Proposed Action may decrease the redd quality stressor that exists in the **environmental baseline** (without the Proposed Action). Gravel size and composition, flow, water temperature, DO, contaminant, sedimentation and pathogens and disease drive the redd quality stressor (Windell et al. 2017). Many of these drivers are analyzed separately in this chapter. This particular subsection considers flows, the subsection just below ("Water Temperature") considers another driver for the redd quality stressor.

Non-discretionary flood control reduces peak flows that may mobilize the bed. Reclamation operates Whiskeytown Dam in the winter for flood control, including both the Whiskeytown Reservoir flood conservation space and Spring Creek releases. Under rare circumstances, uncontrolled spills occur through the Whiskeytown Dam gloryhole spillway which is one of the rare opportunities to cause bed mobilization in Clear Creek. Whiskeytown Lake is annually drawn down by approximately 35 TAF of storage space during November through April to regulate flows for winter and spring flood management. Operations at Whiskeytown Lake during flood conditions are complicated by its operational relationship with the Trinity River, Sacramento River, and Clear Creek. On occasion, imports of Trinity River water to Whiskeytown Reservoir may be suspended to avoid aggravating high flow conditions in the Sacramento Basin. Reclamation's past operation of Whiskeytown Reservoir has influenced the flow of water in Clear Creek. Reclamation has implemented flow and water temperature management actions in coordination with members of the Clear Creek Technical Team, a multi-agency group coordinating Clear Creek operations to reduce stressors on the quality of spring-run Chinook salmon redds.

The **proportion** of the population affected by the Proposed Action is **medium** for the Sacramento River and **medium** for Clear Creek. Redd quality depends on spawning timing, duration of egg incubation, and river stage. Data available from current monitoring programs is limited. Eggs are generally incubating between September and November, with some as late as February. Redds observed from surveys in September are classified as spring-run Chinook salmon but those observed in October are classified as fall-run Chinook salmon. This may underestimate the number of spring-run Chinook salmon redds in the Sacramento River. Currently, Clear Creek is the only tributary within the ESU that has an independent population of spring-run Chinook salmon (NMFS 2019 BiOp). It is difficult to assess the proportion of population affected because there is little data to support a determination.

Literature does not uniquely inform the proportion of the population.

Timing may vary between years, but the majority of redd construction still occurs during times of proposed lower flows.

Models do not uniquely inform the proportion of the population.

The **frequency** of occurrence is **large** on the Sacramento River and **large** in Clear Creek and occurs annually. Flows at the Keswick gage from 2005 – 2022 in general decrease from September to December in all years and flows at the IGO gage are generally steady from October to December and increase from September to October. It is difficult to assess frequency because there is little biological data to support a determination.

To evaluate the **weight of evidence** for the redd quality stressor, there is a quantitative historical record of spring-run Chinook salmon redd monitoring and seasonal releases specific to the Sacramento River and Clear Creek. However, current monitoring protocol and the inability to differentiate between spring-run and fall-run Chinook salmon with a high level of confidence indicates there is a data gap. Published literature is used which shows emergence and survival as functions of flow-influenced sedimentation are specific to Chinook salmon but are not specific to spring-run Chinook salmon nor to the Sacramento River or Clear Creek.

- Historic timing observations, Sac River + Clear Creek: quantitative, species-specific, location-specific, available through multiple sources and QA/QCed from a long time-series, published in technical memos and annual reports from technical teams, not expected to have statistical power
- Historic flows, Sac River + Clear Creek: quantitative, not species-specific (but not expected to be, environmental variable), location-specific, available through multiple sources and QA/QCed from a long time-series, published in technical memos and annual reports from technical teams, not expected to have statistical power
- USRDOM daily flow modeling LOE: quantitative, not species-specific (but not expected to be), environmental variable, location-specific, model developed to evaluate flows using multiple inputs, widely accepted as daily flow modeling system for use in the Central Valley upper watershed

Conservation measures in the Proposed Action that minimize or compensate for effects of the operation of the CVP and SWP on this stressor include:

- Sacramento River
  - Fall and Winter Base Flows for Shasta Reservoir Redd Maintenance
  - SRSC Transfer Delayed Timing
- Clear Creek
  - Minimum Flows

Conservation measures in the Proposed Action for other species, life stages and/or stressors that may exacerbate this stressor include:

- Sacramento River
  - Fall and Winter Base Flows for Shasta Reservoir Refill

- SHOT Water Transfer Timing Approvals
- Drought Actions

6.2.3.3 Water Temperature

The proposed release and blending of water from Whiskeytown Dam may increase or decrease the water temperature stressor. During egg incubation and fry emergence, the releases under the Proposed Action will blend water from different elevations in Whiskeytown Reservoir and import water from Trinity Reservoir that contribute to the management of water temperatures at Clear Creek. Appendix L provides an analysis of water temperature related effects on incubating eggs.

Releases are expected to be **beneficial** overall; however, certain temperature management actions may be **lethal** to some individuals. Spring-run Chinook salmon eggs require cool water temperatures to incubate.

Although the Proposed Action may, at times, increase the water temperature stressor, unsuitable water temperatures for spring-run Chinook salmon egg incubation and fry emergence exists in the **environmental baseline** (without the Proposed Action). The amount of precipitation, local ambient air temperatures and solar radiation drives the water temperature stressor (Windell et al. 2017). It is expected that climate change will result in warmer air temperature and shift in forms of precipitation, with more precipitation falling as rain, which will exacerbate water temperatures in the reservoirs.

In the absence of releases of stored water for water service and water temperature management purposes, flows would remain low in the summer and fall. Water temperatures would increase to levels that result in mortality of spring-run Chinook salmon eggs and fry. Reclamation's past operation of Whiskeytown Dam has influenced the flow and temperature of water in Clear Creek. Reclamation has operated the Whiskeytown Dam to reduce the water temperature stressor during egg incubation and fry emergence by altering flow releases and guard gate configuration to allow for release of water at different elevations.

Whiskeytown provides cold water to sustain spring-run Chinook salmon spawning and egg incubation. In 1992, Reclamation installed two temperature curtains in Whiskeytown Reservoir in an effort to improve passage of cold water through the reservoir during the warm months of the year for downstream coldwater needs both curtains were recently replaced. Since 1999, Reclamation has managed Whiskeytown Dam releases to meet a daily average water temperature of 56°F or less from September 15 to October 31 at the Igo Stream Gauging Station, located at river mile 11 on Clear Creek (U.S. Geological Survey 2019). By September, the coldwater pool in Whiskeytown Reservoir becomes limited, and in some cases may result in less cold water available for Clear Creek during the spring run Chinook salmon spawning period.

The **proportion** of the population affected by the Proposed Action is **medium** for Sacramento River and **medium** for Clear Creek. Water temperature stressors depend on hydrology, meteorology, storage in Shasta and Trinity reservoirs, releases from Keswick Reservoir, operation of the TCD, spawning timing, duration of egg incubation, and distribution of redds. Water temperatures higher than 53.5°F may result in spring-run Chinook salmon egg/fry mortality (McCullough et al. 2001; NMFS BiOp 2019). Eggs and alevin from adults which spawn later in the season (October) may emerge during the period when there are more optimal water temperature conditions. Conversely, when adult spring-run Chinook salmon spawn earlier in the season (August), eggs incubate and fry emerge during less suitable flow and water temperature conditions.

Literature on critical water temperatures historically identified 56°F as the threshold temperature to protect incubating eggs. Martin et al. (2017) applied statistical models calibrated to survival to Red Bluff to identify a critical threshold of 53.5°F at no mortality would be expected. Subsequent studies (e.g., Del Rio et al. [2019]) have explore temperatures and hypoxia to identify temperatures warmer that 53.5°F depending on DO.

Datasets use historical conditions and observation to inform how spring-run Chinook salmon may respond to the Proposed Action. Historical monitoring may support or refute hypotheses and inform the reasonableness of information generated by models. Figure 6-11 shows water temperatures at Sacramento River above Clear Creek 2005 – 2022.

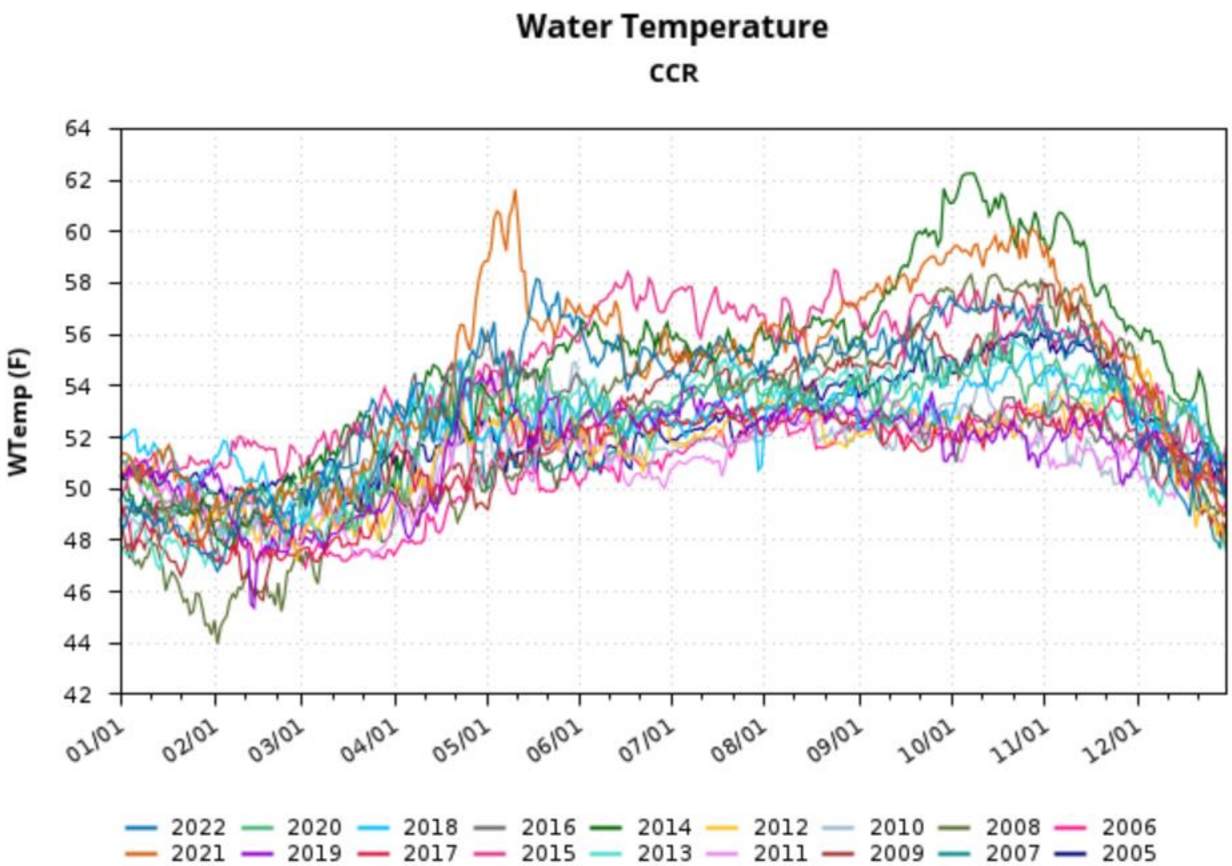


Figure 6-11. Historic water temperature at Sacramento River above Clear Creek, 2005 – 2022.

Models provide quantitative estimates of future conditions under the Proposed Action.

HEC-5Q modeling analysis enumerates the frequency at which mean monthly simulated water temperatures exceed water temperature criteria obtained from scientific literature. Results for the 42.8°F to 56°F range are presented in Table 6-15 for the Sacramento River at Keswick and Table Table 6-16 for the Sacramento River at the Red Bluff Diversion Dam. At Keswick, the percent of months outside the temperature range under the Proposed Action had a range of 0.8% for Below Normal water year types and 22.9% in Critical water year types. Wet and Above Normal water year types, water temperatures were 100% within range for egg incubation and fry emergence throughout the May to November period under the Proposed Action phases.

Table 6-15. Percent of Months outside the Optimal 42.8°F to 56°F Water Temperature Range for egg incubation and fry emergence of Spring-run Chinook Salmon by Water Year Type and for All Years Combined, Sacramento River at Keswick, September–March.

Water Year Type	EXP1	EXP3	NAA	Alt2woTUCPwoVA	Alt2woTUCPDeltaVA	Alt2woTUCPAllVA
Wet	42.3	0.0	0.0	0.0	0.0	0.0
Above Normal	43.0	0.0	0.0	0.0	0.0	0.0
Below Normal	40.5	0.0	0.0	1.6	1.6	0.8
Dry	35.1	0.0	0.0	0.0	0.0	0.0
Critical	32.1	16.5	19.3	22.9	20.2	19.3
All	38.7	2.6	3.0	3.9	3.5	3.2

Modeled scenario legend is as follows: EXP 1 (Exploratory 1), EXP 3 (Exploratory 3), NAA (No Action Alternative), PA woTUCP woVA (Proposed Action without Temporary Urgency Change Petition without Voluntary Agreement), PA woTUCP DeltaVA (Proposed Action without Temporary Urgency Change Petition Delta Voluntary Agreement), PA woTUCP AllVA (Proposed Action without Temporary Urgency Change Petition Systemwide Voluntary Agreement).

At the Sacramento River at the Red Bluff Diversion Dam, the percent of months with water temperature outside the 42.8°F to 56°F range under the Proposed Action phases range from 13.3% during wet water year types to 34.9% during Critical water year types. The percent of months outside the range was generally increased from wetter to drier water year types.

Table 6-16. Percent of Months outside the Optimal 42.8°F to 56°F Water Temperature Range for egg incubation and fry emergence of Spring-run Chinook Salmon by Water Year Type and for All Years Combined, Sacramento River at the Red Bluff Diversion Dam, September–March.

Water Year Type	EXP1	EXP3	NAA	Alt2woTUCPwoVA	Alt2woTUCPDeltaVA	Alt2woTUCPAllVA
Wet	30.1	27.0	14.8	14.3	13.8	13.3
Above Normal	28.0	26.9	17.2	14.0	15.1	16.1
Below Normal	30.2	30.2	23.8	23.8	24.6	23.8
Dry	29.8	26.2	25.0	25.6	25.6	25.0
Critical	30.3	38.5	35.8	34.9	33.9	33.9

Water Year Type	EXP1	EXP3	NAA	Alt2woTUCPwoVA	Alt2woTUCPDeltaVA	Alt2woTUCPAllVA
All	29.8	29.2	22.5	22.0	22.0	21.7

Modeled scenario legend is as follows: EXP 1 (Exploratory 1), EXP 3 (Exploratory 3), NAA (No Action Alternative), PA woTUCP woVA (Proposed Action without Temporary Urgency Change Petition without Voluntary Agreement), PA woTUCP DeltaVA (Proposed Action without Temporary Urgency Change Petition Delta Voluntary Agreement), PA woTUCP AllVA (Proposed Action without Temporary Urgency Change Petition Systemwide Voluntary Agreement).

The **frequency** of occurrence is likely **medium to high**. The water temperature stressor is dependent on coldwater pool availability and is affected primarily by hydrology and meteorology. Historic water temperatures at Sacramento River above Clear Creek have exceeded a mean daily temperature of 53.5°F at least one day between September and November 100% of years 2005 – 2022 and have exceeded 56°F at least one day 50% of years during the same months 2005 – 2022 (Table 6-17, Figure 6-11).

Table 6-17. Days exceeding daily average temperatures of 53.5°F and 56°F at Sacramento River above Clear Creek between September and November 2005 – 2022.

Year	Days Exceeding 53.5°F	Days Exceeding 56°F
2005	87	3
2006	5	0
2007	88	19
2008	91	63
2009	91	36
2010	4	0
2011	2	0
2012	10	0
2013	75	0
2014	91	89
2015	87	67
2016	4	0
2017	1	0
2018	57	0
2019	1	0
2020	75	3
2021	91	79
2022	89	44

To evaluate the **weight of evidence** for the water temperature stressor there are published location-specific water temperature thresholds currently used for temperature management for spring-run Chinook salmon by agencies and a quantitative historic record of spring-run Chinook salmon redd monitoring and seasonal temperature data. However, current monitoring protocol and the inability to differentiate between spring-run and fall-run Chinook salmon with a high level of confidence indicates that data are insufficient.

- Historic water temperatures, Sac River + Clear Creek: quantitative, not species-specific (but not expected to be, environmental variable), location-specific, available through multiple sources and QA/QCed, long timeseries and not expected to have statistical power
- Historic spawning timing observations, Sac River + Clear Creek: quantitative, species-specific, location-specific, available through multiple sources and QA/QCed, long time-series and not expected to have statistical power
- CalSim Reservoir Storage modeling LOE: quantitative, not species-specific (but not expected to be, environmental variable), location-specific, model developed to evaluate reservoir storage using control points, widely accepted as monthly flow and storage modeling system for use in the Central Valley
- Hec-5Q water temperature modeling LOE: quantitative, not species-specific (but not expected to be, environmental variable, location-specific, model developed to evaluate reservoir system using control points, widely accepted as temperature modeling system for use in the Central Valley upper watershed

Conservation measures in the Proposed Action that minimize or compensate for effects of the operation of the CVP and SWP on this stressor include:

- Sacramento River
    - Shasta Reservoir Water Temperature and Storage Management
- Clear Creek
    - Water Temperature Management

Conservation measures in the Proposed Action for other species, life stages and/or stressors that may exacerbate this stressor include:

- Sacramento River
    - SHOT Determination on Temperature Shoulders (requiring releases too cold too early and exhausting coldwater pool)
    - Voluntary Agreement Pulse Flows
    - Sacramento River Pulse Flows

6.2.4 Juvenile Rearing and Outmigration

Some juvenile spring-run Chinook salmon begin emigrating soon after emergence from the gravel. The juvenile emigration period can begin in November and extend to early May or June, with residency in the Delta lessening as the season progresses into the late spring months (NMFS 2009:94). While the majority of juvenile spring-run Chinook salmon outmigrate as fry, a proportion rears in Clear Creek through the spring and summer and emigrates as subyearlings with the first rainstorms in the fall or winter following their birth (NMFS 2014).

Spring-run Chinook salmon outmigration from Clear Creek occurs during late October through late April with peak emigration of juveniles occurring in November, and few fish exiting through the end of May.

The majority of spring-run Chinook salmon juveniles exit tributaries and emigrate through the Sacramento River and the Delta in the spring. The Sacramento River mainly functions as rearing habitat for juveniles and the primary migratory corridor for outmigrating juveniles from Clear, Mill, Deer, and Antelope creeks and from the Feather River. On the mainstem Sacramento River, spring-run Chinook salmon juvenile rearing and migration peak passage is between December and April.

The Delta is utilized by juveniles prior to entering the ocean. Juvenile spring-run Chinook salmon are expected to be present in the northern Delta region from December through May with a peak presence in March and April (Miller et al. 2017; Speegle et al. 2013). Historic salvage data from the CVP and SWP facilities show a slight shift in occurrence with peak presence between April and May. Juvenile spring-run Chinook salmon use the portion of the lower San Joaquin River within the Delta as a migratory pathway though the exact number of spring-run Chinook salmon in the San Joaquin basin is unknown.

Stressors that influence outmigrating juvenile spring-run Chinook salmon include *Toxicity and Contaminants; Predation and Competition; Refuge Habitat; Food Availability and Quality; Outmigration Cues; Stranding Risk; Water Temperature and Dissolved Oxygen; Pathogens and Disease; and Entrainment Risk.*

Stressors that may change at a level that is insignificant or discountable include:

- The Proposed Action may increase or decrease the DO and *water temperature* stressor. During the juvenile rearing and outmigration period, releases of Whiskeytown Reservoir in the fall will increase flows while storage of Whiskeytown Reservoir in the winter will decrease flows. Reduced releases from Shasta Reservoir will decrease flows in the Sacramento River below Keswick and Delta inflow and outflow in the winter and spring. Releases of storage may result in cooler water temperatures and higher flows that may provide a higher DO saturation potential and decreased water temperatures while storing water may do the opposite. The acceptable range of water temperatures for growth of Chinook salmonids gathered from a synthesis of evidence is 40.1°F - 66.4°F, with optimum growth occurring between 50°F – 60°F (McCullough et al. 2001). The evidence presented in Section 6.2.1, *Adult Migration* above is applicable for Juvenile Rearing and Outmigration.

  In Clear Creek, the Proposed Action may decrease water temperatures and increase flows during the fall, decreasing the DO stressor. There is no DO sampling for Clear Creek. However, upper Clear Creek is very steep, and monitoring shows white water which indicates high levels of gas exchange. In the winter, the Proposed Action may decrease flows which may increase the DO stressor.

On the Sacramento River, the Proposed Action may decrease flows increasing the DO stressor for juveniles during the rearing and outmigration period. Historic water quality monitoring has rarely shown DO at levels below 5.0 mg/L when juveniles are rearing and outmigrating. Monitoring has not shown this stressor as a factor affecting the juvenile life stage.

In the Delta, the Proposed Action may decrease Delta inflow and outflow increasing the DO stressor and increasing water temperatures for juveniles during the rearing and outmigration. However, historic water quality monitoring has not shown DO at levels below 5.0 mg/L when juveniles are rearing and outmigrating. CVP and SWP storage and diversion decreases Delta inflow and outflow; however, Bay-Delta water temperature is mainly driven by timing of snowmelt (Knowles and Cayan 2002), air temperature, solar radiation, and meteorology (Vroom et al. 2017, Daniels and Danner 2020). Moreover, it is unlikely that flow alterations from Keswick will influence water temperature in the lower Sacramento River and north Delta (Daniels and Danner 2020).

- The Proposed Action may increase the *pathogens and disease* stressor. During the juvenile rearing and outmigration period, releases of Whiskeytown Reservoir in the fall will increase flows while storage of Whiskeytown Reservoir in the winter will decrease flows. Reduced releases from Shasta Reservoir will decrease flows in the Sacramento River below Keswick and Delta inflow and outflow in the winter and spring. A decrease in flows may influence pathogen and disease exposure, including increased transfer from hatchery fish to natural-origin juveniles; however, transmission directionality is difficult to track and evidence of transfer is lacking (Naish et al. 2007; Kent et al. 2013; Nekouei et al. 2019). The influence of the operation of the CWP and SWP on water temperatures potentially influences pathogens; however, effects of pathogens and disease have not been observed in fish monitoring.

  In Clear Creek, the Proposed Action may increase the pathogens and disease stressor. Juvenile survival is influenced by specific diseases (e.g., *Ceratomyxa shasta*, furunculosis) present in the Sacramento River (reviewed in Lehman et al. 2020). Diseases affecting Chinook salmon become highly virulent at temperatures above 59.9°F (McCullough 1999). The stressor is not anticipated to change in the winter.

  On the Sacramento River, the Proposed Action may increase the pathogens and disease stressor for juveniles during the rearing and outmigration period.

  In the Delta, the Proposed Action may increase water temperatures above the 59.9°F threshold in the spring. However, the volumes of water required to overcome ambient air temperatures make the operation of the CVP and SWP unlikely to influence water temperatures in the Delta.

- The Proposed Action may increase the *toxicity from contaminants* stressor. During the juvenile rearing and outmigration period, releases of Whiskeytown Reservoir in the fall will increase flows while storage of Whiskeytown Reservoir in the winter will decrease flows. Reduced releases from Shasta Reservoir will decrease flows in the Sacramento

River below Keswick and Delta inflow and outflow in the winter and spring. Exposure to contaminants can result in sub-lethal effects such as reduced growth or suppression of juvenile immune systems possibly leading to infection and disease (Arkoosh et al. 2001; Kroglund and Finstad 2003; Lundin et al. 2021).

From historic monitoring efforts, there is no evidence of the effects of contaminants on juveniles in Clear Creek.

From historic monitoring efforts, there is no evidence of the effects of contaminants on juveniles on the Sacramento River.

In the Delta, CVP and SWP storage and diversion of water decreases Delta inflow and outflow concentrating constituents. Historical fisheries monitoring has not reported large-scale evidence of toxicity and contaminants in Bay-Delta fishes. Studies have shown a 0.2 mg/kg threshold for methylmercury as protective of both juvenile and adult fish (Beckvar et al. 2005). Tissue concentrations of Feather River Hatchery juveniles were reported for 199 samples, and approximately 1% of sampled fish (n = 2; 0.234 mg/kg in a floodplain fish and 0.269 mg/kg in a Sacramento River fish) in winter floods between 2001 and 2005 were above this threshold (Henery et al. 2010).

- The Proposed Action may increase the *predation and competition* stressor. During the juvenile rearing and outmigration period, the Proposed Action reduces releases from Shasta Reservoir and will decrease flows in the Sacramento River below Keswick Reservoir. The Proposed Action also reduces Delta inflow and outflow, which may alter hydrodynamic conditions in the Sacramento River and Delta. Storage of water in Shasta Reservoir, particularly in the winter from December through April, may affect juveniles' outmigration travel rates. Increased travel time (slower travel rates) and migration routing, particularly into suboptimal habitat with high predator abundance in the Sacramento River mainstem and the central and south Delta, may lead to increased predation. If fish travel rates through the system increase, the delay increases the risk of exposure to predation.

  Predator presence in the Delta and Sacramento River is ubiquitous. Introduced non-native piscivorous species such as striped and largemouth bass have become well-established predators in the Central Valley system. Predation studies in the Sacramento River at Red Bluff Diversion Dam document predation on Chinook salmon (Tucker et al. 1998). Certain locations in the Delta (e.g., Clifton Court Forebay, the scour hole at Head of Old River, Delta fish collection facilities, the DCC Gates) are considered predator hotspots and operations of these facilities are operating, juvenile winter-run Chinook salmon will be exposed to predation. Studies have been conducted as far back as the 1980s on the abundance of predatory fish inhabiting Clifton Court Forebay (Kano 1990, Gingras and McGee 1997) and more recent studies have predicted high predation hazard for scour holes like the Head of Old River site (Michel et al. 2020).

  Predation rates are a function of correlated variables such as predator presence, prey vulnerability, and environmental conditions (Grossman et al. 2013; Grossman 2016) that are influenced by operations. Predation and competition are not independent from other stressors, such as refuge habitat, food availability and quality, entrainment risk, and outmigration cues. Predation effects associated with the Proposed Action are captured in the analysis of these stressors. Any residual effects of predation and competition associated with the Proposed Action is considered insignificant.

Described below are stressors exacerbated by the Proposed Action, potentially resulting in incidental take. Also described below are conservation measures included as part of the Proposed Action to avoid or compensate for adverse effects. Finally, the Proposed Action may also ameliorate certain stressors in the environmental baseline, and below a description of these beneficial effects is included.

6.2.4.1 Outmigration Cues

The proposed storage of water may increase the outmigration cue stressor. During the juvenile rearing and outmigration period, storage of water in Shasta Reservoir associated with the Proposed Action will reduce downstream flows on the Sacramento River, particularly in the winter and spring from December through April, and may affect juveniles' cue to migrate and their outmigration travel rates. Storage of water in Whiskeytown will reduce downstream flows on Clear Creek, particularly in the winter. Outmigration cues, for the purposes of this document, is defined and discussed in two ways: (1) fish outmigration behavior being impacted by reduced variation and volume of flows in the upper Sacramento River; and (2) fish travel times being affected and increasing their exposure to predators and poor environmental conditions on the mainstem Sacramento River. Outmigration cues are primarily analyzed for the Sacramento River and migration downstream of Red Bluff Diversion Dam to the Delta. Multiple topic-specific appendices address aspects of juvenile migration from the Sacramento River through the Delta.

- Appendix L – analyzes storage and operations needed for Shasta Reservoir coldwater pool management.
- Appendix J – presents analysis of the effects of spring Delta outflow on juvenile survival with a focus on route-specific travel time and survival.
- Appendix H – presents analysis on the "Minimum Flows" conservation measure.

The increase in outmigration cue stressors is expected to be **lethal**. If fish stay in the upper watershed longer, since they are not cued to outmigrate, this delay increases the risk of exposure to sources of mortality (higher exposure to predation). The impact of outmigration cues is not independent from these other stressors which are lethal such as refuge habitat, entrainment risk stressor, and predation and competition. These lethal stressors are described independently in this chapter.

Although the Proposed Action may increase the outmigration cues stressor, changes in outmigration cues that affect spring-run Chinook salmon juveniles exist in the **environmental baseline** (without the Proposed Action). Generally, natural flows in the Clear Creek decrease through the summer and increase into the fall and winter. Natural flows in the Sacramento River decrease through the summer and into fall until late-fall and winter rains. Those flows influence fish outmigration behavior and affect fish travel times in the upper watershed. In addition, other facilities owned by senior water users affect flows in the Sacramento River.

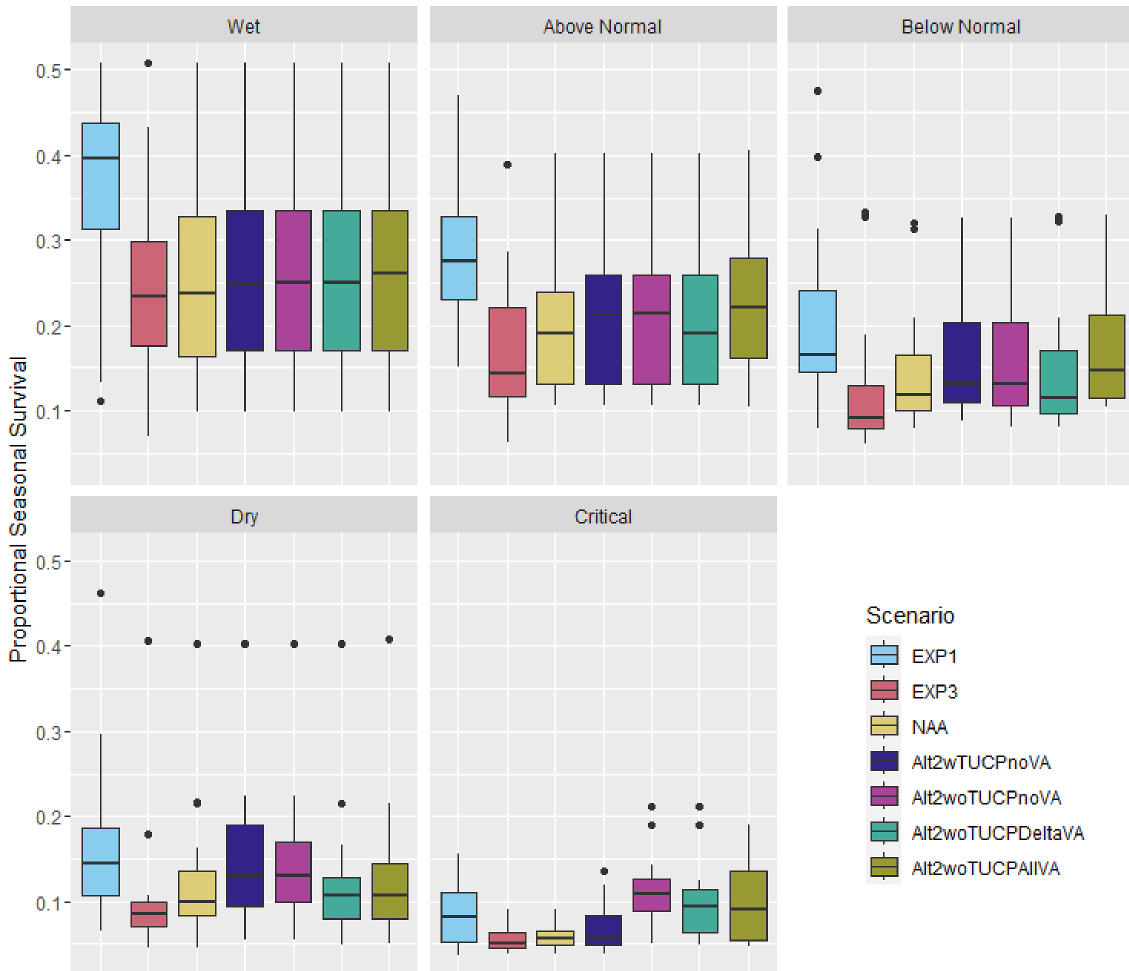
The **proportion** of the population affected by the Proposed Action is **large** for Sacramento River and **medium** for Clear Creek and depends on variations in flows. Outmigration cues impact spring-run Chinook salmon from all CVP and non-CVP tributaries. In the Proposed Action, reduced releases occur for water temperature management, storage rebuilding, rice decomposition smoothing, and redd dewatering avoidance actions. Outmigration, measured at Red Bluff Diversion Dam occurred between October and as late as June. Historically, these actions reduced flows as early as August and as late as January. Historic passage at Red Bluff Diversion Dam, 5% to 95% passage occurred as early as December and as late as May (BY 2004 – 2021). Average 50% passage (BY 2008 – 2021) occurred by March 5th. Further downstream at Knights Landing, 5% to 95% passage occurred as early as December and as late as April.

Literature does not uniquely inform the proportion of the population.

Datasets use historical conditions and observation to inform how spring-run Chinook salmon may respond to the Proposed Action. Historical monitoring may support or refute hypotheses and inform the reasonableness of information generated by models. Empirical estimates of acoustically tagged Chinook salmon can be found below in "Entrainment Risk" stressor section.

Acoustically tagged fish released at locations in the upper Sacramento River under varying hydrological conditions are used to estimate survival probabilities and travel times rates. As fish migrate downstream towards the Delta, individuals encounter a range of environmental conditions and transition from reaches with unidirectional flow (upstream) to reaches with bidirectional flow (tidally driven, downstream). Outmigrating juveniles may be exposed to predation and as inflow declines and tidal influence moves upstream, travel time and distance may increase leading to higher exposure to predators. Travel and survival rates of Chinook salmon in upper Sacramento reaches are strongly correlated (Notch et al. 2020).

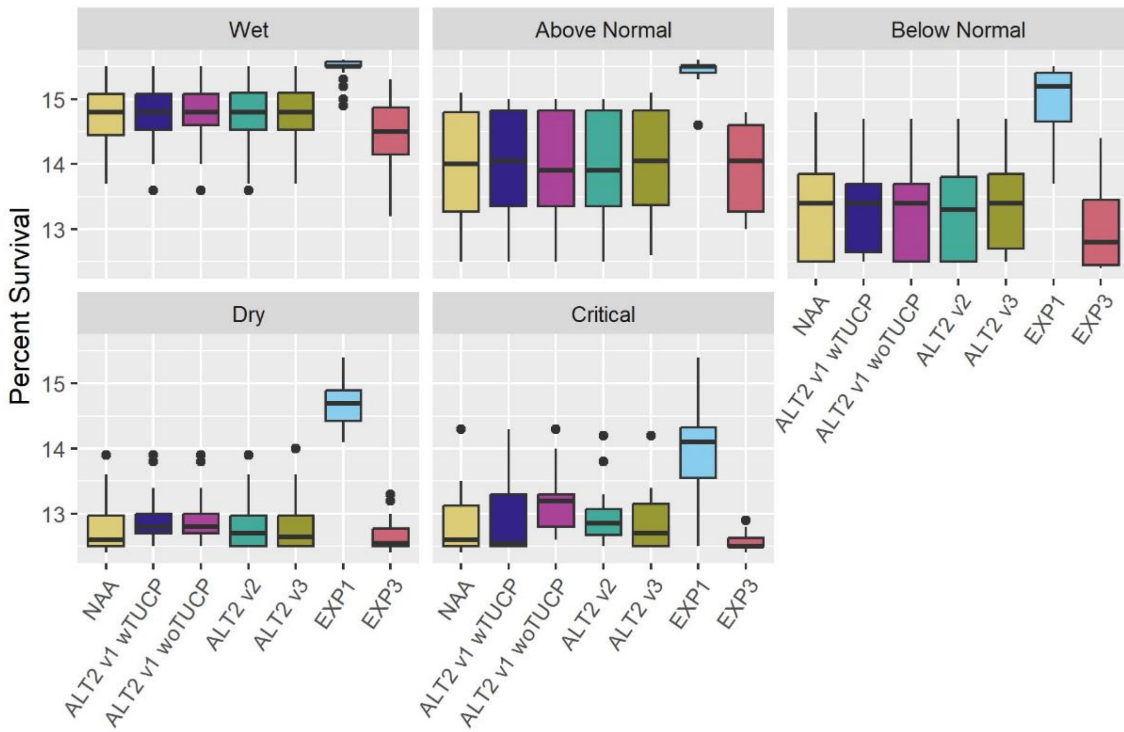
Attachment J.5, *Flow Threshold Salmon Survival Model*, predicts annual mean probability of juvenile Chinook salmon survival in the Sacramento River during the spring outmigration period, Deer Creek to Feather River between March 15 and June 15. Mean annual seasonal March 15th through June 15th survival under the Proposed Action phases ranges from 10% to 26% (Figure 6-12). Overall, survival estimates do not vary much within water year types (WYTs) suggesting a lack of variation in the spring flow ranges in the Proposed Action, However, survival estimates do vary among WYTs suggesting variation of flows among WYTs.



Modeled scenario legend is as follows: EXP 1 (Exploratory 1), EXP 3 (Exploratory 3), NAA (No Action Alternative), PA woTUCP woVA (Proposed Action without Temporary Urgency Change Petition without Voluntary Agreement), PA woTUCP DeltaVA (Proposed Action without Temporary Urgency Change Petition Delta Voluntary Agreement), PA woTUCP AllVA (Proposed Action without Temporary Urgency Change Petition Systemwide Voluntary Agreement).

Figure 6-12. Boxplots of mean annual seasonal March 15th through June 15th survival by water year type.

The XT model, Attachment J.4, *XT Model*, predicts juvenile Chinook salmon survival and travel time from Red Bluff Diversion Dam to the confluence of the Sacramento and American rivers during the March 15th and June 15th spring outmigration period. Mean survival under the Proposed Action phases ranges from 12.9% to 14.7% (Figure 6-13) and mean travel time under the Proposed Action phases ranges from 22.1 to 51.6 days. Overall, survival and travel time estimates do not vary within water year types (WYTs) suggesting a lack of variation in the spring flow ranges in the Proposed Action. Survival estimates did not vary much among WYTs while travel time estimates did vary among WYTs.



Modeled scenario legend is as follows: EXP 1 (Exploratory 1), EXP 3 (Exploratory 3), NAA (No Action Alternative), PA woTUCP woVA (Proposed Action without Temporary Urgency Change Petition without Voluntary Agreement), PA woTUCP DeltaVA (Proposed Action without Temporary Urgency Change Petition Delta Voluntary Agreement), PA woTUCP AllVA (Proposed Action without Temporary Urgency Change Petition Systemwide Voluntary Agreement).

Figure 6-13. Boxplots of mean survival between Red Bluff Diversion Dam and the confluence with the American River for different modeled scenarios by water year type.

The **frequency** of occurrence depends primarily on the timing of exceeding an outmigration cue threshold and is **low** for the Sacramento River and **low** for Clear Creek. There is an outmigration threshold developed for winter-run Chinook salmon. Del Rosario et al. (2013) showed when daily Wilkins Slough flows surpass a 14,126 cfs threshold, winter-run Chinook salmon outmigration cues into the lower Sacramento River increased, and more than 5% of the fish observed annually at the Knights Landing fish monitoring site occurred (400 cms). There is no published threshold for spring-run Chinook salmon outmigration thus it is difficult to make a frequency determination based on historic flows at any monitoring location. Tributary flow increases are used to signal conditions conducive to emigration. An increase in flow greater than 50% from the previous day is used to indicate the appropriate cues for the initiation of salmon emigration. Between October and December at Bend Bridge on the Sacramento River, flows on at least 10% of days in 18 out of 18 years (100%, 2005 – 2022) exhibited a greater than 50% increase from the previous day. Between October and December at Igo on Clear Creek, flows on at least 10% of days in 17 out of 18 years (94%, 2005 – 2022) exhibited a greater than 50% increase from the previous day. The impact will be magnified in years when coldwater pool volume is limited, and releases are limited because of water temperature management, storage rebuilding, and rice decomposition smoothing actions.

To evaluate the **weight of evidence** for the outmigration cues stressor, there is a two-decade quantitative, historic record of flows and Red Bluff and Knights Landing monitoring data for spring-run Chinook salmon. There is a body of literature that is location- but not species-specific that provides flow thresholds relevant to winter-run Chinook salmon (Michel et al. 2021; Del Rosario et al. 2013). Additionally, an existing predator prey model, the mean free-path length model, has been applied in the Sacramento River using hatchery late fall-run Chinook salmon (location- but not species-specific) to evaluate movement patterns of both predators and prey and the probability of encounters (Steel et al. 2020).

- Literature, Del Rosario: quantitative, species-specific, location-specific, publication in the peer reviewed journal, multiple regressions fit on four covariates
- Historic passage at key locations, Sac River + Clear Creek: quantitative, species-specific, location-specific, available through multiple sources and QA/QCed, long time-series and not expected to have statistical power
- Historic flows: quantitative, not species-specific (but not expected to be, environmental variable), location-specific, available through multiple sources and QA/QCed, long time-series and not expected to have statistical power
- USRDOM modeling LOE: quantitative, not species-specific (but not expected to be, environmental USRDOM daily flow modeling LOE: quantitative, not species-specific (but not expected to be), environmental variable, location-specific, model developed to evaluate flows using multiple inputs, widely accepted as daily flow modeling system for use in the Central Valley upper watershed

Conservation measures in the Proposed Action that minimize or compensate for effects of the operation of the CVP and SWP on this stressor include:

- Sacramento River
    - Minimum Instream Flows
    - Voluntary Agreement Pulse Flows
    - Sacramento River Pulse Flows
- Clear Creek
    - Minimum Instream Flows
    - Spring Pulse Flows

Conservation measures in the Proposed Action for other species, life stages and/or stressors that may exacerbate this stressor include:

- Sacramento River
    - Fall and Winter Base Flows for Shasta Reservoir Refill
    - Reduced Wilkins Slough Minimum Flows
- Drought Actions

6.2.4.2 Refuge Habitat

The proposed storage of water may increase the refuge habitat stressor. During the juvenile rearing and outmigration period, the Proposed Action storage of water in Shasta Reservoir in the winter and spring will decrease flows in the Sacramento River and Delta that reduce suitable margin and off-channel habitats available as refuge habitat for juveniles. Storage of water in Whiskeytown will reduce downstream flows on Clear Creek in the winter, increasing the stressor. Increasing releases decrease potential refuge habitat along the mainstem Sacramento River, as well, due to high velocities, until the channel overflows the channel and accesses off-channel habitats. Appendix O presents analysis of this stressor.

In the Delta, operations are not expected to increase the refuge habitat stressor for rearing and outmigrating juvenile spring-run Chinook salmon. All juveniles outmigrating from the Sacramento River and Clear Creek must pass through the Delta on the way to the Pacific Ocean. The Delta is tidally influenced. As such, the effect of Proposed Action storage of water on available shallow-water refuge habitat would be within the daily tidal range near the seaward end of the Delta. Tidal influence dissipated toward the landward edges of the Delta and effects of Proposed Action storage of water would be more similar to that described for the mainstem Sacramento River above. In the Delta, spring-run Chinook salmon utilize side channels and inundated floodplain habitat in the tidal shoreline of the Delta for foraging and growth. The tidal habitat of the Delta also serves the critical role as a physiological transition zone before saltwater entry, with juveniles residing in the Delta for an average of three months (del Rosario et al. 2013). However, only a small fraction of the wetland rearing habitat is still accessible to fish, and much of the modern Delta and bays have been converted to serve agriculture and human population growth (SFEI-ASC 2014). As explained above, the loss of tidal marshes and historical floodplain wetlands have resulted in a loss of refuge habitat for spring-run Chinook salmon. In addition, there are 200 miles of exterior levees in Suisun Marsh, twenty of those miles are along Suisun, Grizzly, and Honker Bays (U.S. Bureau of Reclamation, U.S. Fish and Wildlife Service, and California Department of Fish and Game 2013). Levee construction involves the removal and loss of riparian vegetation (Anderson and Sedell 1979; Pusey and Arthington 2003). There is no known relationship between flows and refuge habitat availability similar to those for the Sacramento River (Gard 2005), inter-annual variation in flows at Freeport during the rearing and outmigration period is greater than below Keswick Dam; thus, flow-dependent refuge habitat is likely limiting less often in the Delta than in the Sacramento River.

The increase in refuge habitat stressor is expected to be **sub-lethal**. A decrease in sufficient refuge habitat can result in juveniles lacking cover to avoid predation or habitat to stop and hold during outmigration. Access to off-channel habitats has been linked to higher growth rates and survival (Limm and Marchetti 2009; Zeug et al. 2020). Very low releases decrease potential refuge habitat for juvenile spring-run Chinook salmon by removing access to side-channels, access to refuge, and changing geomorphic processes. Refuge habitat is not independent of food availability and quantity, another sub-lethal stressor discussed below.

Although the Proposed Action may increase the refuge habitat stressor, changes in refuge habitat of juvenile spring-run Chinook salmon exists in the **environmental baseline** (without the Proposed Action). Turbidity, shallow water habitat, and food production and retention drive this stressor (Windell et al. 2017). Generally, dams impair the recruitment of large woody material to the river channel and floodplain below the dam. Stable year-round flows have resulted in diminished natural channel formation, altered foodweb processes, and slowed regeneration of riparian vegetation.

Since 1900, approximately 95 percent of historical freshwater wetland habitat in the Central Valley floodplain has been lost, typically through the construction of levees and draining for agriculture or residential uses (Hanak et al. 2011). Human expansion has occurred over vast areas in the Delta and Sacramento and San Joaquin Valleys between the 1850s and the early 1930s, completely transforming their physical structure (Thompson 1957, 1965; Suisun Ecological Workgroup 2001; Whipple et al. 2012; San Francisco Estuary Institute 2010). Levee ditches were built to drain land for agriculture, human habitation, mosquito control, and other human uses, while channels were straightened, widened, and dredged to improve shipping access to the Central Valley and to improve downstream water conveyance for flood management. In addition, constructing and armoring levees changes bank configuration and reduces cover (Stillwater Sciences 2006). Constructed levees protected with rock revetment generally create nearshore hydraulic conditions characterized by greater depths and faster, more homogeneous water velocities than occur along natural banks. Higher water velocities typically reduce deposition and retention of sediment and woody debris, thereby reducing the shoreline variability. This reduction in variability eliminates the shallow, slow-velocity river margins used by juvenile fish as refuge escape from fast currents, deep water, and predators (Stillwater Sciences 2006). Reclamation has completed many side-channel restoration projects in the upper Sacramento River that provide refuge habitat for juveniles. Additional restoration projects are ongoing and outside of this consultation.

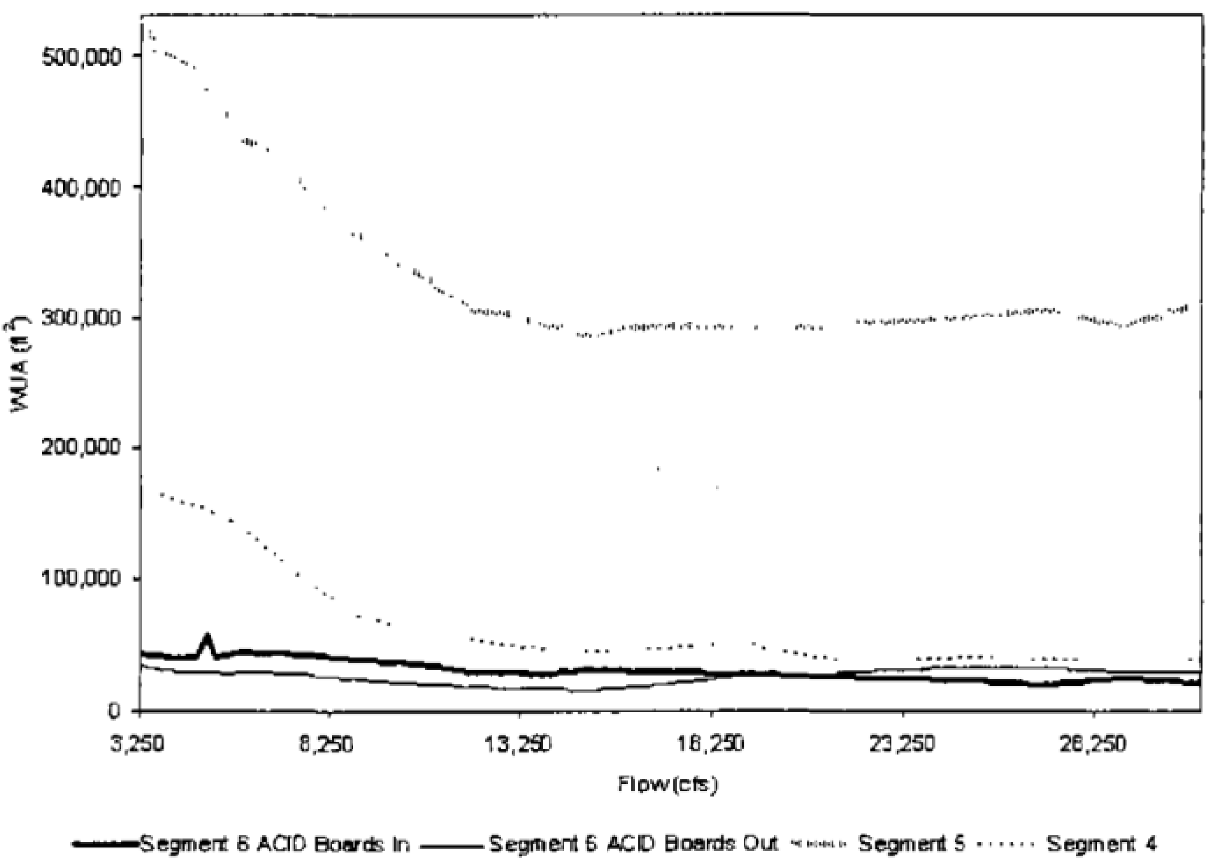
Since 2009, Reclamation has operated Whiskeytown Dam to provide channel maintenance flows. In 2009, NMFS issued an RPA requiring Reclamation to re-operate Whiskeytown Glory Hole spills during the winter and spring to produce channel maintenance flows. In 2019, Reclamation committed to release 10 thousand acre-feet of water from Whiskeytown Dam for channel maintenance in all year-types except for Dry and Critical year-types. Efforts have also been made to restore parts of Lower Clear Creek. For example, the Lower Clear Creek Floodway Restoration Project restored the natural form and function of a 1.8-mile channel and floodplain along Lower Clear Creek to benefit salmon and steelhead.

Restoration projects along the Sacramento River are intended to improve shallow water habitats for rearing and migrating Chinook salmon. The Yolo Bypass Project is intended to improve shallow water habitat and habitat connectivity for Chinook salmon. Operation of the project is expected to provide improved habitat connectivity for ESA-listed fish species to migrate between the Sacramento River and the Yolo Bypass. This enhanced habitat connectivity is expected to improve the ability of anadromous fish to access the Yolo Bypass, resulting in increased growth and decreased stranding events.

The **proportion** of the population affected by decreased refuge habitat depends on bathymetry and hydrology and is **large** in the Sacramento River and **large** in Clear Creek.

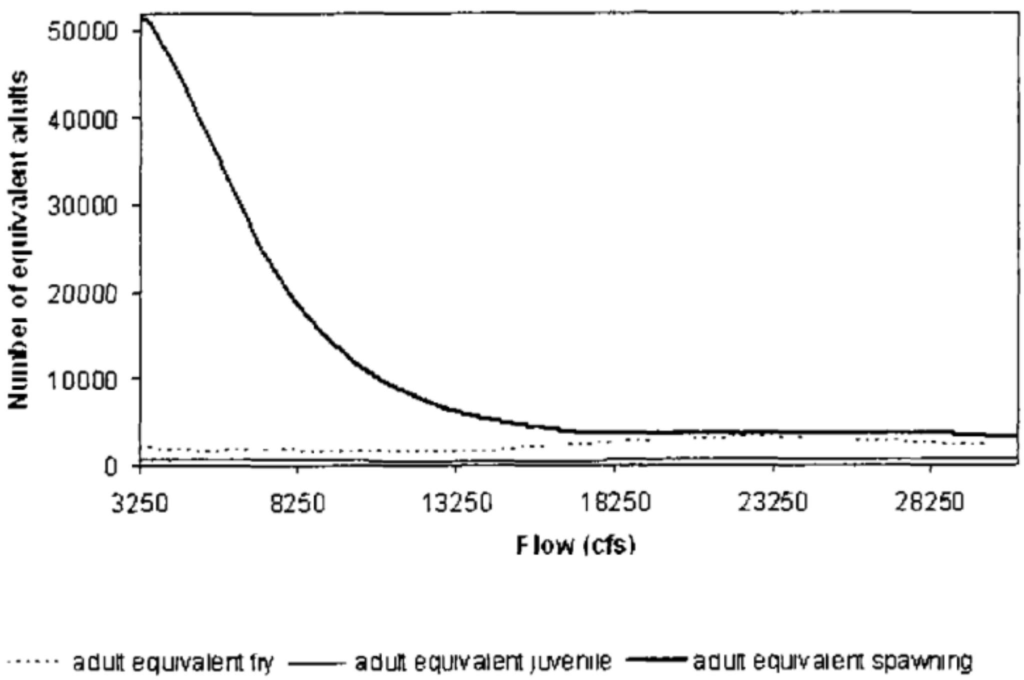
The literature demonstrates that in most cases, limiting life stage analyses indicated that juvenile habitat is limiting (Gard 2005). Access to off-channel habitats has been linked to higher growth rates and survival (Limm and Marchetti 2009; Zeug et al. 2020). Habitat restoration programs are aimed towards providing benefits to native salmonids (quality habitat, increased food availability, refuge) but these efforts also provide benefits to non-native and native predators possibly increasing predation rates. Reduced releases decrease potential refuge habitat for juvenile spring-run Chinook salmon removing access to side channels, access to refuge, and changing geomorphic processes.

The figures below show flow-habitat relationships (Figure 6-14) and limiting life stage analyses for juvenile fall-run Chinook salmon (used as a proxy for spring-run Chinook salmon) by Sacramento River segment 6 (ACID to Keswick Dam, Figure 6-15a) and segment 5 (Cow Creek to Anderson-Cottonwood Irrigation District, ACID, Figure 6-15b). There are no flow-habitat relationships developed for Clear Creek, leading to uncertainty on how WUA changes with varying flows for different stretches along Clear Creek.

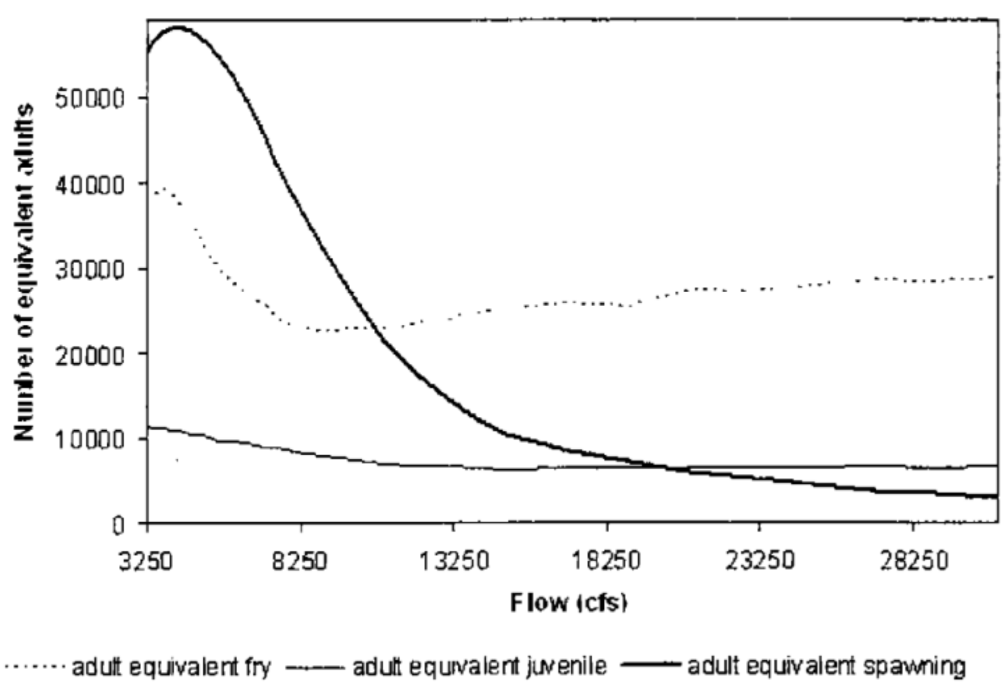


Source: Gard 2005.

Figure 6-14. Juvenile fall-run Chinook salmon rearing flow-habitat relationships for segments 4 through 6 (ACID boards in and out).



a.



b.

Source: Gard 2005.

Figure 6-15 a-b. Limiting life stage analysis for fall-run Chinook salmon in a) segment 6 (ACID to Keswick Dam, ACID boards out) and b) segment 5 (Cow Creek to Anderson-Cottonwood Irrigation District, ACID). Adult equivalent juvenile is represented by the thin solid black line.

Models provide quantitative estimates of future conditions under the Proposed Action.

Attachment O.3, *Sacramento River Weighted Usable Area Analysis* provides context for the WUA available for spring-run Chinook salmon fry and juvenile rearing downstream of Keswick Dam releases. Fall-run Chinook salmon rearing WUA habitat values are used as proxies for Sacramento River spring-run Chinook salmon rearing WUA. The fall-run Chinook salmon WUA habitat values for fry peak at the minimum flow (3,250 cfs). The WUA habitat value under the Proposed Action phases range from 453,691 to 567,869 for fry rearing (Figure 6-16). Overall, these WUA habitat values are lowest in wet water years and successively increase in the drier WYT. This pattern of variation is attributable to the low flows at which spring-run Chinook salmon rearing WUA habitat values peak in the Sacramento River.

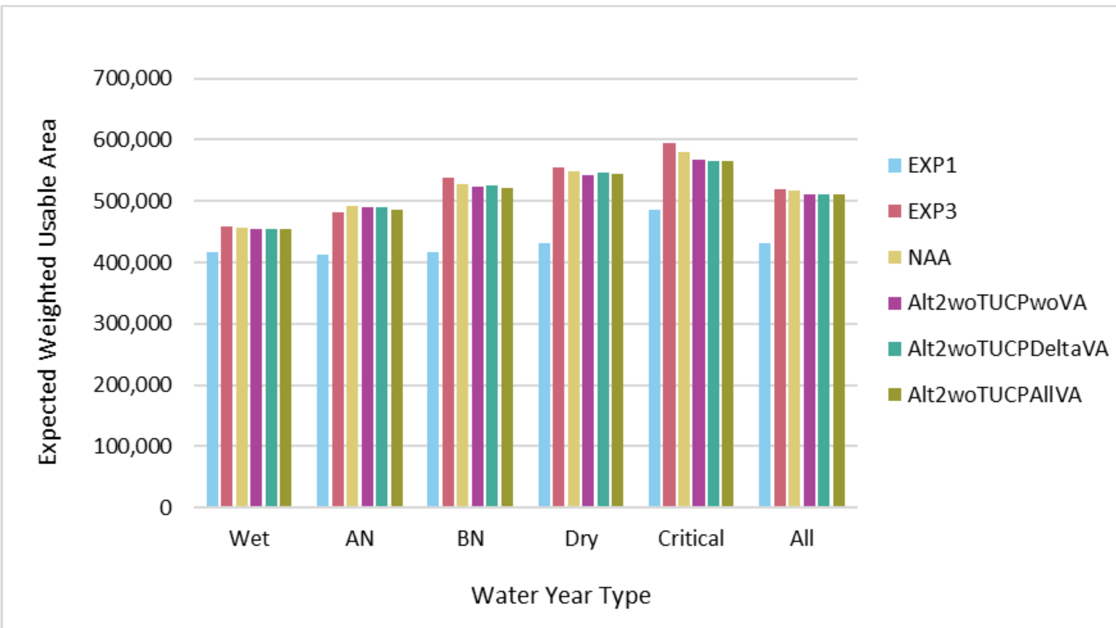


Figure 6-16. Expected Weighted Usable Area for Segments 4-6 by Water Year Type, Spring-run Chinook salmon Fry Rearing the Sacramento River

Attachment O.1, *Clear Creek Weighted Usable Area Analysis* provides context for the WUA available for spring-run Chinook salmon rearing downstream of Whiskeytown releases. Fry rearing WUA for spring-run Chinook salmon peaks at approximately 600 - 900 cfs. The expected WUA habitat value for fry rearing under the Proposed Action phases range from 64,595 in critical water years to 71,406 in wet years (Figure 6-17). Overall, these WUA habitat values do not vary much among Proposed Action phases and WYT. This suggests the summer flow ranges in the Proposed Action provide stable rearing habitats.

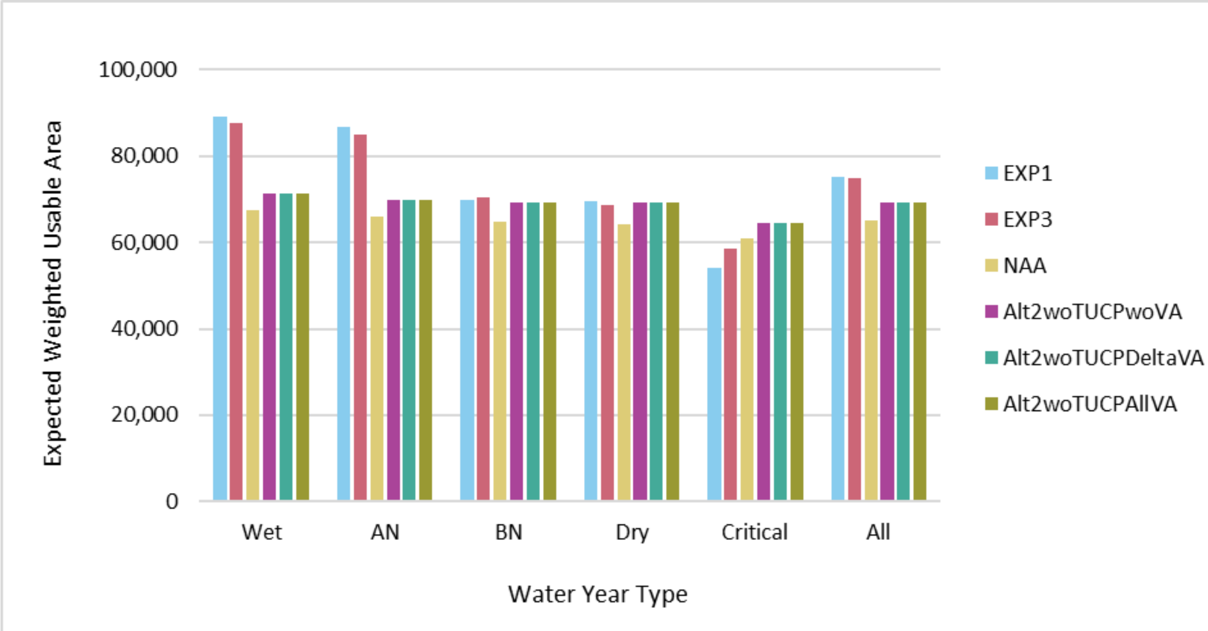


Figure 6-17. Expected Weighted Usable Area for Combined Lower Alluvial, Upper Alluvial and Canyon Segments by Water Year Type, Spring-run Fry Rearing in Clear Creek

Attachment O.2, *SIT LCM Habitat Estimates* provides context for the instream and floodplain rearing habitat area available for spring-run Chinook salmon juveniles in the Upper Sacramento River downstream of Keswick Dam and in Clear Creek in all calendar months.

For instream rearing habitat in the Upper Sacramento River, the monthly habitat values under the Proposed Action phases range from a low of approximately 5 acres to a high of approximately 100 acres (Figure 6-18). Available instream rearing habitat for spring-run Chinook salmon juveniles peaks at low flows and decreases with increasing flows in the Upper Sacramento River. Overall, the habitat values under the Proposed Action phases do not vary much among months, but the lowest habitat values generally occurred in July. Habitat values do vary by WYT, with less instream rearing habitat available in increasing wet WYT.

For floodplain rearing habitat in the Upper Sacramento River, the monthly habitat values under the Proposed Action phases range widely from a low of approximately 0 acres to a high of approximately 875 acres (Figure 6-19). Available floodplain rearing habitat for spring-run Chinook salmon juveniles only increases at flows greater than 25,000 cfs and peaks at flows of approximately 175,000 cfs. Habitat values do vary in response to the combination of both month and WYT. Floodplain rearing habitat availability peaks in December through February in only Above Normal and Wet WYT.

For instream rearing habitat in Clear Creek, the monthly habitat values under the Proposed Action phases range from a low of approximately 4 acres to a high of approximately 16 acres (Figure 6-20). Available instream rearing habitat for spring-run Chinook salmon juveniles increases asymptotically with increasing flow in Clear Creek, up to 875 cfs. The habitat values vary among months under the Proposed Action phases; the lowest habitat values generally occurred in July through October. Habitat values do vary by WYT, with increased instream rearing habitat available in increasing wet WYT.

For floodplain rearing habitat in Clear Creek, the monthly habitat values under the Proposed Action phases range widely from a low of approximately 0 acres to a high of approximately 30 acres (Figure 6-21). Available floodplain rearing habitat for spring-run Chinook salmon juveniles increases asymptotically with increasing flow as high as 2000 cfs. Habitat values do vary in response to both month and WYT. Floodplain rearing habitat availability peaks in December through April across WYT and increases with increasingly wet WYT.

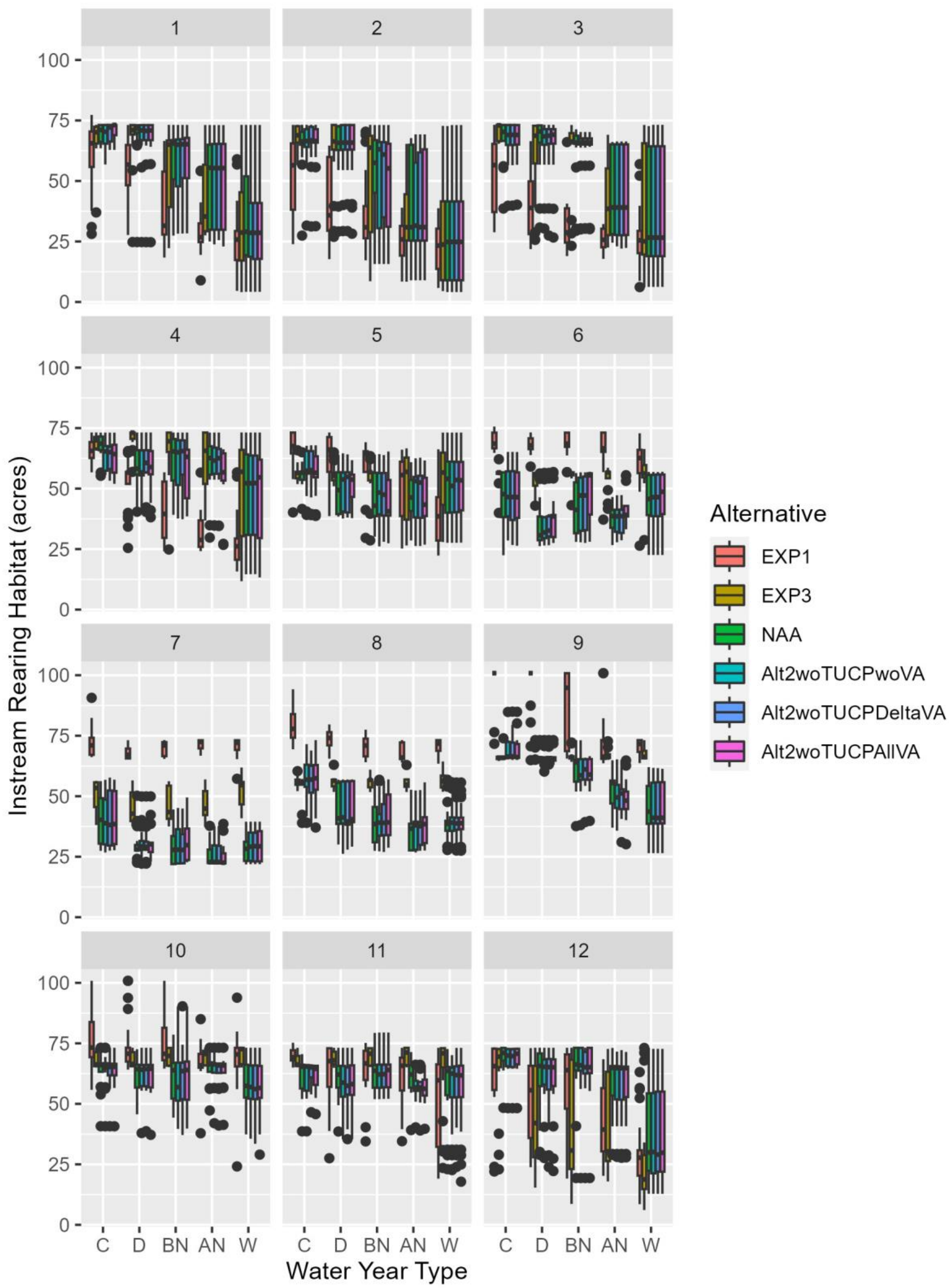


Figure 6-18. Estimated instream rearing habitat for spring-run juveniles in the Upper Sacramento River. Variability within months (facets; January-December) reflects variation across CalSim WYs.

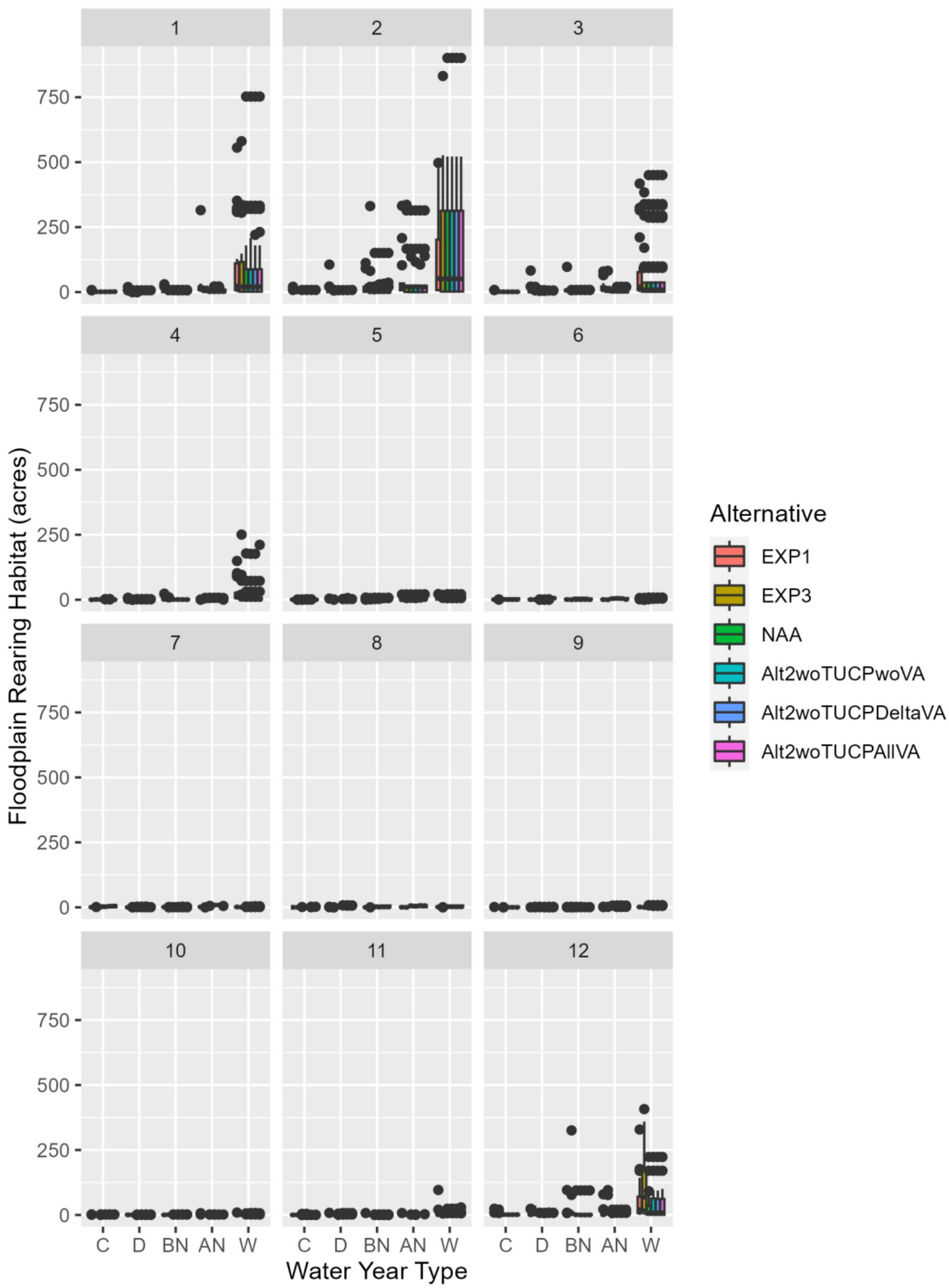


Figure 6-19. Estimated floodplain rearing habitat for spring-run juveniles in the Upper Sacramento River. Variability within months (facets; January-December) reflects variation across CalSim WYs

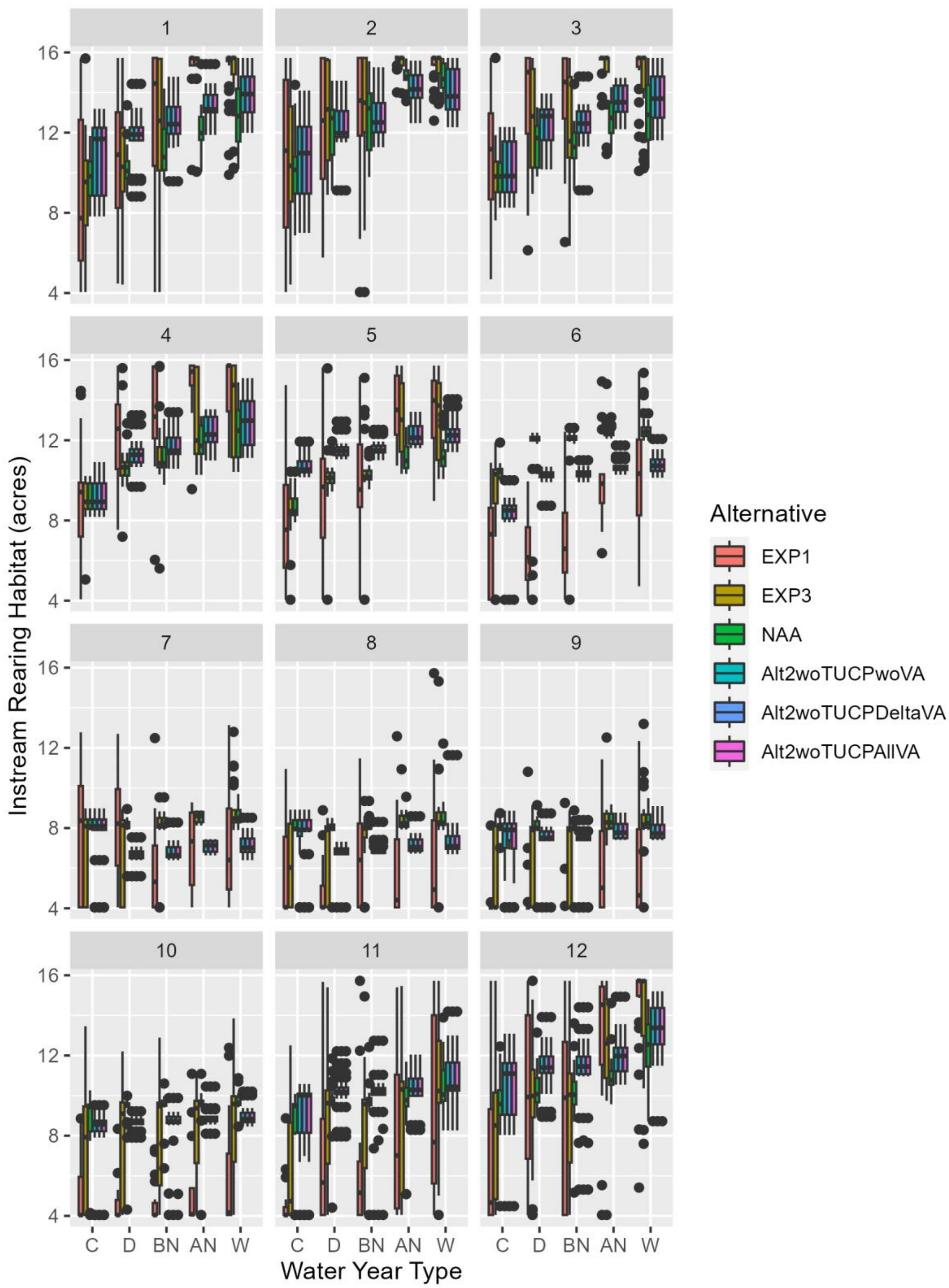


Figure 6-20. Estimated instream rearing habitat for spring-run juveniles in Clear Creek. Variability within months (facets; January-December) reflects variation across CalSim WYs.

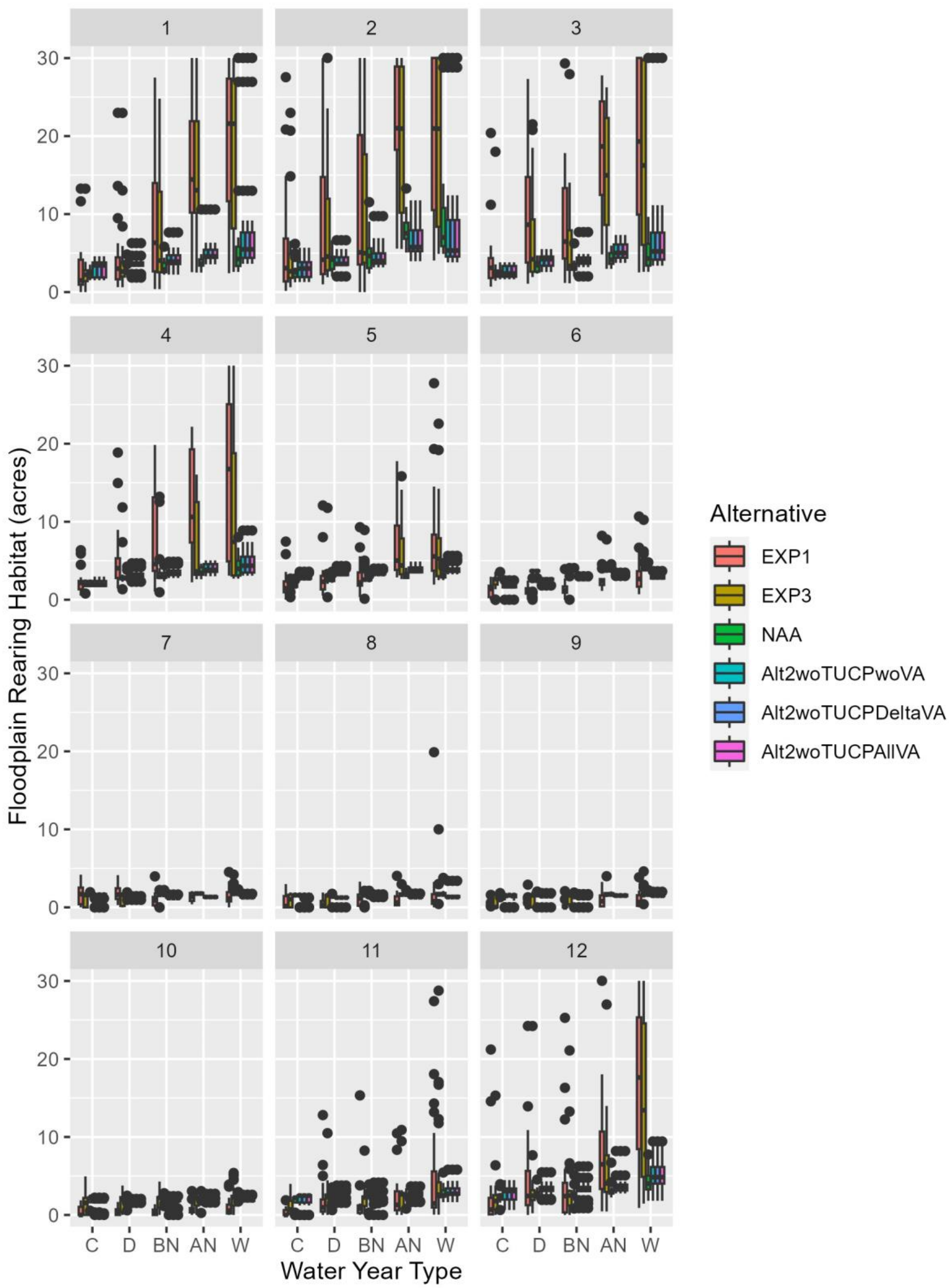
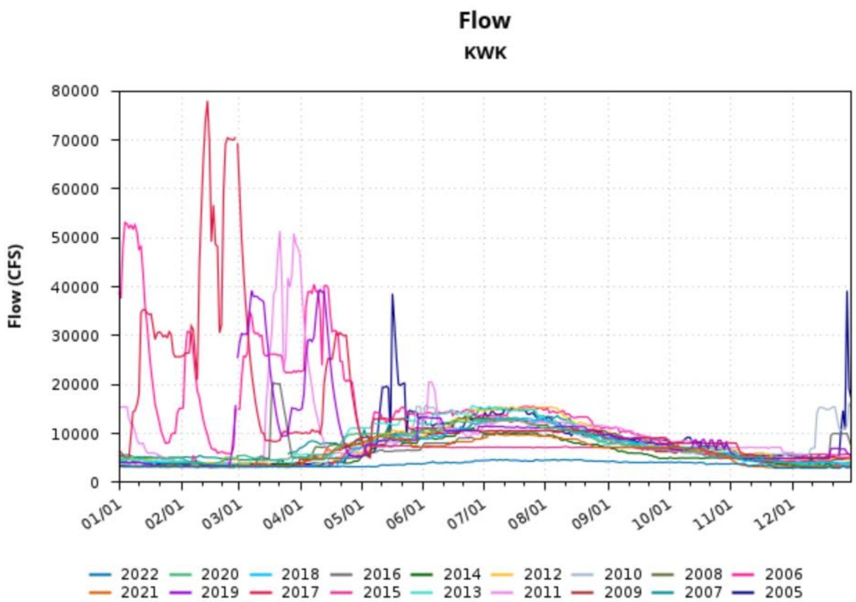
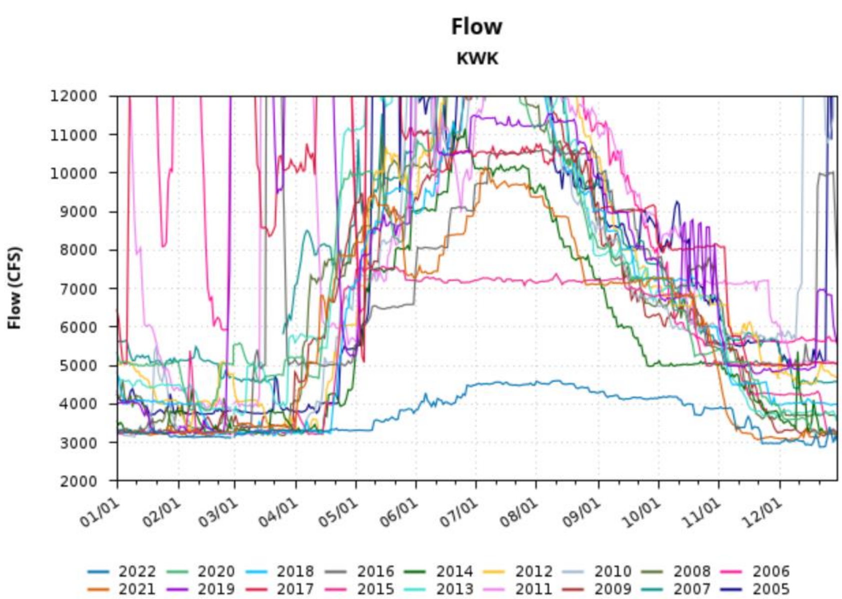


Figure 6-21. Estimated floodplain rearing habitat for spring-run juveniles in Clear Creek. Variability within months (facets; January-December) reflects variation across CalSim WYs.

The **frequency** of occurrence is annual and depends primarily on hydrology and is **low** on the Sacramento River and **medium** on Clear Creek. Between the fall and winter months, flows at Keswick Dam generally decrease, with the exception of wet and above normal WYT (e.g., 2005, 2006, 2010, 2011, 2017, 2019; Figure 6-22a-b). 6 out of 18 years (33%, 2005 – 2022) were wet or above normal WYT (Sacramento Valley Index) and maximum flows between December and April were greater than 15,000 cfs. Limiting life stage analysis for fall-run Chinook salmon shows that flows in Segment 6 do not appear limiting. There are no limiting life stage analysis relationships developed for Clear Creek leading to uncertainty on how abundance by life stage changes with varying flows for stretches along Clear Creek.



a.



b.

Figure 6-22a-b. Keswick flows, 2005 – 2022, (b) scaled to a maximum of 12,000 cfs.

To evaluate the **weight of evidence** for refuge habitat stressor, location-specific but not species-specific (Chinook not spring-run Chinook salmon) information in the literature is used: flow-habitat relationships, limiting life stage analyses (Gard 2005). Studies have shown access to off-channel habitats as linked to higher growth rates and survival (Limm and Marchetti 2009; Zeug et al. 2020).

- The CVPIA SIT DSM, similarly uses habitat suitability curves that are species specific, location specific, and quantitative while relying on multiple experts and peer review (Peterson and Duarte 2020).
- Sacramento WUA analysis is quantitative and species-specific but not location-specific to the Sacramento River (see Assumption 3 in Appendix O, Attachment O.3). WUA analyses are widely used and recognized analytical tools for assessing effects of flow on fish populations (Reiser and Hilgert 2018).
- Clear Creek WUA analysis is quantitative, species-specific, and location-specific to Clear Creek. RIVER2D was the principal hydraulic habitat model used in the USFWS analyses (2007, 2011a, 2011b, 2013) to develop the Clear Creek WUA curves used in this analysis.

Conservation measures in the Proposed Action that minimize or compensate for effects of the operation of the CVP and SWP on this stressor include:

- Sacramento River
    - Minimum Instream Flows
    - Voluntary Agreement Pulse Flows
    - Sacramento River Pulse Flows
- Clear Creek
    - Minimum Instream Flows
    - Spring Pulse Flows

Conservation measures in the Proposed Action for other species, life stages and/or stressors that may exacerbate this stressor include:

- Sacramento River
    - Fall and Winter Base Flows for Shasta Reservoir Refill
    - Reduced Wilkins Slough Minimum Flows
- Drought Actions

6.2.4.3 Food Availability and Quality

The proposed storage of water may increase the food availability and quality stressor. During the juvenile rearing and outmigration period, the Proposed Action will store water decreasing flows on the Sacramento River and Delta outflow and will both release and then store water first increasing then decreasing flows on Clear Creek in the fall and winter. Appendix P, presents analyses of fish response to habitat restoration.

In the Delta, operations are not expected to increase the food availability and quality stressor for outmigrating juvenile spring-run Chinook salmon. All juveniles outmigrating from the Sacramento River and Clear Creek must pass through the Delta on the way to the Pacific Ocean. The Delta is tidally influenced. As such, the effect of Proposed Action storage of water on food availability would be within the daily tidal range near the seaward end of the Delta. Tidal influence dissipated toward the landward edges of the Delta and effects of Proposed Action storage of water would be more similar to that described for the mainstem Sacramento River above. In the Delta, spring-run Chinook salmon utilize side channels and inundated floodplain habitat in the tidal shoreline of the Delta for foraging and growth. The tidal habitat of the Delta also serves the critical role as a physiological transition zone before saltwater entry, with juveniles residing in the Delta for an average of 3 months (del Rosario et al. 2013). Side-channel and floodplain habitat are highly productive and can provide nutrients and food nearby portions of the Delta. Historically, the Yolo Bypass experiences at least some flooding in 80% of years (Reclamation 2012), and recent and ongoing modifications to Fremont Weir are intended to increase the frequency of occurrence.

The increase in food availability and quality stressor is expected to be **sub-lethal** in the Sacramento River. A decrease in quality and quantity of food for foraging juvenile spring-run Chinook salmon will impact growth rates. Additionally, food limitation can weaken juvenile spring-run Chinook salmon, leading to extremes such as starvation, and alter behavior resulting in predation risk. Food availability and quantity is not independent of refuge habitat, another sub-lethal stressor discussed above.

Although the Proposed Action may increase the food availability and quality stressor, changes in food availability and quality for juvenile spring-run Chinook salmon exists in the **environmental baseline** (without the Proposed Action). The level of production and retention drives food availability and quality (Windell et al. 2017). Generally, the presence and operation of dams contribute to channelization, which contributes to a loss of riparian habitat and instream cover. A significant portion of juvenile Chinook salmon diet is composed of aquatic and terrestrial insects, which are dependent on healthy riparian habitat (National Marine Fisheries Service 2014). Levee construction involves the removal of riparian vegetation, which reduces aquatic macroinvertebrate recruitment resulting in decreased food availability for rearing juveniles (Anderson and Sedell 1979; Pusey and Arthington 2003). Channelized, leveed, and riprapped reaches typically have low habitat complexity and low abundance of food organisms. (Lindell 2017).

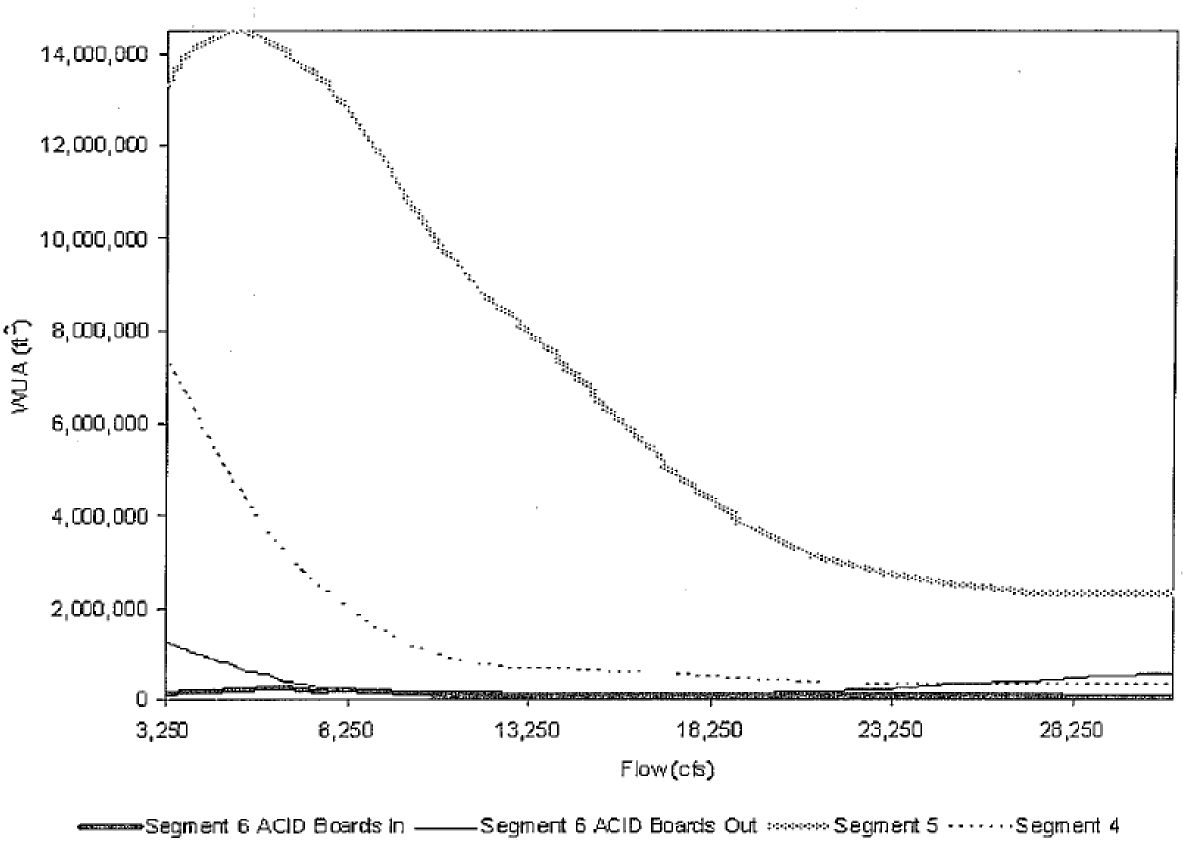
Reclamation has operated Whiskeytown Dam to provide channel maintenance flows since 2009. Efforts have also been made to restore parts of Lower Clear Creek. The Lower Clear Creek Floodway Restoration Project restored the natural form and function of a 1.8 mile channel and floodplain along Lower Clear Creek to benefit salmon and steelhead.

The Yolo Bypass Project is intended to reduce the food availability stressor on Chinook salmon migrating along the Sacramento River. Seasonal inundation of the Yolo Bypass leads to an increase in phytoplankton and other food resources that support fish species residing in the floodplain and provides a source of these food resources to downstream habitats (Sommer *et al.* 2001). Also, the Yolo Bypass has more natural banks and riparian vegetation than the Sacramento River and is better connected to tidal wetlands than the Sacramento River (Goertler et al. 2015). The Yolo Bypass Project should improve food availability and quality for migrating spring-run Chinook salmon. Reclamation and DWR are implementing the Yolo Bypass Project, which is ongoing and outside of this consultation.

In the Delta, levee construction involves the removal and loss of riparian vegetation and reduces aquatic macroinvertebrate recruitment resulting in decreased food availability for rearing juveniles (Anderson and Sedell 1979; Pusey and Arthington 2003). The lack of floodplain connectivity also limits food availability. Invasive species have also affected food availability in the Delta. The native mysid species, *Neomysis mercedis* has experienced severe declines since the introduction and establishment of the invasive overbite clam (Winder and Jassby 2011) and has largely been replaced by a non-native mysid species, *Hyperacnthomysis longirostris* (Avila and Hartman 2020; Winder and Jassby 2011).

The **proportion** of the population affected by decreased food availability and quality depends on bathymetry and hydrology and is **large** in the Sacramento River and **large** on Clear Creek.

The literature demonstrates that in most cases, limiting life stage analyses indicated that juvenile habitat is limiting (Gard 2005). Flow-habitat relationship metrics for juvenile salmonid food supply developed for the Sacramento River, between Keswick Dam and Battle Creek, show (Gard 2006). Optimal flows for the macroinvertebrate index varied by reach and ranged from 3,250 cfs to 6,000 cfs (Figure 6-23; Gard 2006). Access to off-channel habitats has been linked to higher growth rates and survival (Limm and Marchetti 2009; Zeug et al. 2020). Habitat restoration programs are aimed towards providing benefits to native salmonids (quality habitat, increased food availability, refuge) but these efforts also provide benefits to non-native and native predators possibly increasing predation rates. Reduction or loss of seasonally inundated habitats alters food web processes and riparian vegetation, decreasing food availability and quality, and impacting the successful growth and survival of juveniles (Jeffres et al. 2008; Steel et al. 2017; Goertler et al. 2018; Jeffres et al. 2020; Bellido-Leiva et al. 2021). Reduced releases decrease potential refuge habitat for juvenile spring-run Chinook salmon removing access to side-channels, access to refuge, and changing geomorphic processes. See figures in Section 6.2.4.2*, Refuge Habitat* for juvenile fall-run Chinook salmon flow-habitat relationships and limiting life stage analyses (used as a proxy for spring-run Chinook salmon).



Source: Gard 2006.

Figure 6-23. Flow-habitat relationship by reach for juvenile Chinook salmon food supply (biomass of Baetids, Chironomids, and Hydropsychids).

Datasets and models do not uniquely inform the proportion of the population affected.

The **frequency** of occurrence is annual and depends primarily on hydrology and is **low** for Sacramento River and **medium** for Clear Creek. Between the fall and winter months, flows at Keswick Dam generally decrease, except for wet and above normal WYT (e.g., 2005, 2006, 2010, 2011, 2017, 2019; Figure 6-22a-b). 4 out of 18 years (22%, 2005 – 2022) did not have 50% of more daily Keswick flows between December and April in the optimal range (3,250 – 6,000 cfs, see figures above).

To evaluate the **weight of evidence** for the food availability and quality stressor, multiple location- and species-specific studies have been conducted showing the importance of quality available food for rearing and outmigrating juveniles. Studies have been conducted in both the Sacramento River and Bay-Delta.

- Gard (2006) WUA flow-habitat relationships modeling LOE: quantitative, not species-specific (model developed for fall-run Chinook salmon), not location-specific, published in technical reports

Conservation measures in the Proposed Action that minimize or compensate for effects of the operation of the CVP and SWP on this stressor include:

- Sacramento River
    - Minimum Instream Flows
    - Voluntary Agreement Pulse Flows
    - Sacramento River Pulse Flows
- Clear Creek
    - Minimum Instream Flows
    - Spring Pulse Flows

Conservation measures in the Proposed Action for other species, life stages and/or stressors that may exacerbate this stressor include:

- Sacramento River
    - Fall and Winter Base Flows for Shasta Reservoir Refill
    - Reduced Wilkins Slough Minimum Flows
- Drought Actions

6.2.4.4 Entrainment Risk

The proposed diversion of water may increase the entrainment risk stressor. During the juvenile rearing and outmigration period, the proposed diversion of water associated with the Proposed Action alters hydrodynamic conditions in the Sacramento River and Delta. Operations are not anticipated to change the entrainment risk stressor in Clear Creek. This hydrodynamic alteration may influence fish travel time and migration routing in the Sacramento River mainstem and the central and south Delta. Once in the central and south Delta, entrainment into the Jones and Banks pumping plants may occur. Entrainment, for the purposes of this document, is defined and discussed in two ways: (1) fish routed through specific migratory pathways in the Delta (Delta route-specific travel time and survival); and (2) fish encountering CVP and SWP facilities where they may be pulled into diversions or the export facilities. Multiple topic-specific appendices address aspects of juvenile migration through the Delta.

- Appendix G – including sections for "Tracy Fish Collection Facility" and "Skinner Fish Delta Fish Protective Facility."
- Appendix H – presents analysis of "Old and Middle River Management Real Time Operations" and "Delta Cross Channel Gates Closures" conservation measures.
- Appendix J – presents analysis of the effects of spring Delta outflow on juvenile survival with a focus on route-specific travel time and survival.

- Appendix Q – describes the operation of the Georgiana Slough Non-Physical Barrier, one measure that can be taken to prevent juvenile winter-run Chinook salmon from traveling through Georgiana Slough into the central Delta.

The increase in entrainment risk stressor is expected to be **lethal**. Entrainment can result in indirect mortality by routing fish into areas of poor survival (increased predation, reduced habitat quality) or direct mortality during salvage in the Delta fish collection facilities.

Although the Proposed Action may increase the entrainment risk stressor, entrainment of juvenile spring-run Chinook salmon exists in the **environmental baseline** (without the Proposed Action). Proximity to irrigation diversion operations drives the entrainment stressor (Windell et al. 2017). These diversions exist throughout the Delta and along rivers and streams in the Central Valley. Tides and flood releases can influence hydrodynamic transport and move fish into higher risk entrainment areas surrounding diversions or poor habitats which could lead to increased predation. Tidal conditions can facilitate downstream transport or entrainment depending on the flood and ebb of tides during the fortnightly spring-neap cycle (Arthur et al. 1996).

The entrainment risk stressor is influenced by thousands of non-CVP and non-SWP diversions in the rivers and Delta. Senior and junior water users would continue to operate privately-owned facilities to divert water from the Sacramento River and pose a risk of entrainment to juvenile spring-run Chinook salmon, although that risk is reduced where fish screens have been installed. As of 1997, 98.5 percent of the 3,356 diversions included in a Central Valley database were either unscreened or screened insufficiently to prevent fish entrainment (Herren and Kawasaki 2001). Most of the 370 water diversions operating in Suisun Marsh are unscreened (Herren and Kawasaki 2001). Quantification of the effect of small unscreened diversions is limited (Moyle and Israel 2005). The CVPIA Anadromous Fish Screen Program provides grants to screen facilities used to divert water. Diversions greater than 100 cfs are screened on the Sacramento River. Upstream from the Delta, CVP facilities diverting water under water service contracts and SWP diversions are screened (e.g., Red Bluff Pumping Plant, Freeport Regional Water Project, Barker Slough Pumping Plant, Contra Costa Water District).

In the Delta, Reclamation's past operation of the DCC Gates and Reclamation and DWR's past operation of export facilities influenced the flow of water in the Delta. Reclamation and DWR have operated the CVP and SWP to reduce the risk of entrainment under Biological Opinions issued by the USFWS and NMFS in 2004/2005, 2008/2009, and 2019. Under those Biological Opinions, Reclamation and DWR have: (1) closed the DCC Gates; (2) controlled the net negative flows toward the export pumps in Old and Middle rivers to reduce the likelihood that fish would be diverted from the San Joaquin or Sacramento River into the southern or central Delta; and (3) improved fish screening and salvage operations to reduce mortality from entrainment and salvage. Historic data on spring-run Chinook salmon entrainment, salvage, and loss are discussed in detail below. An existing consultation proposes to install operatable gates to increase fish routing into the Yolo Bypass. An existing consultation for the Georgiana Slough Salmonid Migratory Barrier proposed to decrease the existing routing stressor by deterring emigrating juvenile salmonid from entering Georgiana Slough and the central and south Delta, wherein survival is lower relative to remaining in the mainstem Sacramento River, improving survival to Chipps Island.

The **proportion** of the population affected by the Proposed Action varies annually and depends upon flow routing, hydrology, export rates, and migration timing and is **small**. Entrainment impacts spring-run Chinook salmon from all CVP and non-CVP tributaries and records of observations at the fish collection facilities are inclusive of portions of the population that originate outside of CVP-tributaries (e.g., the Feather River, Butte Creek). However, spring-run Chinook salmon loss in years after 2010 are more representative of current Old and Middle River (OMR) management and the Proposed Action compared with years prior to 2010 (1993 – 2009).

Spring-run Chinook salmon travel through different migratory pathways. Using a conceptual model, a single fish in any location could have arrived at that location via one of several pathways (Figure 6-24). For example, a fish observed salvage could have arrived via one of two pathways (San Joaquin Origin via the San Joaquin River, San Joaquin or Sacramento Origin via the South Delta). If a proportion of flows is higher down a migratory pathway documented as a route with higher survival rates for juvenile salmonids then fish migrating through that route will likely have a better chance of surviving to the ocean than fish migrating through a sub-optimal route (e.g., experiencing potential entrainment into the Central Delta through the DCC or Georgiana Slough).

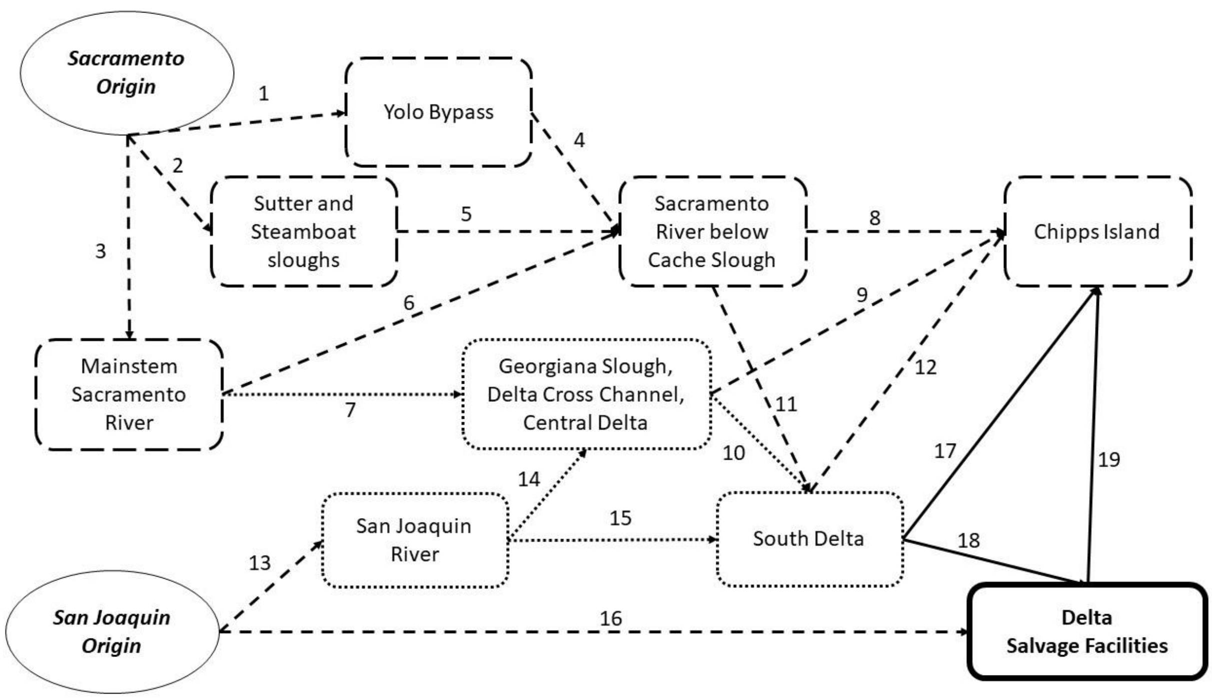


Figure 6-24. Conceptual Model of Delta Regions and Spring-Run Chinook Salmon Routing symbolized by fish fate (higher survival symbolized by heavy dashed lines and boxes, medium to lower survival symbolized by thinner dotted lines and boxes, origin noted by ovals, the Delta Salvage facilities symbolized by a heavy solid line and box).

Studies correlate juvenile Chinook salmon travel time and survival to flow (Conner et al. 2003; Smith et al. 2003; Courter et al. 2016). Romine et al. (2021) modeled routing as a function of tidally varying hydrodynamic data and Perry et al. (2018) showed that as discharge increased, the probability of routing from the mainstem Sacramento River into sloughs like Sutter and Steamboat also increased. Survival is highly variable by reach and WYT as it depends on many environmental variables (discharge, inflow, outflow, OMR, etc.) as estimates for both survival and routing in the published literature demonstrate. In Critical and Dry years and for some routes consistently (Interior Delta, Georgiana Slough), survival is generally lower than in years with higher flow and other routes (mainstem Sacramento, Sutter and Steamboat sloughs). Many studies have estimated survival and routing for hatchery and wild Chinook salmon in the Central Valley during times when released fish would experience a wide range of hydrology. Routing estimates vary widely by migratory route and by hydrologic conditions individual fish experience when they arrive at junctions along their migration. For example, Perry (2010) found migration probabilities matched well with the fraction of total river discharge through individual routes.

The knowledge base paper, solicited literature, datasets, and models were used to analyze entrainment.

Literature for spring-run Chinook salmon entrainment primarily addresses historical datasets and models and does not uniquely inform the proportion of the population affected by the Proposed Action. The covariates most relevant from recent literature included: Fremont Weir overtopping and Yolo Bypass flows, DCC Openings, Georgiana Slough Non-Physical Barrier, and Delta hydrodynamics variously represented by Sacramento River inflow, San Joaquin River inflow, and exports or aggregate parameters such as Export to Inflow ratio, Old and Middle River flows, etc.

Empirical estimates of acoustically tagged fall-run Chinook salmon from CNFH released in late March 2021 experienced routing through Georgiana Slough about 30% (Table 6-18). However, this estimate is only for fish encountering Georgiana through 4/7/2021 due to equipment theft. Studies report proportional flow is a strong predictor of route selection (Kemp et al. 2005, Cavallo et al. 2015, Romine et al. 2021). Additionally, variables like DCC gate status (open / closed) will change routing and survival probabilities for fish traveling along the mainstem Sacramento when they get to both Georgiana Slough and the DCC junctions.

Table 6-18. Survival and entrainment probabilities for hatchery fall-run Chinook released in March 2021: half at Battle Creek at Coleman National Fish Hatchery ("upstream"), half at Butte City ("downstream").

Release Group	Minimum Survival to Tower Bridge % (SE) 95% CI (upper, lower)	Minimum Survival to Benicia Bridge % (SE) 95% CI (upper, lower)	Minimum Through-Delta Survival % (SE) 95% CI (upper, lower)	Routing Probability into Georgiana Slough % (SE) 95% CI (upper, lower)
Downstream	14.0 (1.4) (11.4, 17.0)	4.7 (1.2) (2.8, 7.7)	17.7 (4.3) (10.8, 27.7)	
Upstream	1.7 (0.7) (0.7, 3.9)	0 (NA) (NA, NA) *	0 (NA) (NA, NA) *	
Both groups				26.7 (11.4) (10.4, 53.3) **

Source: CalFish Track Central Valley Enhanced Acoustic Tagging Project, available online: https://oceanview.pfeg.noaa.gov/CalFishTrack/pageREAL.html. Accessed October 9, 2023.
* No fish from upstream group detected at receivers downstream of Sacramento River below Georgiana Slough
** Fish released 3/24/2021 and 3/26/2021, Georgiana Slough routing estimate through 4/7/2021 due to equipment theft

Datasets use historical conditions and observation to inform how spring-run Chinook salmon may respond to the Proposed Action. Historical monitoring may support or refute hypotheses and inform the reasonableness of information generated by models. Additional empirical estimates of tagged spring-run Chinook salmon released throughout the system show varied survival estimates (Table 6-19).

Table 6-19. Acoustic Tagging (AT) survival estimates by project and Water Year (WY) for hatchery and wild spring-run Chinook salmon: 2018 – 2022. Minimum survival, SE, 95% lower and upper confidence intervals (L CI, U CI) to [1] Tower Bridge, [2] Benicia Bridge (East Span), and [3] Through-Delta survival (City of Sacramento to Benicia) estimated using a Cormack-Jolly-Seber (CJS) model. For tagging studies with multiple releases, values are reported for all groups combined. Data available online at CalFish Track (https://oceanview.pfeg.noaa.gov/CalFishTrack/pageREAL.html).

WY	Project	Tower Bridge Survival (%)	SE	95% L CI	95% U CI	Benicia Bridge Survival (%)	SE	95% L CI	95% U CI	Through-Delta Survival (%)	SE	95% L CI	95% U CI
2022	Upper Sacramento spring-run Chinook Salmon surrogates					0.7	0.3	0.2	1.8	12.9	6.0	4.9	29.7
2021	Feather River Hatchery Spring-run Chinook Salmon	28.6	1.9	25.1	32.4	2.2	0.6	1.3	3.8	7.7	2.0	4.5	12.8
2021	Butte Creek wild spring-run Chinook Salmon	NED	NA	NA	NA	NDY	NA	NA	NA	NED	NA	NA	NA
2020	Feather River Hatchery Spring-run Chinook Salmon	26.8	2.0	23.1	30.8	2.6	0.7	1.5	4.4	10.2	2.7	6.0	16.7
2019	Deer Creek wild spring-run Chinook salmon	12.5	0	12.5	12.5	NDY	NA	NA	NA				
2019	Feather River Hatchery Spring-run Chinook Salmon	49.4	2.1	45.4	53.5	26.2	1.8	22.8	29.8	NC	NC	NC	NC
2019	Butte Creek wild spring-run Chinook Salmon	16.3	2.6	11.8	22.0	1.5	0.8	0.5	4.4	NC	NC	NC	NC
2018	Butte Creek wild spring-run Chinook salmon	27.2	2.4	22.8	32.1	ND	ND	ND	ND	ND	ND	ND	ND
2018	Mill and Deer Creek wild spring-run Chinook Salmon	3.8	3.8	0.5	22.8	ND	ND	ND	ND	ND	ND	ND	ND

NED = Not Enough Detections; NDY = No Detections Yet; NA = Not Applicable; ND = No Data; NC = No Calculation

Historic records of salvage and loss of spring-run Chinook salmon (length-at-date [LAD]) at the CVP and SWP Delta fish collection facilities (1993 – 2022) show loss varies annually (Table 6-20). Genetic testing of individuals classified as spring-run Chinook salmon by LAD methods reveals most of these spring-run are fall-run (Table 6-20); however, there were years when a number of fish were not genetically sampled. Therefore, the genetic loss of spring-run Chinook salmon presented in Table 6-20 is likely an underestimate. These loss records represent spring-run Chinook salmon from both CVP and non-CVP tributaries. There is currently not a juvenile production estimate (JPE) developed for spring-run Chinook salmon or annual loss thresholds developed in the Proposed Action to determine the proportion of the population represented by loss at the facilities.

Table 6-20. Annual LAD and genetic spring-run Chinook salmon loss at the CVP and SWP Delta fish collection facilities LAD (1993–2022) including Sacramento Valley Index water year type (WYT). Unclipped Chinook salmon salvaged, total genotyped, and total number of confirmed observations of genetic spring-run linked to the salvage database.

Water Year	Loss (LAD)	Loss (genetic)	WYT	Total unclipped Chinook salvaged	Total unclipped genotyped [1]	Total confirmed genetic SR observations
1993	13,248.25		AN	1,822		
1994	3,776.74		C	1,015		
1995	30,022.68		W	5,243		
1996	36,851.66		W	4,792		
1997	54,848.61		W	6,233		
1998	24,942.95		W	13,336		
1999	105,613.12		AN	17,916		
2000	90,036.08		AN	13,769		
2001	40,668.36		D	6,698		
2002	10,206.37		D	1,552		
2003	40,382.37		BN	3,751		
2004	10,985.10		D	3,220		
2005	27,319.20		W	3,752		
2006	13,002.13		W	3,121		
2007	5,212.27		C	1,104		
2008	11,771.05		C	2,998		
2009	8,840.32		BN	1,817		
2010	6,082.67		AN	2,147		
2011	52,504.40	1,743.38	W	7,325	6,118	174
2012	2,394.43	169.05	D	786	556	37
2013	2,495.97	31.93	C	1,566	643	3
2014	349.01	70.09	C	319	314	26
2015	70.03	7.15	C	26	20	2

Water Year	Loss (LAD)	Loss (genetic)	WYT	Total unclipped Chinook salvaged	Total unclipped genotyped [1]	Total confirmed genetic SR observations
2016	297.81	29.74	D	111	108	5
2017	72,010.92	261.06	W	10,692	9,475	46
2018	18,787.67	200.69	BN	5,729	3,461	18
2019	6,101	20.72	W	3,208	2,799	2
2020	4,167.89	23.63	D	1,151	1,123	3
2021	518.1	4.33	C	195	194	1
2022	552.64		C	243		

[1] Denotes successfully genotyped with acceptable probability scores. Some number of identified fish fail to yield viable DNA, others have probability scores below accepted cutoff values.

Models provide quantitative estimates of future conditions under the Proposed Action. Reclamation evaluated multiple lines of evidence, with different assumptions and complexity, to narrow the likely range of potential effects. A "Volumetric Influence" line of evidence considered the proportion of Sacramento inflow in exports as if fish moved in direct proportion to flow. However, fish can swim and may make routing decisions in response to local physical and hydraulic conditions. Local changes in velocities may influence routing; therefore, the hydraulic footprint or "zone of influence" line of evidence evaluates the change in tidally influenced velocities where export levels may influence fish to make a different routing decision and move towards the export facilities. "Flow into Junctions" represents an influence from the routing of water. "Particle Tracking Models" captures advection and tidal dispersion to simulate the fate of fish as indestructible passive particles. The ECO-PTM model adds survival terms for particles. Finally, the negative binomial and salvage density models estimate loss and salvage at the facilities.

Results from *Volumetric Influence*, *Zone of Influence*, *Flow into Junctions*, *Particle Tracking Models*, and ECO-PTM are available in Chapter 5. Spring-run Chinook salmon species-specific results from the Delta Passage Model, salvage density model, and the negative binomial loss model follow.

The Delta Passage Model (Attachment I.6, *Delta Passage Model*) simulates migration of Chinook salmon smolts entering the Delta from the Sacramento River, Mokelumne River, and San Joaquin River and estimates survival to Chipps Island. For this application, only survival of fish entering the Delta from the Sacramento River are evaluated. The DPM uses available time-series data and values taken from empirical studies or other sources to parameterize model relationships and inform uncertainty, thereby using the greatest amount of data available to dynamically simulate responses of smolt survival to changes in water management.

The major model functions in the DPM are as follows.

1. Delta Entry Timing, which models the temporal distribution of smolts entering the Delta for each race of Chinook salmon.

2. Fish Behavior at Junctions, which models fish movement as they approach river junctions.

3. Migration Speed, which models reach-specific smolt migration speed and travel time.

4. Route-Specific Survival, which models route-specific survival response to non-flow factors.

5. Flow-Dependent Survival, which models reach-specific survival response to flow.

6. Export-Dependent Survival, which models survival response to water export levels in the interior Delta reach

The highest mean predicted survival to Chipps Island for spring-run Chinook salmon occurred under NAA in wet water years, followed by wet water years under Alt2 Without TUCP Systemwide VA. The lowest survival of spring-run Chinook salmon occurred under NAA in critical water years followed by critical water years under Alt2 With TUCP Without VA. (Figure 6-25, Table 6-21).

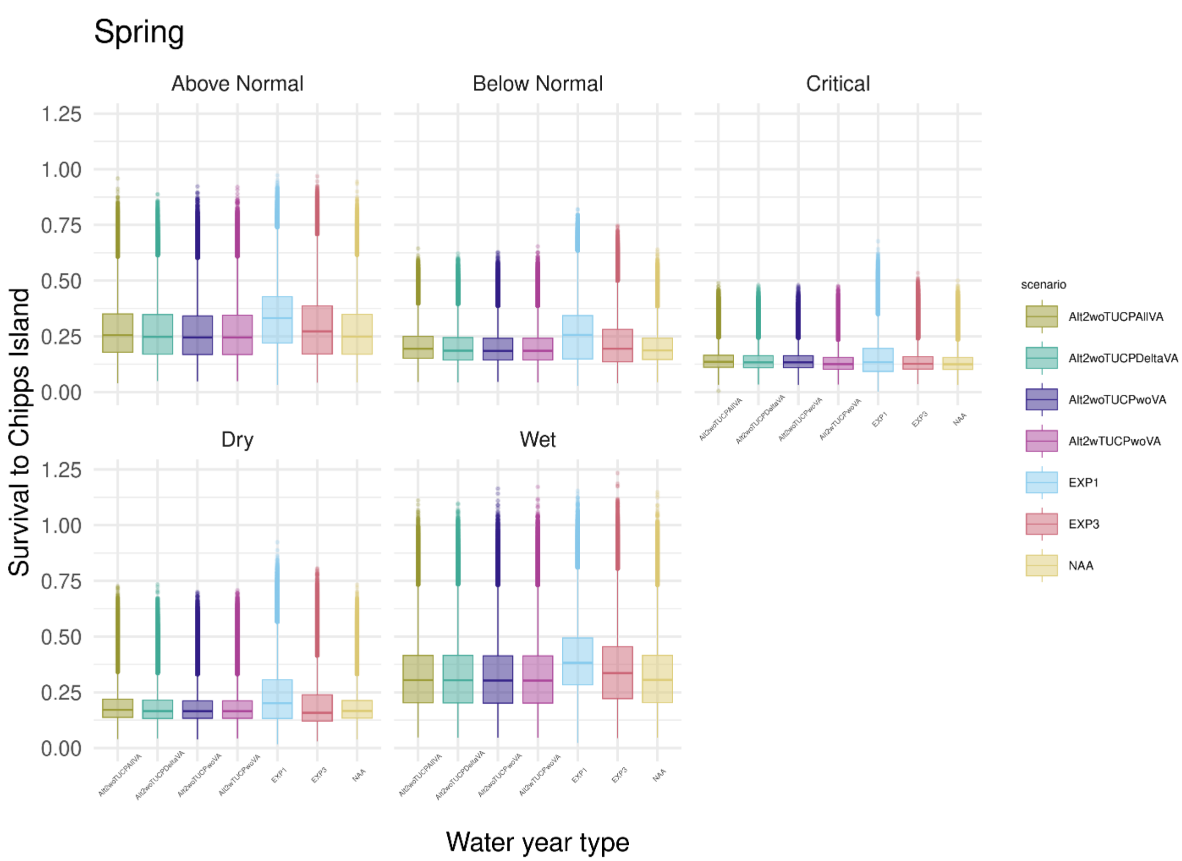


Figure 6-25. Predicted spring-run Chinook salmon survival to Chipps Island averaged by water year type for Alt2 phases, EXP 1, EXP 3, and NAA.

Table 6-21. Mean predicted spring-run Chinook salmon survival to Chipps Island averaged by water year type for Alt2 phases, EXP 1, EXP 3, and NAA.

Water Year Type	Run	EXP1	EXP3	NAA	Alt2wTUCP woVA	Alt2woTUCP woVA	Alt2woTUCP DeltaVA	Alt2woTUCP AllVA
Above Normal	Spring	0.33	0.29	0.27	0.27	0.27	0.27	0.28
Below Normal	Spring	0.26	0.22	0.2	0.2	0.2	0.2	0.21
Critical	Spring	0.15	0.14	0.13	0.13	0.14	0.14	0.14
Dry	Spring	0.23	0.19	0.18	0.18	0.18	0.18	0.19
Wet	Spring	0.39	0.36	0.33	0.33	0.33	0.33	0.33

The Salvage Density Analysis, Appendix I, Attachment I.2, *OMR Salvage-Density Model Loss*, provides context for LAD spring-run Chinook salmon at the export facilities. This analysis weighs south Delta exports at the export facilities by historical salvage per unit volume. Predicted cumulative annual loss of LAD spring-run Chinook salmon at the facilities under the Proposed Action phases range from 656 to 74,155 (Figure 6-26). EXP1 and EXP3 predicted loss is 0. Overall, predicted loss varies among WYT. The lowest predicted cumulative loss occurred in Proposed Action phases for critical WYT. The highest predicted loss occurred in Proposed Action phases for wet WYT. Loss of LAD spring-run Chinook salmon at the facilities in the Proposed Action phases range over an order of magnitude among WYT, which is similar to historically observed salvage in the recent past.

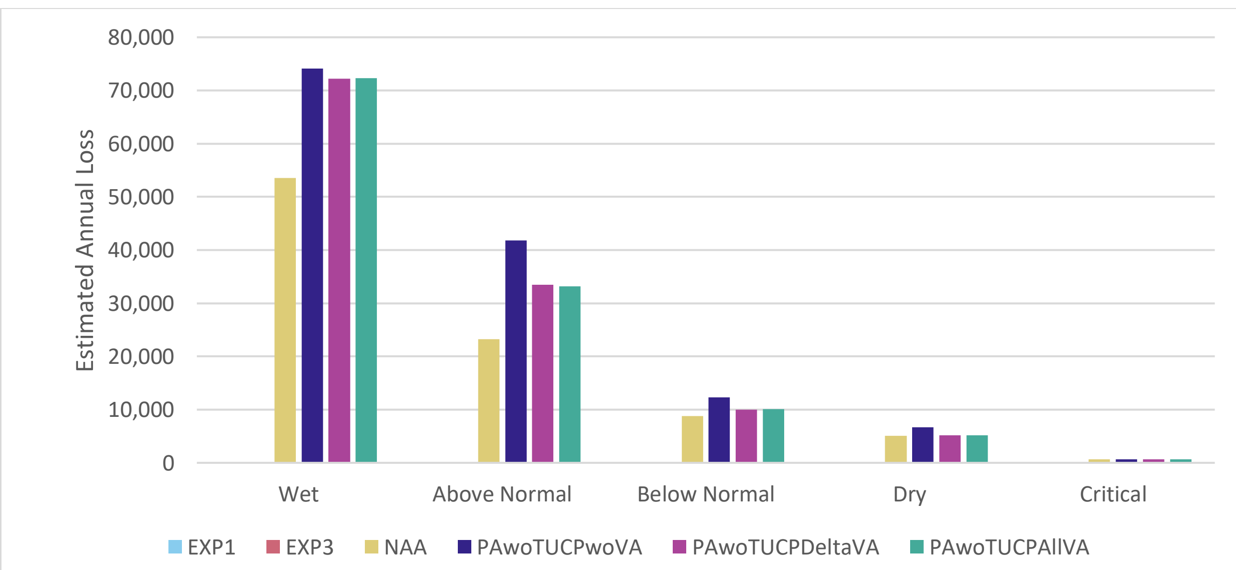


Figure 6-26. Estimated cumulative annual loss of Sacramento River origin LAD spring-run Chinook salmon at the export facilities by WYT based on salvage-density method. Under EXP1 and EXP3 exports are set at 0 resulting in a predicted loss of 0.

Negative Binomial Loss Model (Appendix I, Attachment I.1, *Negative Binomial Salvage Model*) provides context for estimated salvage of LAD spring-run Chinook salmon at the Delta Fish Collection Facilities, combined. The analysis assumes the Proposed Action may change the presence of spring-run Chinook salmon in the South Delta near the facilities when flows are changed. The model uses species-specific regression equations to predict salvage. The top supported model for spring-run Chinook salmon included month, combined exports from CVP and SWP, and San Joaquin River flow through a model selection process.

Predicted cumulative annual salvage of LAD spring-run Chinook salmon at the facilities under the Proposed Action phases range from 35 to 2,188 (Figure 6-27). Overall, predicted cumulative salvage varies among WYT. The highest predicted cumulative salvage occurred in Proposed Action phases for wet WYT. Salvage of LAD spring-run Chinook salmon under the Proposed Action phases range over an order of magnitude among WYT, particularly between wet WYT and the other four WYT, which is similar to historically observed salvage in the recent past. These values are a large overestimation of the effect on young-of-year spring-run Chinook salmon as many of juvenile unmarked fall-run hatchery chinook salmon are salvaged at the facilities each year and overlap in size with spring-run chinook salmon LAD. This large overestimation is further demonstrated by Table 6-20 above that shows a small fraction of LAD spring-run Chinook salmon are actually genetically spring-run Chinook salmon.

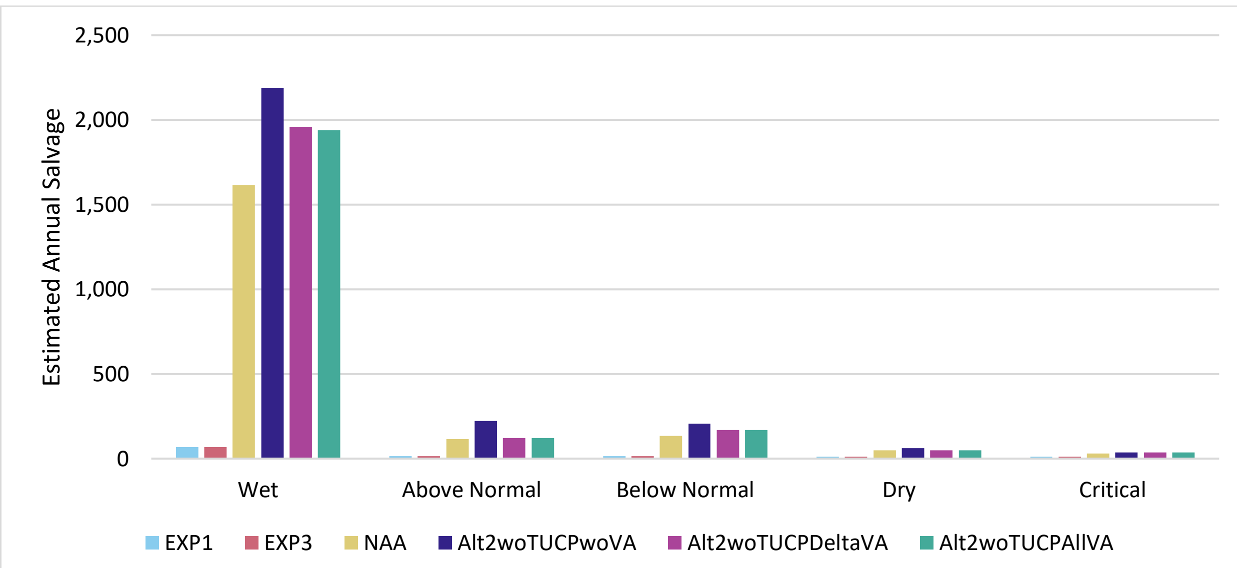


Figure 6-27. Estimated mean annual salvage of Sacramento River origin LAD spring-run Chinook salmon at the export facilities by WYT based on negative binomial salvage method.

The **frequency** of occurrence of the stressor is directly linked to hydrology, dependent on the Proposed Action OMR Management actions (e.g., -5,000 OMR, first flush, weekly or monthly winter-run Chinook salmon loss threshold, etc.). The **frequency** of occurrence is **high** and likely to occur annually as the CVP and SWP will operate to no more negative than -5,000 cfs.

The **weight of evidence** for entrainment risk includes empirical species- and route-specific entrainment estimates from acoustically tagged salmonids (hatchery and wild, multiple runs), decades of quantitative OMR flows, decades of historical salvage and loss data from the Delta fish facilities, and location-specific but not species-specific validated models including particle tracking and zone of influence analyses.

- Literature, Kimmerer and Nobriga 2008: quantitative, not species-specific, location-specific, publication in a peer reviewed journal, uses widely accepted particle tracking model (PTM) established for the Bay-Delta to estimate particle movement with several covariates
- Historic migration timing: quantitative, species-specific, location-specific, available through multiple sources and QA/QCed, long time-series and not expected to have statistical power
- Historic salvage observations: quantitative, species-specific, location-specific, available through multiple sources and QA/QCed, long time-series and not expected to have statistical power
- Historic AT and Coded Wire Tag (CWT) information: quantitative, species-specific, location-specific, data used in many peer-reviewed publications
- ZOI modeling LOE: quantitative, not species-specific (but not expected to be., environmental variable), location-specific, not published, widely accepted method for evaluating spatial extent of varying levels of exports within the Bay-Delta
- PTM modeling LOE: quantitative, not species-specific (but not expected to be, environmental variable), location-specific, used in multiple peer-reviewed publications, PTM is a widely accepted method to estimate particle movement and can be evaluated with covariates
- ECO-PTM modeling LOE: quantitative, species-specific (model developed with tagged Chinook salmon), location-specific, model under development with U.S. Geological Survey (USGS) and DWR presented at conferences / meetings and used by inter-agency working groups (e.g., Georgiana Slough SDM group), individual-based model combining PTM and swimming behavior from tagged salmonids calibrated and validated with field data
- DPM modeling LOE: quantitative, species-specific, location-specific, publication in peer reviewed journal
- Salvage Density modeling LOE: quantitative, species-specific, location-specific, widely accepted and historically used as a salvage/loss estimation tool, single covariate
- Negative Binomial modeling LOE: quantitative, species-specific, location-specific, newly developed unpublished method for estimating loss specific to salmonids, final covariates unique to each species from model selection process

The Proposed Action includes a special study to continue development of a spring-run Chinook salmon Juvenile Production Estimate (SR-JPE) and Lifecycle Model (SR-LCM) to inform management decisions across the Central Valley to improve population status. These efforts will serve as the basis for consideration of updated entrainment minimization measures, including updating hatchery surrogate measures. Newly collected data, from existing and/or new monitoring programs, will be used to develop the SR-JPE and SR-LCM. For additional information, refer to the Main Body Public Draft Alternatives document, Section 6.11.2 “Spring-Run Juvenile Production Estimate and Life-Cycle Model” and Section 6.11.3 “Spring-Run Chinook salmon JPE, OMR Management, and Lifecycle Model.”

Conservation measures in the Proposed Action that minimize or compensate for effects of the operation of the CVP and SWP on this stressor include:

- DCC Gate Closure
- Winter-Run Chinook Salmon Early Season Salvage Threshold
- January 1 and Start of OMR Management
- Spring-run Chinook Salmon and Surrogate Thresholds
- Winter and Spring Delta Outflows
- Salvage Facilities

Conservation measures in the Proposed Action for other species, life stages and/or stressors that may exacerbate this stressor include:

- SHOT Reduction in Sacramento River Fall and Winter Flows
- Reduced Wilkins Slough Minimum Flows
- SHOT Water Transfer Timing Approvals
- Drought Actions

6.2.4.5 Stranding Risk

The proposed storage and release of water may increase the stranding risk stressor. During the juvenile rearing and outmigration period, reducing flows by reducing releases from Shasta Reservoir under the Proposed Action can trap juveniles in habitat disconnected from the main channel. Similarly, the Proposed Action will both release and then store water, first increasing, then decreasing, flows on Clear Creek. Appendix H presents analyses of “Minimum Instream Flows” and “Ramping Rates” conservation measures.

In the Delta, operations are not expected to increase the stranding risk stressor for outmigrating juvenile spring-run Chinook salmon. Juvenile stranding is not commonly observed in the Delta and there are no stranding monitoring programs focused on the Delta. Densities of wild Chinook salmon 1998 – 2000 were highly variable during floodplain drainage events, with no statistically significant difference between densities in isolated earthen ponds and contiguous water sources (Sommer et al. 2005).

The increase in stranding risk stressors from the Proposed Action is expected to be **lethal**. Where habitats are desiccated, fish cannot survive, or they may be in isolated pools or shallow areas off the mainstem increasing their exposure to higher levels of predation.

Although the Proposed Action may increase the stranding risk, stranding of juvenile spring-run Chinook salmon exists in the **environmental baseline** (without the Proposed Action). The physical attributes of the habitat and magnitude of the change in flows drive the stranding stressor (Windell et al. 2017). Historically, fish in California rivers and streams, even before construction of CVP and SWP facilities, have been subject to stranding and dewatering. Flow fluctuations due to hydrology and other factors contributed to the risk of dewatering and stranding. Flow fluctuations from past and current Clear Creek operations have contributed to Chinook salmon stranding in Clear Creek. Generally, natural flows in the Sacramento River increase in the summer months and decrease in the late-fall and winter months. As part of routine Chinook salmon monitoring in the Sacramento River, the California Department of Fish and Wildlife identifies juveniles stranded in isolated pools and relocates them back to the main channel. Reclamation has implemented the Fall and Winter Refill and Redd Maintenance action which coordinates with members of the Upper Sacramento Scheduling Team. While the multi-agency group coordinates fall flow reductions mainly to reduce dewatering of spring-run Chinook salmon redds, members also consider whether proposed flows may strand juveniles. Reclamation, in coordination with the Clear Creek Technical Team has also implemented flow management actions to reduce dewatering of spring-run Chinook salmon redds and stranding of juveniles.

The **proportion** of the population affected by the Proposed Action depends on presence of juveniles and hydrology and is **medium** for Sacramento River and **low** for Clear Creek. There are no contemporary data or reports on stranding in Clear Creek. In the Proposed Action, reduced releases occur for water temperature management, storage rebuilding, rice decomposition smoothing, and redd dewatering avoidance actions.

Literature does not uniquely inform the proportion of the population affected.

Historical monitoring may support or refute hypotheses and inform the reasonableness of information generated by models. Outmigration, measured at Red Bluff Diversion Dam occurred between October and as late as June. On average, 50% passage (BY 2008 – 2021) occurred by March 5th. Rotary screw trap data on spring-run Chinook salmon outmigration from Clear Creek show fish emigrating during late October through late April (Schraml et al. 2018). Peak emigration of spring-run Chinook salmon juveniles occurs in November, with few fish exiting each week through the end of May. After November, when flow reduction starts in the Proposed Action, a portion of the current brood year spring-run Chinook salmon juveniles are potentially at risk of stranding in the Sacramento River. Although spring-run Chinook salmon stranding has not been recorded in annual stranding reports, the fall-run Chinook salmon may serve as a possible surrogate species. An average of 4,492 fall-run Chinook salmon were observed stranded between 2012 and 2021 (17 to 8,165, Table 6-22). In the 2016-2017 stranding report a total of 19,892 juvenile Chinook strandings were reported, but this count lumped all spring/fall/late-fall run Chinook salmon juveniles together.

There is limited information on juvenile stranding on Clear Creek. Generally, the channel morphology does not allow much floodplain inundation, except for large flow events (>3,000 cfs). More than half of the system is contained within a steep canyon with little opportunity for stranding. The other, less than half of the system has wide alluvial valleys where some stranding could be possible. However, with large channel capacity, achieving floodplain inundation is difficult. An uncontrolled spill which occurred in WY 2023 had the potential to strand fish, and a few fry were observed in floodplain pools (Rupert pers. comm). The maximum controlled release from Whiskeytown is 840 cfs. Controlled releases are too low to get water onto floodplains, except in isolated areas. These isolated areas are directly adjacent to gravel augmentation sites, which aim to reduce channel capacity and improve floodplain inundation threshold (i.e., lower flows can access floodplains).

Table 6-22. Fall-run Chinook salmon direct count of stranded juveniles for Sacramento River, as a surrogate for Spring-run Chinook salmon juvenile stranding.

Brood Year	**Direct Count of Stranded Fall-Run Chinook salmon juveniles: Sacramento River**
2012-2013	8,165
2013-2014	6389
2014-2015	2143
2015-2016	6748
2017-2018	7016
2018-2019	5239
2019-2020	221
2020-2021	17

Models provide quantitative estimates of future conditions under the Proposed Action.

Juvenile stranding of salmon occurs when the water level (stage) falls and water recedes from habitats occupied by juveniles in such a way as to isolate the juveniles from river mainstem. The juvenile stranding analysis (Attachment L.5, *Sacramento River Juvenile Stranding Analysis*) was computed using USRDOM daily flow estimates for the model scenarios at three locations in the upper Sacramento River: Keswick Dam, Clear Creek, and Battle Creek. The results show modest and inconsistent variation with water year type in stranding of spring-run fry under the modeled scenarios (Table 6-23). Stranding peaks in wet years under EXP3, the No Action Alternative, and phases of Alternative 2, but the lowest stranding varies from critical water years to below normal years, depending on the scenario. For EXP1, stranding peaks in critical years and is lowest in wet years. The high levels of stranding in wet years are expected for spring-run fry because their rearing occurs from late fall through winter. During wet winters, periodic storms and high runoff increase flow fluctuations, which tends to result in greater juvenile stranding. In drier winters, flow fluctuations are reduced and fewer fry are stranded.

Table 6-23. Potential Juvenile Stranding (Number of Individuals) for Spring-run Chinook Fry Rearing in the Sacramento River from Keswick Dam to the Battle Creek Confluence for EXP1, EXP3, the NAA, and Four Phases of Alternative 2

WYT	EXP1	EXP3	NAA	Alt2wTUCP wo VA	Alt2woTUC PwoVA	Alt2woTUC PDeltaVA	Alt2woTUC PAllVA
W	2,939	11,335	9,639	9,302	9,354	9,266	9,143
AN	3,815	9,226	8,837	8,688	8,632	8,615	8,036
BN	4,166	6,542	7,231	7,244	7,250	7,466	6,482
D	5,061	6,726	7,422	7,028	7,087	7,674	7,428
C	7,994	5,787	7,384	8,131	6,703	7,121	7,655
All	4,604	8,199	8,213	8,114	7,916	8,132	7,864

The results for spring-run juvenile stranding grouped by months are represented in Figure 6-28. Peak stranding occurs in November and February under the modeled scenarios. The highest median value for stranding is under EXP3 in November, and the lowest median value for stranding is in January under EXP1.

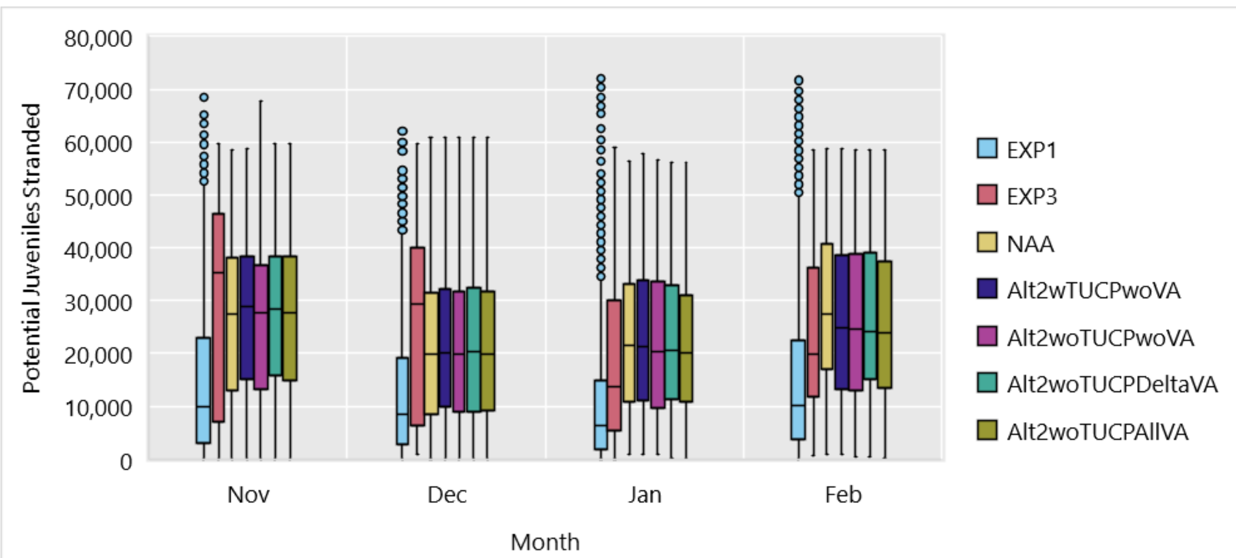


Figure 6-28. Potential Juvenile Stranding for Spring-run Chinook Salmon in the Sacramento River from Keswick Dam to the Battle Creek Confluence for EXP1, EXP3, the NAA, and four phases of Alternative 2, by Month

The **frequency** of occurrence is **high**, since it is likely to occur annually in the Proposed Action. Use of Minimum Flows defines a floor, or flow threshold below which habitat can become disconnected allowing an area to remain viable for spring-run Chinook salmon juveniles. Additionally, ramping rates provide cues through changes in flows, generating time needed by some juvenile salmon to exit areas that may become disconnected. The frequency within a year depends upon hydrologic conditions which may result in multiple increases and decreases in releases from Shasta Reservoir during the outmigration and rearing period.

To evaluate the **weight of evidence** for stranding stressors, there is a historical record of spring-run Chinook juvenile stranding monitoring and releases specific to the Sacramento River; however, it is inconsistent and sometimes not run-specific. In these analyses, fall-run Chinook salmon were used as a surrogate to assess effects on spring-run Chinook salmon.

- Historic stranding observations: quantitative, species-specific, location-specific, available through multiple sources and QA/QCed, long time-series and not expected to have statistical power
- Historic proportion of population in stranding area: quantitative, species-specific, location-specific or not location-specific, available through multiple sources and QA/QCed, long time series and not expected to have statistical power
- Historic flows and disconnected sites: quantitative, not species-specific (but not expected to be, environmental variable), location-specific, available through multiple sources and QA/QCed, long time-series and not expected to have statistical power
- USRDOM daily flow modeling LOE: quantitative, not species-specific (but not expected to be), environmental variable, location-specific, model developed to evaluate flows using multiple inputs, widely accepted as daily flow modeling system for use in the Central Valley upper watershed.

Conservation measures in the Proposed Action that minimize or compensate for effects of the operation of the CVP and SWP on this stressor include:

- Sacramento River
  - Minimum Instream Flows
  - Ramping Rates
- Clear Creek
  - Minimum Instream Flows
  - Ramping Rates

6.2.5 Yearling Rearing

While the majority of juvenile spring-run Chinook salmon outmigrate as fry, a portion of the spring-run Chinook salmon population rears in Clear Creek through the spring and summer and emigrates as sub-yearlings.

Stressors that influence yearling rearing spring-run Chinook salmon include *Toxicity and Contaminants; Predation and Competition; Refuge Habitat; Food Availability and Quality; Outmigration Cues; Stranding Risk; Water Temperature and Dissolved Oxygen; Pathogens and Disease; and Entrainment Risk.*

Yearlings rearing in Clear Creek will not experience the full suite of stressors identified in the SAIL model. Stressors that are not applicable to rearing yearlings include *entrainment risk* and *outmigration risk* because rearing yearlings do not outmigrate during the rearing stage and will not be exposed to entrainment risk as there is no entrainment risk in Clear Creek. The remaining stressors would continue to influence spring-run Chinook salmon that migrate as sub-yearlings even if the Proposed Action is not implemented.

Stressors that may change at a level that is insignificant or discountable include:

- The Proposed Action may decrease the *pathogens and disease* stressor. During the yearling rearing period, the Proposed Action will store water decreasing flows in the spring and release water increasing flows in the summer on Clear Creek below Whiskeytown Dam. A release of water from Shasta Reservoir may result in cooler water temperatures while storage of water may decrease flows resulting in increased water temperatures. Juvenile survival is influenced by specific diseases (e.g., *Ceratomyxa shasta*, furunculosis) present in the Sacramento River (reviewed in Lehman et al. 2020). Diseases affecting Chinook salmon become highly virulent at temperatures above 59.9°F (McCullough 1999).
- The Proposed Action may increase or decrease the *toxicity from contaminants* stressor. During the yearling rearing period, on Clear Creek the Proposed Action will store water decreasing flows in the spring and release water increasing flows in the summer on Clear Creek below Whiskeytown Dam. Exposure to contaminants can result in sub-lethal effects such as reduced growth or suppression of juvenile immune systems possibly leading to infection and disease (Arkoosh et al. 2001; Kroglund and Finstad 2003; Lundin et al. 2021).

  From historic monitoring efforts, there is no evidence of the effects of contaminants on yearlings in Clear Creek.
- The Proposed Action may increase the *predation and competition* stressor. During the yearling rearing period, the Proposed Action will store water decreasing flows in the spring and release water increasing flows in the summer on Clear Creek below Whiskeytown Dam.

  Predator presence in Clear Creek is ubiquitous. While there are no introduced non-native piscivorous species such as striped and largemouth bass in Clear Creek, there is a population of native predators such as pikeminnow.

  Predation rates are a function of correlated variables such as predator presence, prey vulnerability, and environmental conditions (Grossman et al. 2013; Grossman 2016) that are influenced by operations. Predation and competition are not independent from other stressors, such as refuge habitat and food availability and quality. Predation effects associated with the Proposed Action are captured in the analysis of these stressors. Any residual effects of predation and competition associated with the Proposed Action are considered insignificant.

Described below are stressors exacerbated by the Proposed Action, potentially resulting in incidental take. Also described below are conservation measures included as part of the Proposed

Action to avoid or compensate for adverse effects. Finally, the Proposed Action may also ameliorate certain stressors in the environmental baseline, and below a description of these beneficial effects is included.

6.2.5.1 Refuge Habitat

The proposed storage and release of water may increase or decrease the refuge habitat stressor. During the yearling rearing period, the Proposed Action will store water decreasing flows in the spring and release water increasing flows in the summer on Clear Creek below Whiskeytown Dam. A decrease of flows may reduce suitable margin and off-channel habitats available as refuge habitat for yearlings. The stressor may increase in the spring and decrease in the summer months. Appendix O presents analysis of this stressor.

The increase in refuge habitat stressor is expected to be **sub-lethal**. A decrease in sufficient refuge habitat can result in yearlings lacking cover to avoid predation. The decrease in the refuge habitat stressor is expected to be **beneficial**. Refuge habitat is not independent of food availability and quantity, another sub-lethal stressor discussed below.

Although the Proposed Action may, at times, increase the refuge habitat stressor, changes in refuge habitat of juvenile spring-run Chinook salmon exists in the **environmental baseline** (without the Proposed Action). Turbidity, shallow water habitat, and food production and retention drive this stressor (Windell et al. 2017). Generally, dams impair the recruitment of large woody material to the river channel and floodplain below the dam. Non-discretionary flood control operations limit high flows that historically drive geomorphic processes and overbank flows. Stable year-round flows have resulted in diminished natural channel formation, altered foodweb processes, and slowed regeneration of riparian vegetation.

Since 2009, Reclamation has operated Whiskeytown Dam to provide channel maintenance flows. In 2009, NMFS issued an RPA requiring Reclamation to re-operate Whiskeytown Glory Hole spills during the winter and spring to produce channel maintenance flows. In 2019, Reclamation committed to release 10 thousand acre-feet of water from Whiskeytown Dam for channel maintenance in all year-types except for Dry and Critical year-types. Efforts have also been made to restore parts of lower Clear Creek. For example, the Lower Clear Creek Floodway Restoration Project restored the natural form and function of a 1.8-mile channel and floodplain along lower Clear Creek to benefit salmon and steelhead.

The **proportion** of the population affected by decreased refuge habitat depends on bathymetry and hydrology and is **small** in Clear Creek.

The literature demonstrates that in most cases, limiting life stage analyses indicated that juvenile habitat is limiting (Gard 2005). Access to off-channel habitats has been linked to higher growth rates and survival (Limm and Marchetti 2009; Zeug et al. 2020). Habitat restoration programs are aimed towards providing benefits to native salmonids (quality habitat, increased food availability, refuge) but these efforts also provide benefits to non-native and native predators possibly increasing predation rates. Reduced releases decrease potential refuge habitat for yearling spring-run Chinook salmon removing access to side-channels, access to refuge, and changing geomorphic processes. There are no flow-habitat relationships developed for Clear Creek, leading to uncertainty on how WUA changes with varying flows for different stretches along Clear Creek. However, the proportion of the population of spring-run Chinook salmon rearing as yearlings in Clear Creek is likely small.

Models provide quantitative estimates of future conditions under the Proposed Action.

Attachment O.3, *Sacramento River Weighted Usable Area Analysis* provides context for the WUA available for spring-run Chinook salmon rearing downstream of Keswick releases. Fall-run Chinook salmon rearing WUA habitat values are used as proxies for Sacramento River spring-run Chinook salmon rearing WUA. The fall-run Chinook salmon WUA habitat values for juvenile (Yearling) rearing peak at the minimum flow (3,250 cfs). The expected WUA habitat value for juvenile (Yearling) rearing under the Proposed Action phases ranges from 701,435 in wet water years to 899,145 in critical years (Figure 6-29). Overall, these WUA habitat values are lowest in wet water years and successively increase in the drier WYT. This pattern of variation is attributable to the low flows at which spring-run Chinook salmon rearing WUA habitat values peak in the Sacramento River.

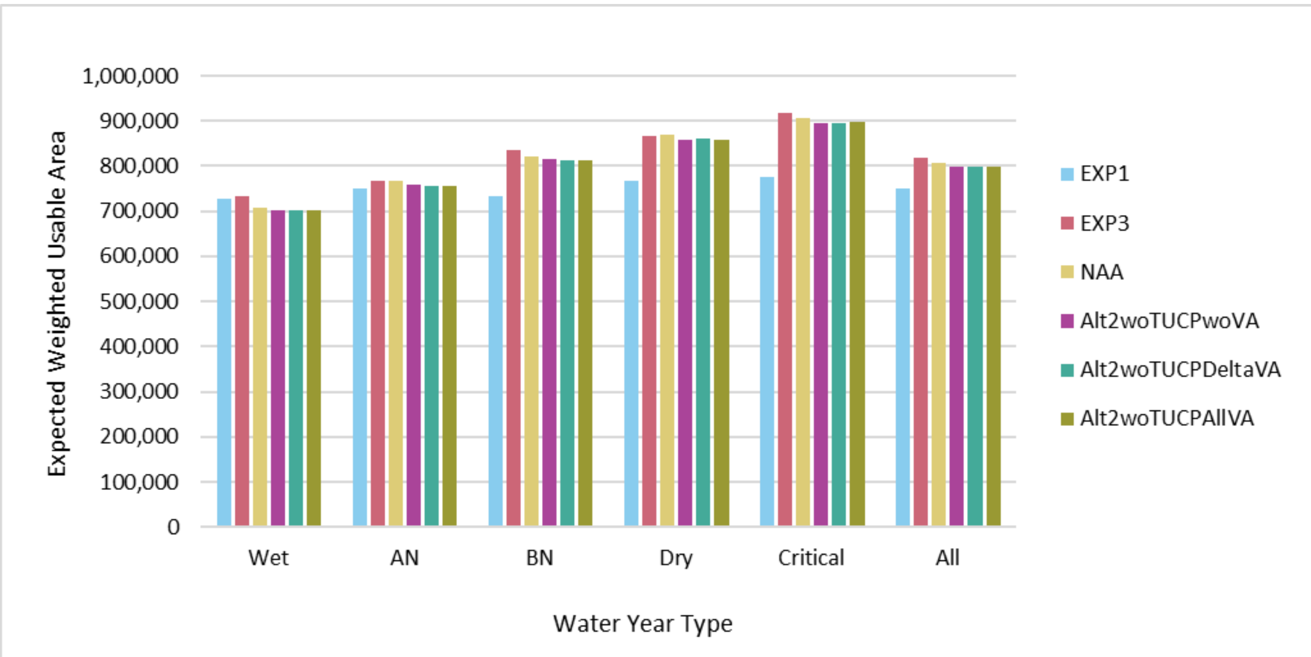


Figure 6-29. Expected Weighted Usable Area for Segments 4-6 by Water Year Type, Spring-run Chinook Salmon Juvenile (Yearling) Rearing in the Sacramento River

Attachment O.1, *Clear Creek Weighted Usable Area Analysis* provides context for the WUA available for spring-run Chinook salmon rearing downstream of Whiskeytown releases. Juvenile (Yearling) rearing WUA for spring-run Chinook salmon peaks at approximately 700 - 900 cfs. The expected WUA habitat value for juvenile (Yearling) rearing under the Proposed Action phases range from 68,673 in critical water years to 78,986 in wet years (Figure 6-30). Overall, these WUA habitat values do not vary much among Proposed Action phases and WYT. This suggests the summer flow ranges in the Proposed Action provide stable rearing habitats.

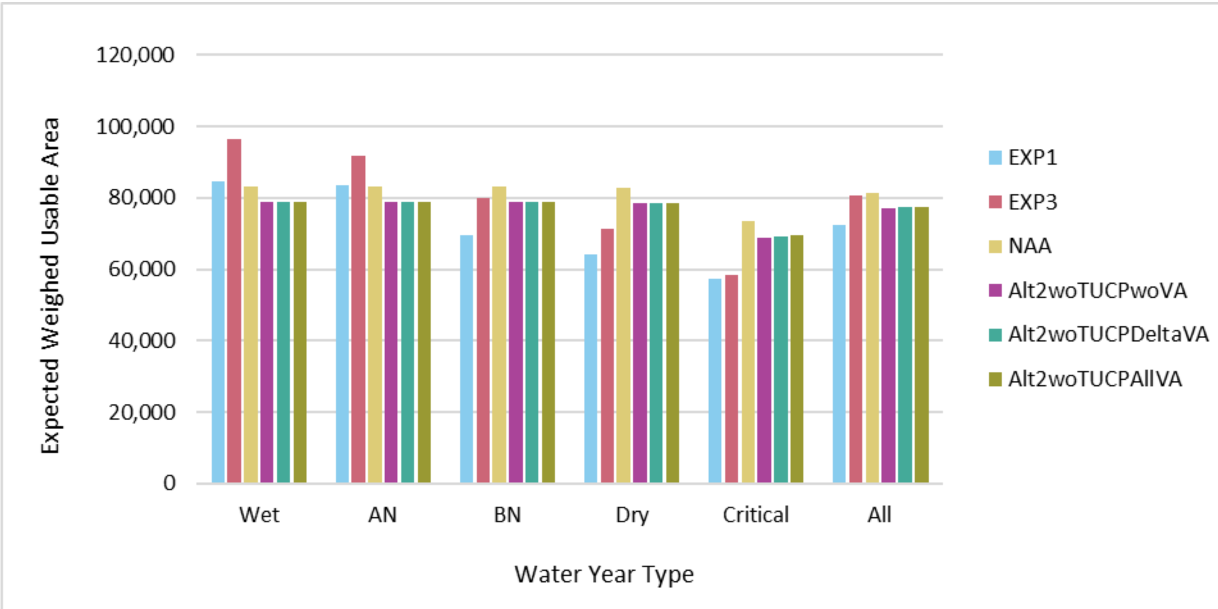


Figure 6-30. Expected Weighted Usable Area for the Lower Alluvial, Upper Alluvial, and Canyon Segments by Water Year Type, Spring-run Chinook Salmon Juvenile (Yearling) Rearing in Clear Creek

The **frequency** of occurrence is annual and depends primarily on hydrology and is **medium**. Between the spring and summer months, flows generally increase.

Weight of evidence: Species-specific information is not available. There are no limiting life stage analysis relationships developed for Clear Creek leading to uncertainty on how abundance by life stage changes with varying flows for stretches along Clear Creek.

- Historic flows: quantitative, not species-specific (not expected to be, environmental variable), location-specific, available through multiple sources and QA/QCed, long time-series and not expected to have statistical power.
- Sacramento WUA analysis is quantitative and species-specific but not location-specific to the Sacramento River (see Assumption 3 in Attachment O.3). WUA analyses are widely used and recognized analytical tools for assessing effects of flow on fish populations (Reiser and Hilgert 2018).
- Clear Creek WUA analysis is quantitative, species-specific, and location-specific to Clear Creek. RIVER2D was the principal hydraulic habitat model used in the USFWS analyses (2007, 2011a, 2011b, 2013) to develop the Clear Creek WUA curves used in this analysis.

Conservation measures in the Proposed Action that minimize or compensate for effects of the operation of the CVP and SWP on this stressor include:

- Sacramento River
    - Minimum Instream Flows
- Clear Creek
    - Minimum Instream Flows

Conservation measures in the Proposed Action for other species, life stages and/or stressors that may exacerbate this stressor include:

- Fall and Winter Base Flows for Shasta Reservoir Refill
- SRSC Diversion Spring Delays and Shifting
- Allocation Reductions for Shasta Reservoir End of September Storage
- Rebalancing between other CVP Reservoirs for Shasta Reservoir End of September Storage
- Reduced Wilkins Slough Minimum Flows for Shasta Reservoir End of September Storage
- Minimum Refuge Summer Deliveries North of Delta

6.2.5.2 Food Availability and Quality

The proposed storage and release of water may increase or decrease the food availability and quality stressor. During the yearling rearing period, the Proposed Action will store water decreasing flows in the spring and release water increasing flows in the summer on Clear Creek below Whiskeytown Dam. These changes may modify food web processes and cause a decrease in quality food available to yearling spring-run Chinook salmon. The stressor may increase in the spring and may decrease in the summer months. Appendix O presents analyses of fish response to habitat restoration.

The increase in food availability and quality is expected to be **sub-lethal**. A decrease in quality and quantity of food for rearing yearling spring-run Chinook salmon will impact growth rates. Food availability and quantity is not independent of refuge habitat, another sub-lethal stressor discussed above. The decrease in food availability and quality stressor is expected to be **beneficial**.

Although the Proposed Action may increase the food availability and quality stressor, changes in food availability and quality for juvenile spring-run Chinook salmon exists in the **environmental baseline** (without the Proposed Action). The level of production and retention drives food availability and quality (Windell et al. 2017). Generally, the presence and operation of dams contribute to channelization, which contributes to a loss of riparian habitat and instream cover. A significant portion of the juvenile Chinook salmon diet is composed of aquatic and terrestrial insects, which are dependent on healthy riparian habitat (National Marine Fisheries Service 2014).

Reclamation has operated Whiskeytown to provide channel maintenance flows since 2009. Efforts have also been made to restore parts of Lower Clear Creek. The Lower Clear Creek Floodway Restoration Project restored the natural form and function of a 1.8 mile channel and floodplain along Lower Clear Creek to benefit salmon and steelhead.

The **proportion** of the population affected by decreased food availability and quality depends on bathymetry and hydrology and is **small** on Clear Creek.

The literature demonstrates that in most cases, limiting life stage analyses indicated that juvenile habitat is limiting (Gard 2005). Access to off-channel habitats has been linked to higher growth rates and survival (Limm and Marchetti 2009; Zeug et al. 2020). Habitat restoration programs are aimed towards providing benefits to native salmonids (quality habitat, increased food availability, refuge) but these efforts also provide benefits to non-native and native predators possibly increasing predation rates. Reduction or loss of seasonally inundated habitats alters food web processes and riparian vegetation, decreasing food availability and quality, and impacting the successful growth and survival of juveniles (Jeffres et al. 2008; Steel et al. 2017; Goertler et al. 2018; Jeffres et al. 2020; Bellido-Leiva et al. 2021). Reduced releases decrease potential refuge habitat for yearling spring-run Chinook salmon removing access to side-channels, access to refuge, and changing geomorphic processes. There are no flow-habitat relationship metrics for juvenile salmonid food supply developed for Clear Creek, leading to uncertainty. However, the proportion of the population of spring-run Chinook salmon rearing as yearlings in Clear Creek is likely small.

Datasets and models do not uniquely inform the proportion of the population affected.

The **frequency** of occurrence is annual and depends primarily on hydrology and is **medium**. Between the spring and summer months, flows generally increase, but the steep canyon rarely connects to off-channel habitats that would provide food items.

Weight of evidence: There is little to evaluate the food availability stressor. There are no developed flow-habitat relationship metrics for juvenile salmonid food supply developed for Clear Creek.

- Gard (2006) WUA flow-habitat relationships modeling LOE: quantitative, not species-specific (models developed for fall-run Chinook salmon), *not* location-specific, published in technical reports

Conservation measures in the Proposed Action that minimize or compensate for effects of the operation of the CVP and SWP on this stressor include:

- Sacramento River
    - Minimum Instream Flows
- Clear Creek
    - Minimum Instream Flows

Conservation measures in the Proposed Action for other species, life stages and/or stressors that may exacerbate this stressor include:

- Fall and Winter Base Flows for Shasta Reservoir Refill
- SRSC Diversion Spring Delays and Shifting
- Allocation Reductions for Shasta Reservoir End of September Storage
- Rebalancing between other CVP Reservoirs for Shasta Reservoir End of September Storage
- Reduced Wilkins Slough Minimum Flows for Shasta Reservoir End of September Storage
- Minimum Refuge Summer Deliveries North of Delta

6.2.5.3 Stranding Risk

The proposed storage and release of water may decrease the stranding risk stressor. During the yearling rearing period, the Proposed Action will store water decreasing flows in the spring and release water increasing flows in the summer on Clear Creek below Whiskeytown Dam. Reducing releases and the storage of water reduces flows where yearlings can become stranded in habitat disconnected from the main channel. Appendix O presents analysis of this stressor. Appendix H presents analysis of this stressor through the "**Minimum Instream Flows**" and "**Ramping Rates**" conservation measures.

The decrease in the stranding risk stressor is expected to be **beneficial**. While proposed operations will both decrease and increase flows during the times of year yearlings are present in Clear Creek, flows are expected to be stable, resulting in yearlings not becoming stranded.

The Proposed Action may reduce the stranding risk of yearling spring-run Chinook salmon that exists in the **environmental baseline** (without the Proposed Action). The physical attributes of the habitat and magnitude of the change in flows drive the stranding stressor (Windell et al. 2017). Historically, fish in California rivers and streams, even before construction of CVP and SWP facilities, have been subject to stranding and dewatering. Flow fluctuations due to hydrology and other factors contributed to the risk of dewatering and stranding. Flow fluctuations from past and current Clear Creek operations have contributed to Chinook salmon stranding in Clear Creek. Over the past 20 years, Reclamation has implemented the Lower Clear Creek Floodway Restoration Project to fill in remnant gravel mining pits in lower Clear Creek which addressed juvenile stranding in isolated pools. Reclamation, in coordination with the Clear Creek Technical Team has also implemented flow management actions to reduce dewatering of spring-run Chinook salmon redds and stranding of juveniles.

The **proportion** of the population affected by the Proposed Action depends on the presence of yearlings and hydrology and is **low** for Clear Creek. The proportion of the population of spring-run Chinook salmon rearing as yearlings in Clear Creek is likely small and there are no contemporary data or reports on stranding in Clear Creek. Generally, the channel morphology does not allow much floodplain inundation, except for large flow events (>3,000 cfs). More than half of the system is contained within a steep canyon with little opportunity for stranding. The other, less than half of the system has wide alluvial valleys where some stranding could be possible. However, with large channel capacity, achieving floodplain inundation is difficult.

Literature, datasets, or models do not uniquely inform the proportion of the population affected.

The **frequency** of occurrence is **low**. The frequency within a year depends on hydrologic conditions which may result in fluctuations in releases during the rearing period. An uncontrolled spill which occurred in WY 2023 had the potential to strand fish, and a few fry were observed in floodplain pools (Rupert pers comm.). The maximum controlled release from WT is 840 cfs. Controlled releases are too low to get water onto floodplains, except in isolated areas. These isolated areas are directly adjacent to gravel augmentation sites, where Reclamation aims to reduce channel capacity and improve floodplain inundation threshold (that is lower flows can access floodplains).

Weight of evidence: There is quantitative flow information for Clear Creek, but no formal monitoring of juvenile stranding.

- Historic stranding observations, Clear Creek: quantitative, species-specific (but no formal monitoring), location-specific (but no formal monitoring), available through sources and QA/QCed, and not expected to have statistical power
- Historic proportion of population in stranding area, Clear Creek: quantitative, species-specific (but no formal monitoring), location-specific (but no formal monitoring), available through sources and QA/QCed, and not expected to have statistical power
- Historic flows and disconnected sites, Clear Creek: quantitative, not species-specific (but not expected to be, environmental variable), location-specific, available through multiple sources and QA/QCed, long time-series and not expected to have statistical power
- USRDOM daily flow modeling LOE: quantitative, not species-specific (but not expected to be), environmental variable, location-specific, model developed to evaluate flows using multiple inputs, widely accepted as daily flow modeling system for use in the Central Valley upper watershed

Conservation measures in the Proposed Action that minimize or compensate for effects of the operation of the CVP and SWP on this stressor include:

- Sacramento River
    - Minimum Instream Flows
    - Ramping Rates
- Clear Creek
    - Minimum Instream Flows
    - Ramping Rates

6.2.5.4 Water Temperature and Dissolved Oxygen

The proposed release and blending of water may decrease water temperature and DO stressor. During the yearling rearing period, the Proposed Action will store water decreasing flows in the spring and release water increasing flows in the summer on Clear Creek below Whiskeytown Dam. Spring-run chinook salmon require cool water temperature for optimal growth. Additionally, cooler water temperatures may reduce overall harm to yearlings spending time in Clear Creek before outmigrating through the Sacramento River and the Delta. Appendix L addresses temperature related effects.

The release of water may result in cooler water temperatures and higher flows that provide a higher DO level. However, monitoring has not shown this stressor as a factor affecting the juvenile lifestage. Upper Clear Creek is steep and there is often white water. In the spring and summer, DO is likely at saturation due to the facilitation of gas exchange in white water conditions.

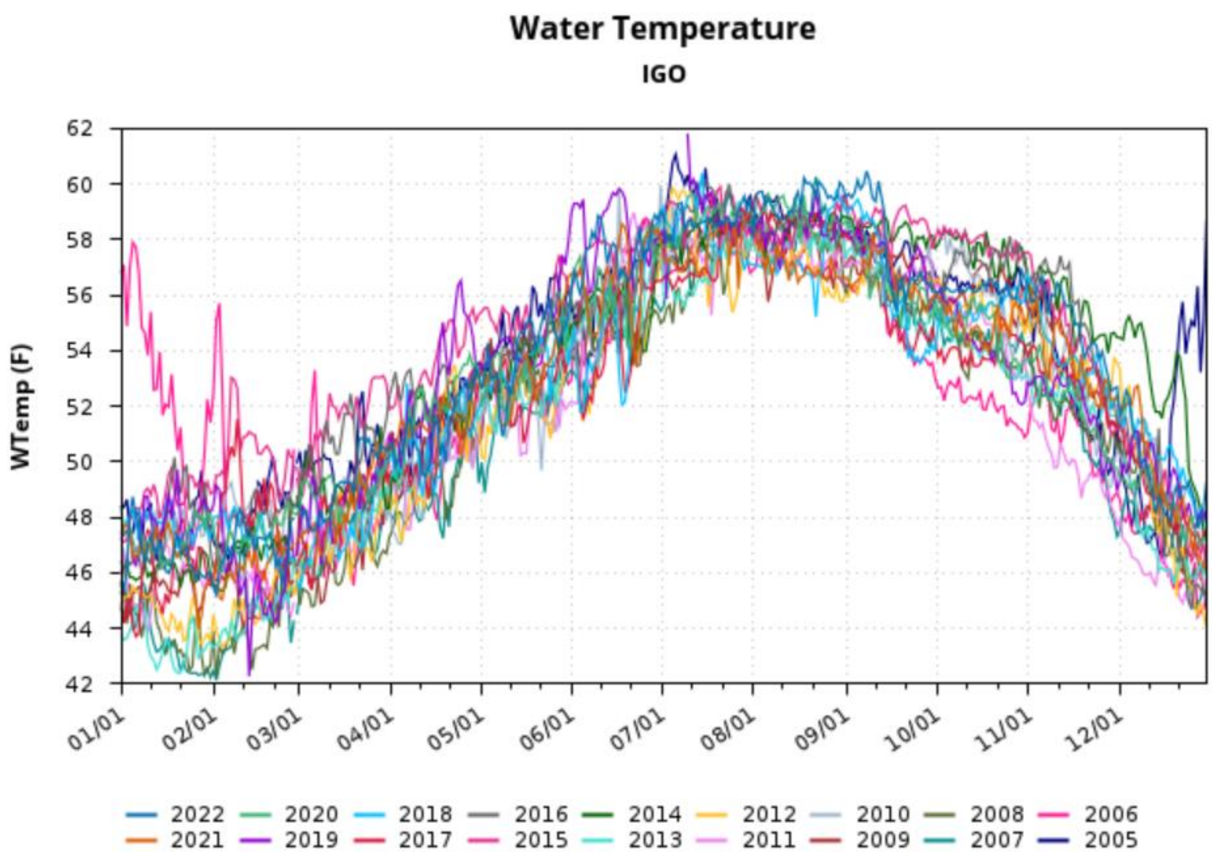
The decrease in the temperature stressor is expected to be **beneficial**. Cooler water temperatures may reduce overall harm to yearlings spending time in Clear Creek.

The Proposed Action may decrease the water temperature stressor experienced by yearling spring-run Chinook salmon in the **environmental baseline** (without the Proposed Action). The amount of precipitation, local ambient air temperatures, and Whiskeytown releases drive the water temperature stressor (Windell et al. 2017). It is expected that climate change will result in warmer air temperature and shift in forms of precipitation, with more precipitation falling as rain, which will exacerbate water temperatures in the reservoirs. In Clear Creek, flow would remain low, particularly in the summer, and water temperatures would increase. Reclamation operates Whiskeytown Dam to reduce the water temperature stressor during the yearling rearing period by managing flow and releasing water from two different elevations using the guard gates on the dam. Reclamation also operates Whiskeytown Dam to meet temperature standards at the Igo gage.

The **proportion** of the population affected by the Proposed Action is likely **low**. Water temperature stressor depends on hydrology, meteorology, and storage in Whiskeytown Reservoir. A documented acceptable range of temperatures for growth of Chinook salmonids, from a synthesis of evidence, is 40.1°F–- 66.4°F, with optimum growth occurring between 50°F – 60°F (McCullough 1999). The proportion of the population of spring-run Chinook salmon rearing as yearlings in Clear Creek is likely small and there are no contemporary data or reports for Clear Creek.

Literature does not uniquely inform the proportion of the population affected.

Datasets use historical conditions and observation to inform how spring-run Chinook salmon may respond to the Proposed Action. Historical monitoring may support or refute hypotheses and inform the reasonableness of information generated by models. The figure below shows historic water temperatures on Clear Creek (2005 – 2022) that yearling spring-run rearing in Clear Creek in the spring and summer months would have experienced (Figure 6-31). Water temperatures varied annually but in 100% of the historic record (18 of 18 years) water temperatures fell within the acceptable temperature range for growth. In May, June, and August 100% of the historic record (18 of 18 years) water temperatures fell within the optimum growth range. In March and April, historic water temperatures in most years were cooler than the low end for optimum growth (50°F). In July, historic water temperatures in two of 18 years (11%) were warmer than the high end for optimum growth (60°F, 2005 and 2019).



Source: SacPAS, CDEC.

Figure 6-31. Historic water temperatures on Clear Creek at Igo, 2005 – 2022. Water temperatures are symbolized by year.

Models provide quantitative estimates of future conditions under the Proposed Action.

HEC-5Q modeling analysis enumerates the frequency at which mean monthly simulated water temperatures exceed water temperature criteria obtained from scientific literature. Modeled water temperatures (Hec-5Q) during yearling spring-run Chinook salmon rearing are as follows:

Results for the 55.4 °F to 68 °F range are presented in Table 6-24 for Clear Creek below Whiskeytown, Table 6-25 for the Sacramento River at Keswick, and Table 6-26 for the Sacramento River at the Red Bluff Diversion Dam. At Clear Creek, the percentage of months outside the range, ranged from 100.0% in Dry to 96.5% in Critical WYT. In Below Normal, and Dry WYT, the percentage of months outside of the optimal temperature range was 100% for all phases of the Proposed Action. Overall, under the Proposed Action phases, the percentage of months outside of the optimal range was similar for all WYT, during the period of April through December.

Table 6-24. Percent of months outside the optimal 55.4 °F to 68 °F water temperature range for successful yearling rearing of spring-run Chinook salmon by water year type and for all years combined, Clear Creek below Whiskeytown, April through December.

WYT	EXP1	EXP3	NAA	Alt2woTUCPwoVA	Alt2woTUCPDeltaVA	Alt2woTUCPAllVA
W	44.0	100.0	98.4	99.6	98.4	98.4
AN	38.7	100.0	100.0	99.2	99.2	99.2
BN	54.9	98.1	100.0	100.0	100.0	100.0
D	58.3	94.9	100.0	100.0	100.0	100.0
C	65.2	94.3	97.2	96.5	96.5	96.5
All	52.1	97.5	99.1	99.2	98.9	98.9

At the Sacramento River at Keswick, the percentage of months outside the optimal temperature range of 55.4 °F to 68 °F under the Proposed Action phases ranged from 100.0% during Wet water years to 72.3% for Critical WYT. Overall, the percentage of months outside the optimal temperature range increased from drier to wetter WYT during the period of April through December.

Table 6-25. Percent of months outside the optimal 55.4 °F to 68 °F water temperature range for successful yearling rearing of spring-run Chinook salmon by water year type and for all years combined, Sacramento River at Keswick, April through December.

WYT	EXP1	EXP3	NAA	Alt2woTUCPwoVA	Alt2woTUCPDeltaVA	Alt2woTUCPAllVA
W	43.7	98.8	100.0	100.0	100.0	100.0
AN	41.2	99.2	99.2	99.2	98.3	100.0
BN	40.1	97.5	96.9	96.9	96.9	96.9
D	37.5	97.2	94.0	96.8	97.7	97.2
C	40.4	80.1	72.3	73.0	72.3	73.8
All	40.7	95.3	93.5	94.3	94.3	94.6

At the Sacramento River at the Red Bluff Diversion Dam, the percentage of months outside the optimal temperature range of 55.4 °F to 68 °F under the three phases of the Proposed Action ranged from 34.1% during Wet water years to 19.9% for Critical WYT. Overall, the percentage of months outside the optimal temperature range increased from drier to wetter WYT during the period of April through December.

Table 6-26. Percent of months outside the optimal 55.4 °F to 68 °F water temperature range for successful yearling rearing of spring-run Chinook salmon by water year type and for all years combined, Sacramento River at the Red Bluff Diversion Dam, April through December.

WYT	EXP1	EXP3	NAA	Alt2woTUCPwoVA	Alt2woTUCPDeltaVA	Alt2woTUCPAllVA
W	60.7	25.8	33.3	34.1	34.1	34.1
AN	65.5	24.4	27.7	28.6	28.6	28.6
BN	65.4	22.8	25.9	24.7	25.3	25.9
D	66.7	22.2	23.6	23.6	23.6	23.1
C	68.1	15.6	16.3	20.6	20.6	19.9
All	64.8	22.6	26.2	27.0	27.1	27.0

The **frequency** of occurrence of benefits for rearing yearling spring-run Chinook salmon is **high**. Fish rearing during the spring and summer months would have experienced water temperatures optimal for growth, even in Critical and Dry WYT.

To evaluate the **weight of evidence** for the water temperature stressor, a twenty-year quantitative historic record of water temperatures on Clear Creek and several published temperature thresholds from lab and in-situ studies were reviewed.

- Historic water temperature observations: quantitative, not species-specific (but not expected to be, environmental variable), location-specific, available through multiple sources and QA/QCed, long time-series and not expected to have statistical power
- Hec-5Q water temperature modeling LOE: quantitative, not species-specific (but not expected to be, environmental variable, location-specific, model developed to evaluate reservoir system using control points, widely accepted as temperature modeling system for use in the Central Valley upper watershed

Conservation measures in the Proposed Action that minimize or compensate for effects of the operation of the CVP and SWP on this stressor include:

- Sacramento River
    - Minimum Instream Flows
    - Fall and Winter Base Flows for Shasta Reservoir Redd Maintenance
    - Shasta Reservoir Water Temperature and Storage Management
- Clear Creek
    - Minimum Instream Flows
    - Water Temperature Management

Conservation measures in the Proposed Action for other species, life stages and/or stressors that may exacerbate this stressor include:

- Shasta Reservoir Water Temperature and Storage Management

6.2.6 Yearling Outmigration

Yearlings from Clear Creek are not observed in any significant fraction of the outmigrating population of spring-run Chinook salmon. On the mainstem Sacramento River, peak movement of yearling spring-run Chinook salmon occurs between October and December (Goertler et al. 2020). For those fish that over summer in natal habitats, outmigration begins with the first rainstorms in the fall or winter following their birth. Peak movement of yearling spring-run Chinook salmon in the Sacramento River at Knights Landing occurs in December (NMFS 2009).

By April, juvenile spring-run Chinook salmon are reaching the size that smoltification occurs, and the majority of smolts would be moving downriver to enter the Delta on their emigration to the ocean. Spring-run Chinook salmon smolt outmigration is mostly over by mid-May with only a few late fish emigrating in early June.

The stressors that affect the outmigration of yearling spring-run Chinook salmon include *Toxicity and Contaminants; Stranding; Outmigration Cues; Water Temperature and Dissolved Oxygen; Pathogens and Disease; Entrainment; Refuge Habitat; Food Availability and Quality; and Predation and Competition.*

Stressors that may change at a level that is discountable or insignificant include:

- The Proposed Action may increase or decrease the *water temperature and DO* stressor.

  During the yearling outmigration period, the Proposed Action will release water increasing flows and then store water decreasing flows on the Sacramento River below Keswick Dam and in the Delta. Releases of Shasta Reservoir storage may result in cooler water temperatures and higher flows that may provide a higher DO saturation potential and decreased water temperatures while storage may do the opposite. Juvenile Chinook salmon swimming performance declines at DO less than 7 mg O2/l at a water temperature at and below 67.1°F (Davis et al. 1963). A documented acceptable range of temperatures for growth of Chinook salmonids, from a synthesis of evidence, is 40.1°F–-66.4°F, with optimum growth occurring between 50°F – 60°F (U.S. Environmental Protection Agency 2001).

  On the Sacramento River above Clear Creek, historic water quality monitoring during fall shows four out of 18 years (2005 – 2022) with DO levels below 7.5 mg O2/l, with most of lower values in November and into December. In the winter on the Sacramento River, the Proposed Action may increase the DO stressor for migrating yearlings. Decreased flows may provide a lower DO saturation potential. On the Sacramento River above Clear Creek, fall historic water temperatures were within the documented optimum growth range in all but 1 of 18 years (2005 – 2022). In the winter, the Proposed Action is not anticipated to change the water temperature stressor for migrating yearlings.

In the Delta, the Proposed Action is not anticipated to change the DO stressor for migrating yearlings because it is unlikely the Proposed Action operations changes in flows will cause changes to DO in the Delta. In the winter, the Proposed Action is not anticipated to change the water temperature stressor for migrating yearlings. Moreover, it is unlikely that flow alterations from Keswick will influence water temperature in the lower Sacramento River and north Delta (Daniels and Danner 2020).

- The Proposed Action may decrease or may increase the *pathogens and disease* stressor. During the yearling outmigration period, the Proposed Action will release water increasing flows and then store water decreasing flows on the Sacramento River below Keswick Dam and in the Delta. A release of water from Shasta Reservoir may result in cooler water temperatures while storage of water may decrease flows resulting in increased water temperatures. Juvenile survival is influenced by specific diseases (e.g., *Ceratomyxa shasta*, furunculosis) present in the Sacramento River (reviewed in Lehman et al. 2020). Diseases affecting Chinook salmon become highly virulent at temperatures above 59.9°F (McCullough 1999).

  On the Sacramento River above Clear Creek, fall historic temperatures were below the 59.9°F threshold in all but 1 of 18 years (2005 – 2022). The Proposed Action may decrease the stressor in the fall. In the winter, the Proposed Action is not anticipated to change the water temperature stressor for migrating yearlings, water temperatures in the winter have not exceeded the 59.9°F threshold in the last 18 years (2005 – 2022).

  In the winter, the Proposed Action is not anticipated to change the water temperature stressor for migrating yearlings in the Delta.

- The Proposed Action may increase the *toxicity from contaminants* stressor. During the yearling outmigration period, the Proposed Action will release water increasing flows and then store water decreasing flows on the Sacramento River below Keswick Dam and in the Delta. Exposure to contaminants can result in sub-lethal effects such as reduced growth or suppression of juvenile immune systems possibly leading to infection and disease (Arkoosh et al. 2001; Kroglund and Finstad 2003; Lundin et al. 2021).

  From historic monitoring efforts, there is no evidence of effects of contaminants on yearlings in the Sacramento River.

  In the Delta during winter, the Proposed Action may increase the toxicity from contaminants stressor for migrating yearlings. The Proposed Action decreases Delta inflow and outflow concentrating constituents. Historical fisheries monitoring has not reported large-scale evidence of toxicity and contaminants in Bay-Delta fishes. Studies have shown a 0.2 mg/kg threshold for methylmercury as protective of both juvenile and adult fish (Beckvar et al. 2005). Tissue concentrations of Feather River Hatchery juveniles were reported for 199 samples, and approximately 1% of sampled fish (n = 2; 0.234 mg/kg in a floodplain fish and 0.269 mg/kg in a Sacramento River fish) in winter floods between 2001 and 2005 were above this threshold (Henery et al. 2010).

- The Proposed Action may increase the *predation and competition* stressor. During the yearling outmigration period, the Proposed Action will release water increasing flows and then store water decreasing flows on the Sacramento River below Keswick Dam and in the Delta.

Storage of water in Shasta Reservoir, particularly in the winter from December through February, may affect yearlings' outmigration travel rates. Increased travel time (slower travel rates) and migration routing, particularly into suboptimal habitat with high predator abundance in the Sacramento River mainstem and the central and south Delta, may lead to increased predation. If fish travel rates through the system increase, the delay increases the risk of exposure to predation.

Predator presence in the Delta and Sacramento River is ubiquitous. Introduced non-native piscivorous species such as striped and largemouth bass have become well-established predators in the Central Valley system. Predation studies in the Sacramento River at Red Bluff Diversion Dam also document predation on Chinook salmon (Tucker et al. 1998). Certain locations in the Delta (e.g., Clifton Court Forebay, the scour hole at Head of Old River, Delta fish collection facilities, the DCC Gates) are considered predator hotspots and, juvenile spring-run Chinook salmon will be exposed to predation when these facilities are operating. Studies have been conducted as far back as the 1980s on the abundance of predatory fish inhabiting Clifton Court Forebay (Kano 1990, Gingras and McGee 1997) and more recent studies have predicted high predation hazard for scour holes like the Head of Old River site (Michel et al. 2020).

Predation rates are a function of correlated variables such as predator presence, prey vulnerability, and environmental conditions (Grossman et al. 2013; Grossman 2016) that are influenced by operations. Predation and competition is not independent from other stressors, such as refuge habitat, food availability and quality, entrainment risk, and outmigration cues. Predation effects associated with the Proposed Action are captured in the analysis of these stressors. Any residual effects of predation and competition associated with the Proposed Action is considered insignificant.

Described below are stressors exacerbated by the Proposed Action, potentially resulting in incidental take. Also described below are conservation measures included as part of the Proposed Action to avoid or compensate for adverse effects. Finally, the Proposed Action may also ameliorate certain stressors in the environmental baseline, and below a description of these beneficial effects is included.

6.2.6.1 Outmigration Cues

The proposed storage of water may increase the outmigration cue stressor. During the yearling outmigration period, the Proposed Action will store water decreasing flows on the Sacramento River and Delta outflow. These changes may affect yearlings' cue to migrate and their outmigration travel rates. Outmigration cues, for the purposes of this document, are defined and discussed as fish outmigration behavior being impacted by reduced variation and volume of flows in the upper Sacramento River. Outmigration cues primarily analyzes the Sacramento River and Clear Creek and the migration downstream to Red Bluff Diversion Dam to the Delta. The cause of this stressor is primarily storage for Shasta Reservoir Coldwater Pool analyzed in Appendix L and releases in Appendix J. Appendix H describes the "Minimum Instream Flows" conservation measure.

The increase in outmigration cue stressors is expected to be **lethal**. If fish stay in the upper Sacramento River longer because they are not cued to outmigrate, the risk of exposure to sources of mortality increases (e.g., higher exposure to predation). The impact of outmigration cues is not independent from these other stressors such as refuge habitat, entrainment risk stressor, and predation and competition. These stressors are described independently in this chapter.

Although the Proposed Action may increase the outmigration cues stressor, changes in outmigration cues that affect spring-run Chinook salmon yearlings exist in the **environmental baseline** (without the Proposed Action). Flows influence fish outmigration behavior and affect fish travel times in the upper watershed. In addition, other facilities owned by senior water users affect flows in the Sacramento River.

The **proportion** of the population affected by the Proposed Action is **high** for fish in the Sacramento River migrating towards the Delta and depends on variations in flows. Outmigration cues impact spring-run Chinook salmon from all CVP and non-CVP tributaries. In the Proposed Action, reduced releases occur for water temperature management, storage rebuilding, rice decomposition smoothing, and redd dewatering avoidance actions. Peak movement of yearling spring-run Chinook salmon in the Sacramento River at Knights Landing occurs in December.

Literature does not uniquely inform the proportion of the population.

Datasets use historical conditions and observation to inform how spring-run Chinook salmon may respond to the Proposed Action. Historical monitoring may support or refute hypotheses and inform the reasonableness of information generated by models. Empirical estimates of acoustically tagged Chinook salmon can be found below in “Entrainment Risk” stressor section.

Acoustically tagged fish released at locations in the upper Sacramento River under varying hydrological conditions are used to estimate survival probabilities and travel times rates. As fish migrate downstream towards the Delta, individuals encounter a range of environmental conditions and transition from reaches with unidirectional flow (upstream) to reaches with bidirectional flow (tidally driven, downstream). Perry et al. (2018) show that survival increased sharply with river inflow (Sacramento River at Freeport) in reaches classified as “transitional,” but that relationship was not true in riverine or tidal reaches. Survival in riverine reaches were higher than “transitional” or tidal regardless of discharge, approaching 100% as flow increased. Outmigrating juveniles may be exposed to predation and as inflow declines and tidal influence moves upstream, travel time and distance may increase leading to higher exposure to predators. Travel and survival rates of Chinook in upper Sacramento reaches are strongly correlated (Notch et al. 2020).

The **frequency** of occurrence depends primarily on the timing of exceeding an outmigration cue threshold and is **high** for the Sacramento River. There is an outmigration threshold developed for winter-run Chinook salmon. Del Rosario et al. (2013) showed when daily Wilkins Slough flows surpass a 14,126 cfs threshold, winter-run Chinook salmon outmigration cues into the lower Sacramento River increased, and more than 5% of the fish observed annually at the Knights Landing fish monitoring site occurred (400 cms). There is no published threshold for spring-run Chinook salmon outmigration thus it is difficult to make a frequency determination based on historic flows at any monitoring location. Tributary flow increases are used to signal conditions conducive to emigration. An increase in flow greater than 50% from the previous day is used to indicate the appropriate cues for the initiation of salmon emigration. Between October and December at Bend Bridge on the Sacramento River, flows on at least 10% of days in 18 out of 18 years (100%, 2005 – 2022) exhibited a greater than 50% increase from the previous day. The impact will be magnified in years when coldwater pool volume is limited, and releases are limited because of water temperature management, storage rebuilding, and rice decomposition smoothing actions.

To evaluate the **weight of evidence** for the outmigration cues stressor, there is a two decade quantitative, historic record of flows and Red Bluff and Knights Landing monitoring data for spring-run Chinook salmon. There is a body of literature that is location- but not species-specific that provides flow thresholds relevant to winter-run Chinook salmon (Michel et al. 2021; Del Rosario et al. 2013). Additionally, an existing predator prey model, the mean free-path length model, has been applied in the Sacramento River using hatchery late fall-run Chinook salmon (location- but not species-specific) to evaluate movement patterns of both predators and prey and the probability of encounters (Steel et al. 2020).

- Literature, Del Rosario: quantitative, not species-specific (developed for winter-run Chinook salmon), location-specific, publication in the peer reviewed journal, multiple regressions fit on four covariates
- Literature, AT literature: quantitative, species-specific, location-specific, data published in peer-review publications
- Historic passage at key locations: quantitative, species-specific, location-specific, available through multiple sources and QA/QCed, long time-series and not expected to have statistical power
- Historic flows: quantitative, not species-specific (but not expected to be, environmental variable), location-specific, available through multiple sources and QA/QCed, long time-series and not expected to have statistical power
- USRDOM daily flow modeling LOE: quantitative, not species-specific (but not expected to be), environmental variable, location-specific, model developed to evaluate flows using multiple inputs, widely accepted as daily flow modeling system for use in the Central Valley upper watershed

Conservation measures in the Proposed Action that minimize or compensate for effects of the operation of the CVP and SWP on this stressor include:

- Sacramento River
    - Minimum Instream Flows
    - Fall and Winter Base Flows for Shasta Reservoir Redd Maintenance
- Clear Creek
    - Minimum Instream Flows

Conservation measures in the Proposed Action for other species, life stages and/or stressors that may exacerbate this stressor include:

- Sacramento River
    - Fall and Winter Base Flows for Shasta Reservoir Refill
    - Reduced Wilkins Slough Minimum Flows
- Drought Actions

6.2.6.2 Refuge Habitat

The proposed storage of water may increase the refuge habitat stressor. During the yearling outmigration period, the Proposed Action will store water in the winter decreasing flows on the Sacramento River and Delta outflow. Reduced flows may decrease suitable margin and off-channel habitats available as refuge habitat for outmigrating yearlings in both the Sacramento River and the Delta. Appendix O presents an analysis of this stressor.

In the Delta, operations are not expected to increase the refuge habitat stressor for outmigrating yearling spring-run Chinook salmon. All yearlings outmigrating from the Sacramento River and Clear Creek must pass through the Delta on the way to the Pacific Ocean. The Delta is tidally influenced. As such, the effect of Proposed Action storage of water on available shallow-water refuge habitat would be within the daily tidal range near the seaward end of the Delta. Tidal influence dissipated toward the landward edges of the Delta and effects of Proposed Action storage of water would be more similar to that described for the mainstem Sacramento River above. In the Delta, spring-run Chinook salmon utilize side channel and inundated floodplain habitat in the tidal shoreline of the Delta for foraging and growth. The tidal habitat of the Delta also serves the critical role as a physiological transition zone before saltwater entry, with juveniles and yearlings residing in the Delta for an average of 3 months (del Rosario et al. 2013). However, only a small fraction of the wetland rearing habitat is still accessible to fish, and much of the modern Delta and bays have been converted to serve agriculture and human population growth (SFEI-ASC 2014). As explained above, the loss of tidal marshes and historical floodplain wetlands have resulted in a loss of refuge habitat for spring-run Chinook salmon. In addition, there are 200 miles of exterior levees in Suisun Marsh, twenty of those miles are along Suisun, Grizzly, and Honker Bays (SMP 2013). Levee construction involves the removal and loss of riparian vegetation (Anderson and Sedell 1979; Pusey and Arthington 2003). There is no known relationship between flows and refuge habitat availability similar to those for the Sacramento River (Gard 2005), inter-annual variation in flows at Freeport during the rearing and outmigration period is greater than at Kewsick; thus, flow-dependent refuge habitat is likely limiting less often in the Delta than in the Sacramento River.

The increase in refuge habitat stressor is expected to be **sub-lethal**. A decrease in sufficient refuge habitat can result in yearlings lacking cover to avoid predation or habitat to stop and hold during outmigration. Access to off-channel habitats has been linked to higher growth rates and survival (Limm and Marchetti 2009; Zeug et al. 2020). Very low releases decrease potential refuge habitat for yearling spring-run Chinook salmon by removing access to side-channels, access to refuge, and changing geomorphic processes. Refuge habitat is not independent of food availability and quantity, another sub-lethal stressor discussed below.

Although the Proposed Action may increase the refuge habitat stressor, changes in refuge habitat of yearling spring-run Chinook salmon exists in the **environmental baseline** (without the Proposed Action). Turbidity, shallow water habitat, and food production and retention drive this stressor (Windell et al. 2017). Generally, dams impair the recruitment of large woody material to the river channel and floodplain below the dam. Stable year-round flows have resulted in diminished natural channel formation, altered foodweb processes, and slowed regeneration of riparian vegetation.

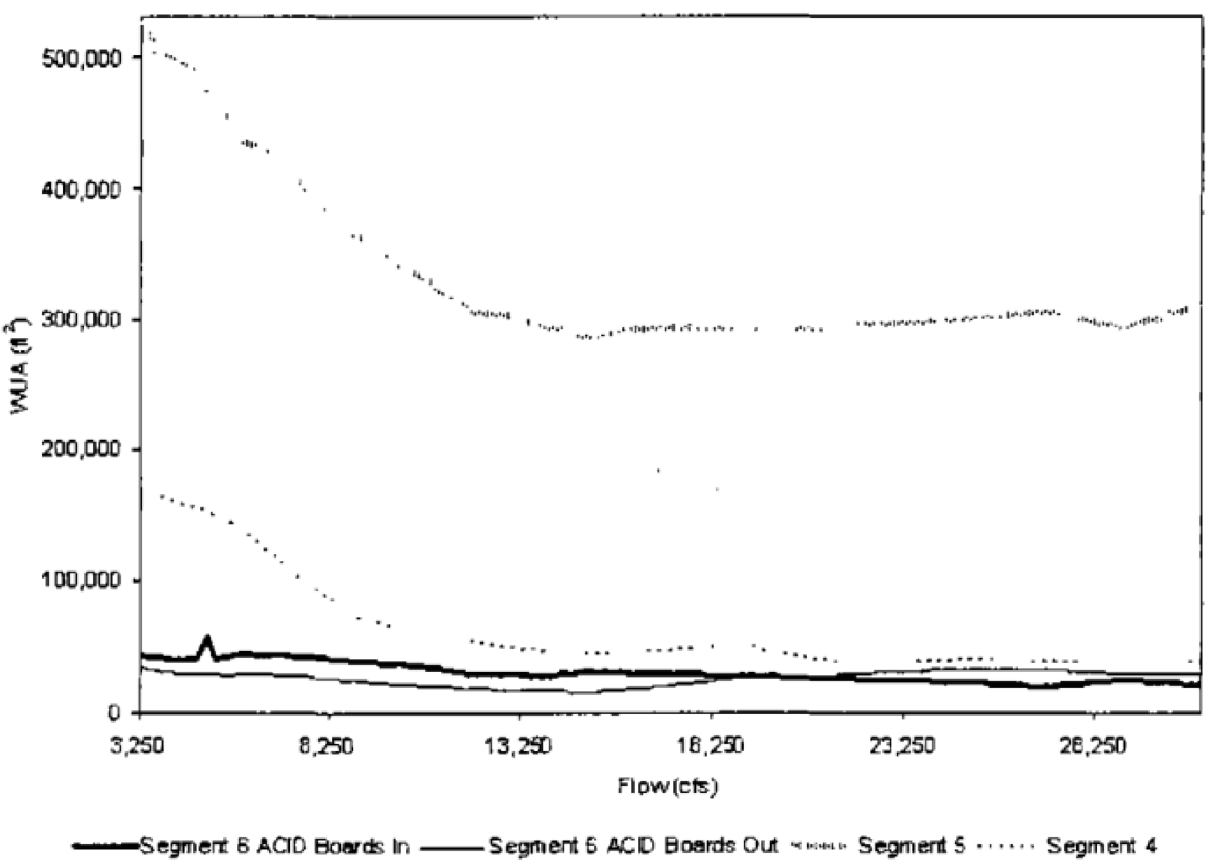
Since 1900, approximately 95 percent of historical freshwater wetland habitat in the Central Valley floodplain has been lost, typically through the construction of levees and draining for agriculture or residential uses (Hanak et al. 2011). Human expansion has occurred over vast areas in the Delta and Sacramento and San Joaquin Valleys between the 1850s and the early 1930s, completely transforming their physical structure (Thompson 1957, 1965; Suisun Ecological Workgroup 2001; Whipple et al. 2012; San Francisco Estuary Institute 2010). Levee ditches were built to drain land for agriculture, human habitation, mosquito control, and other human uses, while channels were straightened, widened, and dredged to improve shipping access to the Central Valley and to improve downstream water conveyance for flood management. In addition, constructing and armoring levees changes bank configuration and reduces cover (Stillwater Sciences 2006). Constructed levees protected with rock revetment generally create nearshore hydraulic conditions characterized by greater depths and faster, more homogeneous water velocities than occur along natural banks. Higher water velocities typically reduce deposition and retention of sediment and woody debris, thereby reducing the shoreline variability. This reduction in variability eliminates the shallow, slow-velocity river margins used by juvenile fish as refuge escape from fast currents, deep water, and predators (Stillwater Sciences 2006). Reclamation has completed many side-channel restoration projects in the upper Sacramento River that provide refuge habitat for juveniles. Additional restoration projects are ongoing and outside of this consultation.

Since 2009, Reclamation has operated Whiskeytown Dam to provide channel maintenance flows. In 2009, NMFS issued an RPA requiring Reclamation to re-operate Whiskeytown Glory Hole spills during the winter and spring to produce channel maintenance flows. In 2019, Reclamation committed to release 10 thousand acre-feet of water from Whiskeytown Dam for channel maintenance in all year-types except for Dry and Critical year-types. Efforts have also been made to restore parts of Lower Clear Creek. For example, the Lower Clear Creek Floodway Restoration Project restored the natural form and function of a 1.8 mile channel and floodplain along Lower Clear Creek to benefit salmon and steelhead.

The **proportion** of the population affected by decreased refuge habitat depends on bathymetry and hydrology and is **large** in the Sacramento River.

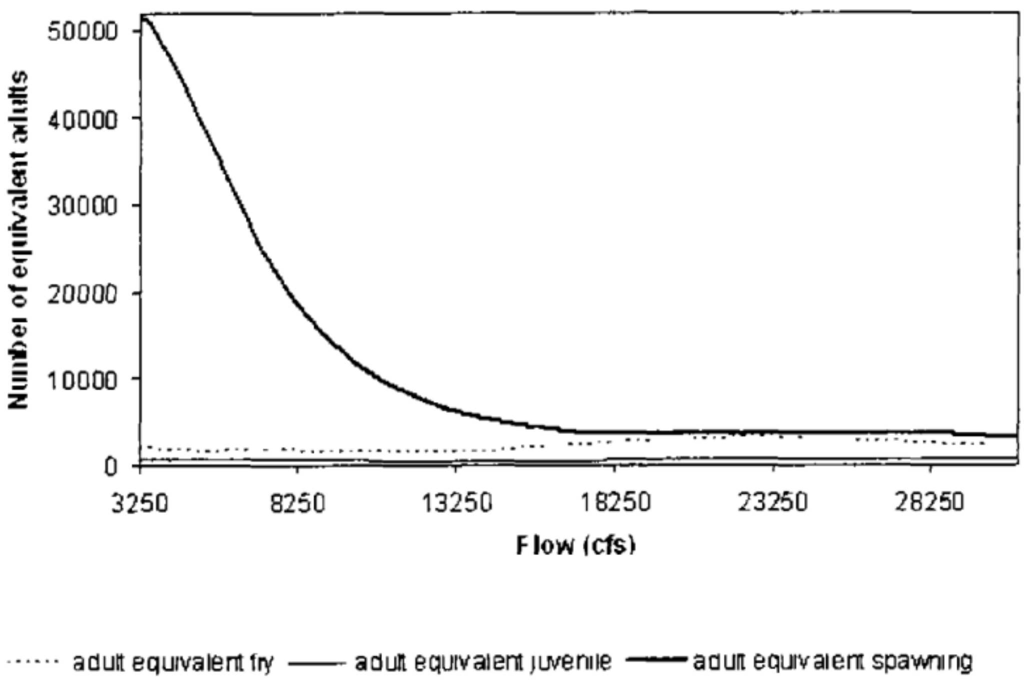
The literature demonstrates that in most cases, limiting life stage analyses indicated that juvenile habitat is limiting (Gard 2005). This is used as an assumption for yearlings. Access to off-channel habitats has been linked to higher growth rates and survival (Limm and Marchetti 2009; Zeug et al. 2020). Habitat restoration programs are aimed towards providing benefits to native salmonids (quality habitat, increased food availability, refuge) but these efforts also provide benefits to non-native and native predators possibly increasing predation rates. Reduced releases decrease potential refuge habitat for yearling spring-run Chinook salmon removing access to side-channels, access to refuge, and changing geomorphic processes.

The figures below show flow-habitat relationships (Figure 6-32) and limiting life stage analyses for juvenile fall-run Chinook salmon (used as a proxy for spring-run Chinook salmon yearlings) by Sacramento River segment 6 (ACID to Keswick Dam, Figure 6-33a) and segment 5 (Cow Creek to Anderson-Cottonwood Irrigation District, ACID, Figure 6-33b).

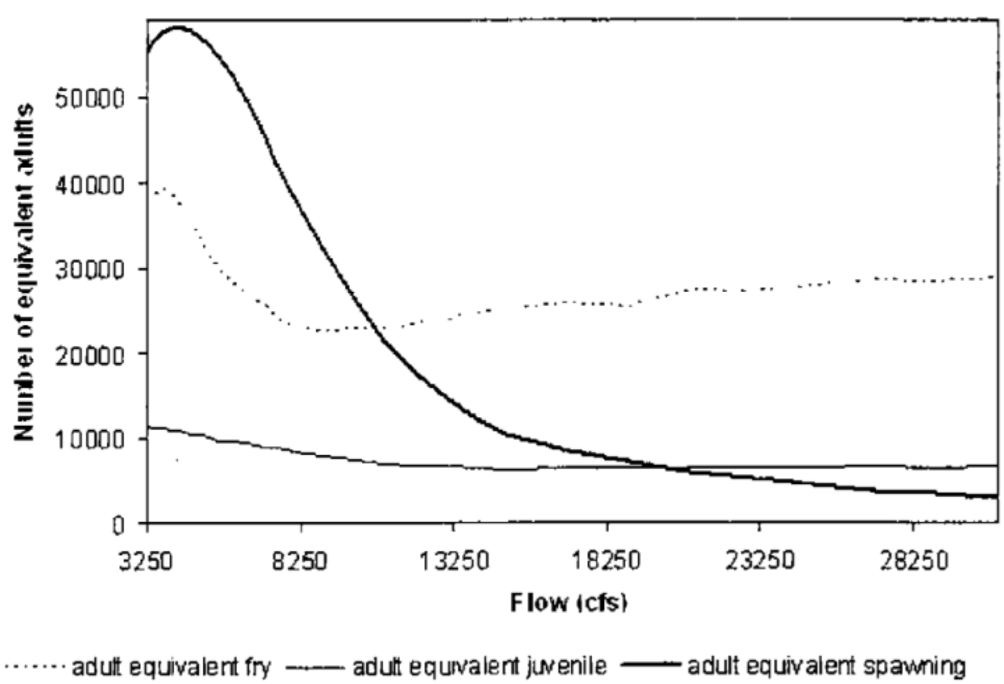


Source: Gard 2005.

Figure 6-32. Juvenile fall-run Chinook salmon rearing flow-habitat relationships for segments 4 through 6 (ACID boards in and out).



a.



b.

Source: Gard 2005.

Figure 6-33a-b. Limiting life stage analysis for fall-run Chinook salmon in a) segment 6 (ACID to Keswick Dam, ACID boards out) and b) segment 5 (Cow Creek to Anderson-Cottonwood Irrigation District, ACID). Adult equivalent juvenile is represented by the thin solid black line.

Models provide quantitative estimates of future conditions under the Proposed Action.

Attachment O.3, *Sacramento River Weighted Usable Area Analysis* provides context for the WUA available for spring-run Chinook salmon rearing downstream of Keswick releases. Fall-run Chinook salmon rearing WUA habitat values are used as proxies for Sacramento River spring-run Chinook salmon rearing WUA. The fall-run Chinook salmon WUA habitat values for juvenile (Yearling) rearing peak at the minimum flow (3,250 cfs). The expected WUA habitat value for juvenile (Yearling) rearing under the Proposed Action phases range from 701,435 in wet water years to 899,145 in critical years (Figure 6-34). Overall, these WUA habitat values are lowest in wet water years and successively increase in the drier WYT. This pattern of variation is attributable to the low flows at which spring-run Chinook salmon rearing WUA habitat values peak in the Sacramento River.

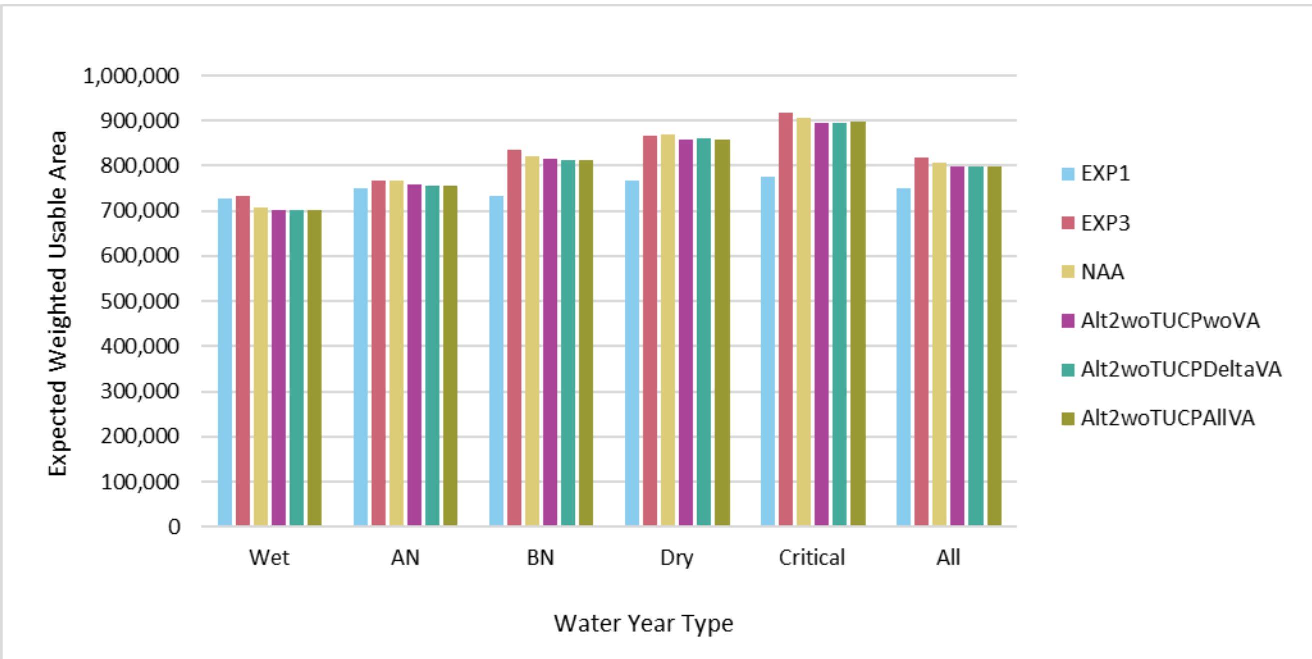


Figure 6-34. Expected Weighted Usable Area for Segments 4-6 by Water Year Type, Spring-run Chinook Salmon Juvenile (Yearling) Rearing in the Sacramento River

Attachment O.1, *Clear Creek Weighted Usable Area Analysis* provides context for the WUA available for spring-run Chinook salmon rearing downstream of Whiskeytown releases. Juvenile (Yearling) rearing WUA for spring-run Chinook salmon peaks at approximately 700 - 900 cfs. The expected WUA habitat value for juvenile (Yearling) rearing under the Proposed Action phases range from 68,673 in critical water years to 78,986 in wet years (Figure 6-35). Overall, these WUA habitat values do not vary much among Proposed Action phases and WYT. This suggests the summer flow ranges in the Proposed Action provide stable rearing habitats.

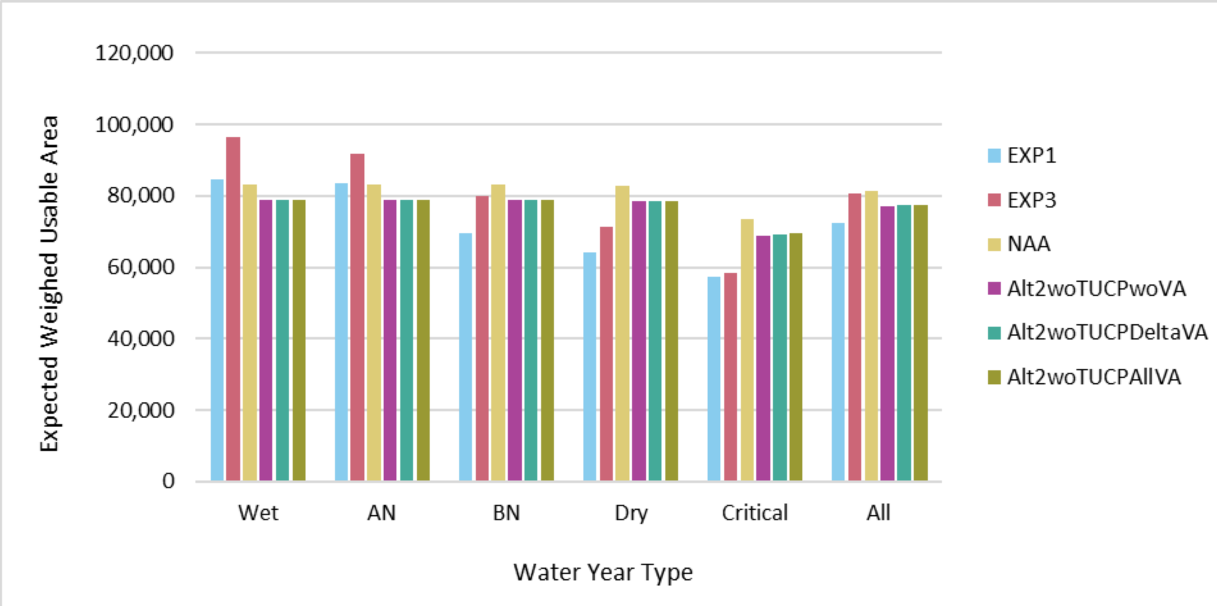
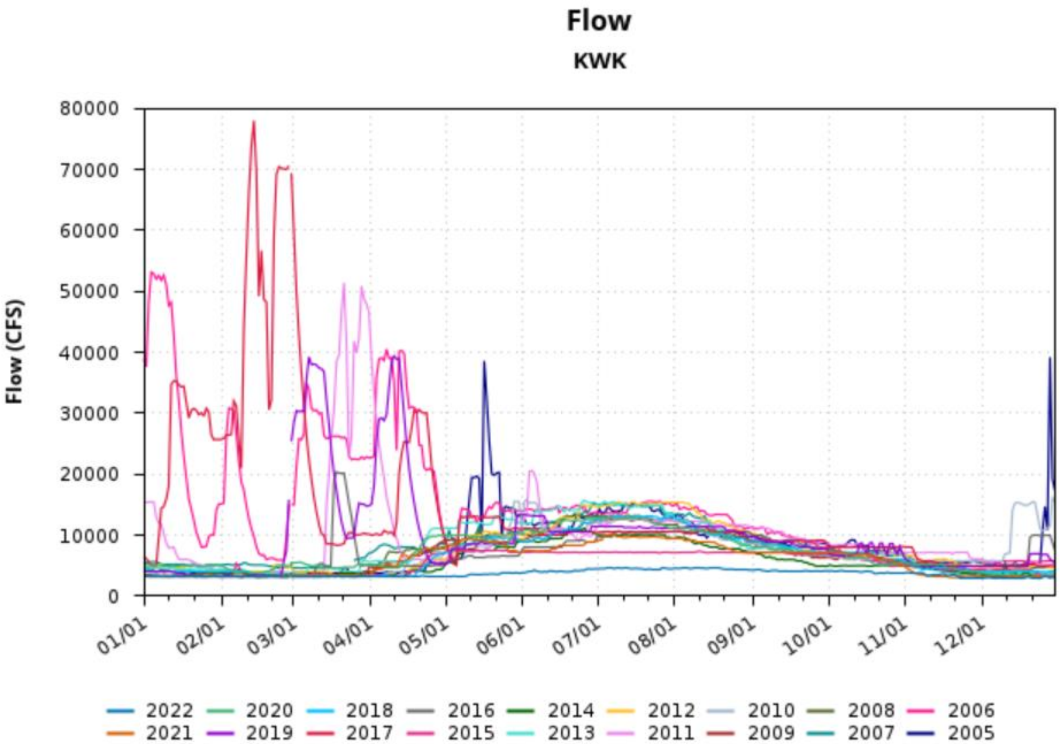
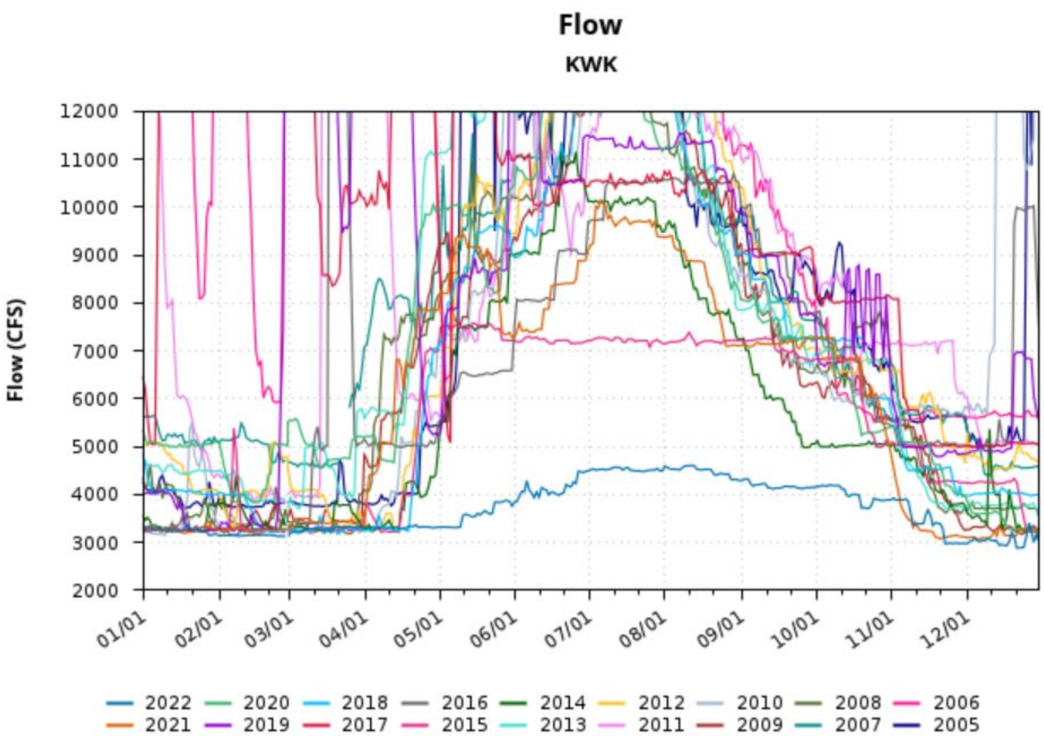


Figure 6-35. Expected Weighted Usable Area for the Lower Alluvial, Upper Alluvial, and Canyon Segments by Water Year Type, Spring-run Chinook Salmon Juvenile (Yearling) Rearing in Clear Creek

The **frequency** of occurrence is annual and depends primarily on hydrology and is **low** on the Sacramento River. Between the fall and winter months, flows at Keswick generally decrease, with the exception of wet and above normal WYT (e.g., 2005, 2006, 2010, 2011, 2017, 2019, Figure 6-36). 6 out of 18 years (33%, 2005 – 2022) were wet or above normal WYT (Sacramento Valley Index). Limiting life stage analysis for fall-run Chinook salmon shows that flows in Segment 6 do not appear limiting.



a.



b.

Figure 6-36a-b. Keswick flows, 2005 – 2022, (b) scaled to a maximum of 12,000 cfs.

To evaluate the **weight of evidence** for refuge habitat stressor, location-specific but not species-specific (Chinook not spring-run Chinook salmon) information in the literature is used: flow-habitat relationships, limiting life stage analyses (Gard 2005). Studies have shown access to off-channel habitats as linked to higher growth rates and survival (Limm and Marchetti 2009; Zeug et al. 2020).

- Sacramento WUA analysis is quantitative and species-specific but not location-specific to the Sacramento River (see Assumption 3 in Attachment O.3). WUA analyses are widely used and recognized analytical tools for assessing effects of flow on fish populations (Reiser and Hilgert 2018).
- Clear Creek WUA analysis is quantitative, species-specific, and location-specific to Clear Creek. RIVER2D was the principal hydraulic habitat model used in the USFWS analyses (2007, 2011a, 2011b, 2013) to develop the Clear Creek WUA curves used in this analysis.

Conservation measures in the Proposed Action that minimize or compensate for effects of the operation of the CVP and SWP on this stressor include:

- Sacramento River
    - Minimum Instream Flows
    - Fall and Winter Base Flows for Shasta Reservoir Redd Maintenance
- Clear Creek
    - Minimum Instream Flows

Conservation measures in the Proposed Action for other species, life stages and/or stressors that may exacerbate this stressor include:

- Sacramento River
    - Fall and Winter Base Flows for Shasta Reservoir Refill
    - Reduced Wilkins Slough Minimum Flows
- Drought Actions

6.2.6.3 Food Availability and Quality

The proposed storage of water may increase the food availability and quality stressor. During the yearling outmigration period, the Proposed Action will store water decreasing flows on the Sacramento River and Delta outflow. These changes may modify food web processes and cause a decrease in quality food available to yearling spring-run Chinook salmon. Appendix O analyzes this stressor.

In the Delta, operations are not expected to increase the food availability and quality stressor for outmigrating yearling spring-run Chinook salmon. All yearlings outmigrating from the Sacramento River and Clear Creek must pass through the Delta on the way to the Pacific Ocean.

The Delta is tidally influenced. As such, the effect of Proposed Action storage of water on food availability would be within the daily tidal range near the seaward end of the Delta. Tidal influence dissipated toward the landward edges of the Delta and effects of Proposed Action storage of water would be more similar to that described for the mainstem Sacramento River above. In the Delta, spring-run Chinook salmon utilize side channels and inundated floodplain habitat in the tidal shoreline of the Delta for foraging and growth. The tidal habitat of the Delta also serves the critical role as a physiological transition zone before saltwater entry, with juveniles and yearlings residing in the Delta for an average of 3 months (del Rosario et al. 2013). Side-channel and floodplain habitat are highly productive and can provide nutrients and food nearby portions of the Delta. Historically, the Yolo Bypass experiences at least some flooding in 80% of years (Reclamation 2012), and recent and ongoing modifications to Fremont Weir are intended to increase the frequency of occurrence.

The increase in food availability and quality is expected to be **sub-lethal**. A decrease in quality and quantity of food for foraging yearling spring-run Chinook salmon will impact growth rates. Additionally, food limitation can weaken yearling spring-run Chinook salmon, leading to extremes such as starvation, and alter behavior resulting in predation risk. Food availability and quantity is not independent of refuge habitat, another sub-lethal stressor discussed above.

Although the Proposed Action may increase the food availability and quality stressor, changes in food availability and quality for outmigrating yearling spring-run Chinook salmon exists in the **environmental baseline** (without the Proposed Action). The level of production and retention drives food availability and quality (Windell et al. 2017). Generally, the presence and operation of dams contribute to channelization, which contributes to a loss of riparian habitat and instream cover. A significant portion of the juvenile Chinook salmon diet is composed of aquatic and terrestrial insects, which are dependent on healthy riparian habitat (National Marine Fisheries Service 2014). Levee construction involves the removal of riparian vegetation, which reduces aquatic macroinvertebrate recruitment resulting in decreased food availability for rearing juveniles (Anderson and Sedell 1979; Pusey and Arthington 2003). Channelized, leveed, and riprapped reaches typically have low habitat complexity and low abundance of food organisms. (Lindell 2017).

Reclamation has operated Whiskeytown to provide channel maintenance flows since 2009. Efforts have also been made to restore parts of Lower Clear Creek. The Lower Clear Creek Floodway Restoration Project restored the natural form and function of a 1.8-mile channel and floodplain along Lower Clear Creek to benefit salmon and steelhead.

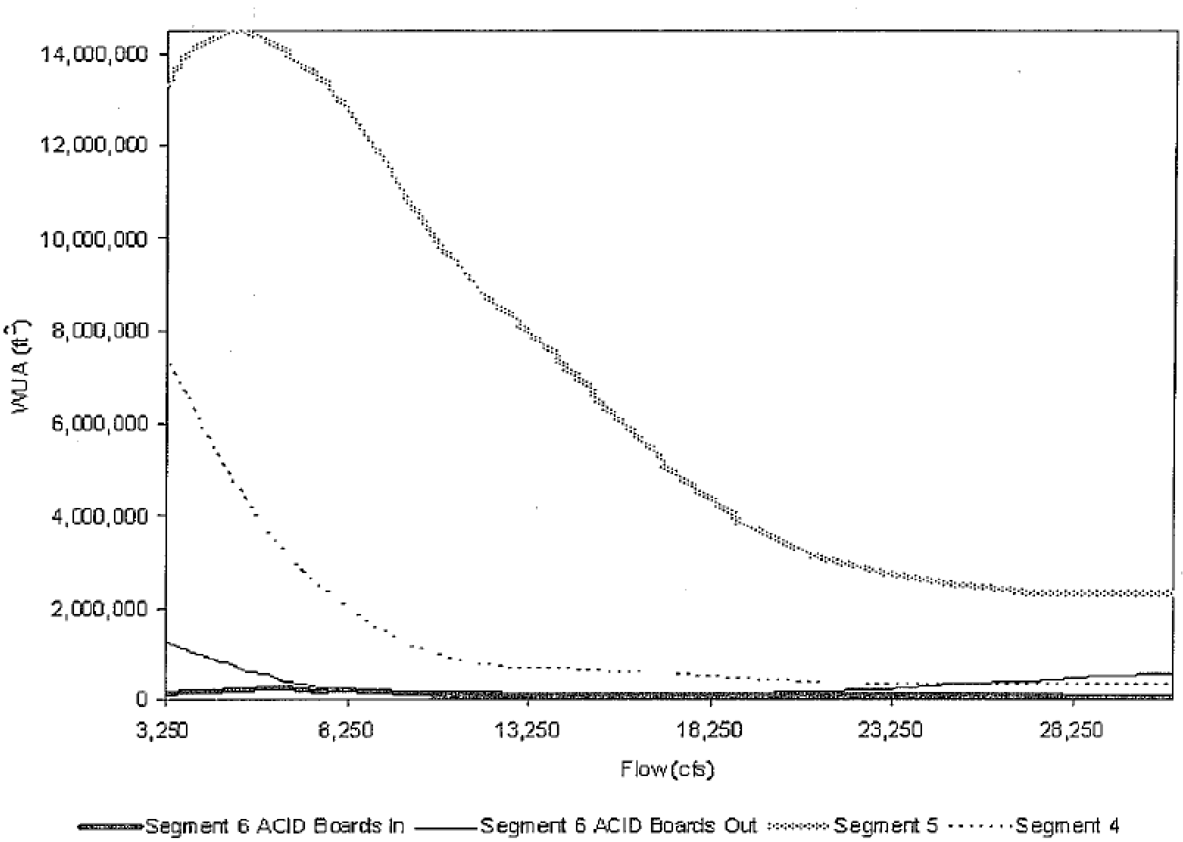
The Yolo Bypass Project is intended to reduce the food availability stressor on Chinook salmon migrating along the Sacramento River. Seasonal inundation of the Yolo Bypass leads to an increase in phytoplankton and other food resources that support fish species residing in the floodplain and provides a source of these food resources to downstream habitats (Sommer *et al.* 2001). Also, the Yolo Bypass has more natural banks and riparian vegetation than the Sacramento River and is better connected to tidal wetlands than the Sacramento River (Goertler et al. 2015). The Yolo Bypass Project should improve food availability and quality for migrating spring-run Chinook salmon. Reclamation and DWR are implementing the Yolo Bypass Project, which is ongoing and outside of this consultation.

In the Delta, levee construction involves the removal and loss of riparian vegetation and reduces aquatic macroinvertebrate recruitment resulting in decreased food availability (Anderson and Sedell 1979; Pusey and Arthington 2003). The lack of floodplain connectivity also limits food availability.

Invasive species have also affected food availability in the Delta. The native mysid species, *Neomysis mercedis* has experienced severe declines since the introduction and establishment of the invasive overbite clam (Winder and Jassby 2011) and has largely been replaced by a non-native mysid species, *Hyperacnthomysis longirostris* (Avila and Hartman 2020; Winder and Jassby 2011).

The **proportion** of the population affected by decreased food availability and quality in the Delta depends on bathymetry and hydrology and is **large**. All spring-run Chinook salmon yearlings pass through the Delta on their way to the Pacific Ocean. The Delta is tidally influenced. As such, the effect of Proposed Action storage of water on food availability would be within the daily tidal range near the seaward end of the Delta. Tidal influence dissipates toward the landward edges of the Delta and effects of Proposed Action storage of water would be more similar to that described for the mainstem Sacramento River above.

The literature demonstrates that in most cases, limiting life stage analyses indicated that juvenile habitat is limiting (Gard 2005). This is used as an assumption for yearlings. Flow-habitat relationship metrics for juvenile salmonid food supply developed for the Sacramento River, between Keswick and Battle Creek, show (Gard 2006). Optimal flows for the macroinvertebrate index varied by reach and ranged from 3,250 cfs to 6,000 cfs (Figure 6-37; Gard 2006). Access to off-channel habitats has been linked to higher growth rates and survival (Limm and Marchetti 2009; Zeug et al. 2020). Habitat restoration programs are aimed towards providing benefits to native salmonids (quality habitat, increased food availability, refuge) but these efforts also provide benefits to non-native and native predators possibly increasing predation rates. Reduction or loss of seasonally inundated habitats alters food web processes and riparian vegetation, decreasing food availability and quality, and impacting the successful growth and survival of juveniles (Jeffres et al. 2008; Steel et al. 2017; Goertler et al. 2018; Jeffres et al. 2020; Bellido-Leiva et al. 2021). Reduced releases decrease potential refuge habitat for juvenile spring-run Chinook salmon removing access to side-channels, access to refuge, and changing geomorphic processes. See figures in “Refuge Habitat” for juvenile fall-run Chinook salmon flow-habitat relationships and limiting life stage analyses (used as a proxy for spring-run Chinook salmon yearlings).



Source: Gard 2006.

Figure 6-37. Flow-habitat relationship by reach for juvenile chinook salmon food supply (biomass of Baetids, Chironomids, and Hydropsychids).

Datasets and models do not uniquely inform the proportion of the population affected.

The **frequency** of occurrence is annual and depends primarily on hydrology and is **low** for Sacramento River. Between the fall and winter months, flows at Keswick generally decrease, with the exception of wet and above normal WYT (e.g., 2005, 2006, 2010, 2011, 2017, 2019, Figure 6-36). 4 out of 18 years (22%, 2005 – 2022) did not have 50% of more daily Keswick flows between December and April in the optimal range (3,250 – 6,000 cfs, Figure 6-36).

The **frequency** of occurrence in the Delta is annual and depends primarily on hydrology and is **high**. Reduced releases decrease the inundation of side-channel and floodplain habitat, which are highly productive and can provide nutrients and food nearby portions of the Delta. Historically, the Yolo Bypass experiences at least some flooding in 80% of years (Reclamation 2012), and recent and ongoing modifications to Fremont Weir are intended to increase the frequency of occurrence. Reduced flows due to Proposed Action storage of water would reduce the frequency of spills into the Yolo Bypass.

To evaluate the **weight of evidence** for the food availability and quality stressor, multiple location- and species-specific studies have been conducted showing the importance of quality available food for rearing and outmigrating juveniles, used as a proxy for outmigrating yearlings. Studies have been conducted in both the Sacramento River and Bay-Delta.

- Gard 2006 WUA flow-habitat relationships modeling LOE: quantitative, species-specific, location-specific, published in technical reports

Conservation measures in the Proposed Action that minimize or compensate for effects of the operation of the CVP and SWP on this stressor include:

- Sacramento River
  - Minimum Instream Flows
  - Fall and Winter Base Flows for Shasta Reservoir Redd Maintenance
- Clear Creek
  - Minimum Instream Flows

Conservation measures in the Proposed Action for other species, life stages and/or stressors that may exacerbate this stressor include:

- Sacramento River
  - Fall and Winter Base Flows for Shasta Reservoir Refill
  - Reduced Wilkins Slough Minimum Flows
- Drought Actions

6.2.6.4 Entrainment Risk

The proposed diversion of water may increase the entrainment risk stressor. During the yearling outmigration period, the Proposed Action will store water decreasing flows on the Sacramento River and Delta outflow. This influences fish travel time and routing migrating in the Sacramento River mainstem and the central and south Delta. Once in the central and south Delta, entrainment into the Jones and Banks pumping plants may occur. Entrainment, for the purposes of this document, is defined and discussed in two ways: (1) fish encountering CVP facilities where they may be pulled into diversions or the export facilities and (2) fish routed through specific migratory pathways in the Delta (Delta route-specific travel time and survival). In both, outmigrating juveniles may be exposed to predation in different locations within the Delta. When yearling spring-run Chinook salmon are entrained into the South Delta, they are exposed to greater predation risk since those areas of the Delta provide habitat for invasive predators which prey on yearlings. The entrainment risk stressor is not anticipated to change in the mainstem and upper Sacramento.

- Appendix G – including sections for "Tracy Fish Collection Facility" and "Skinner Fish Delta Fish Protective Facility"
- Appendix I – presents analysis of "Old and Middle River Management" and "Delta Cross Channel Closure" conservation measures

- Appendix J – presents analysis of the effects of spring Delta outflow on juvenile survival with a focus on route-specific travel time and survival
- Appendix Q – describes the operation of the Georgiana Slough Non-Physical Barrier, one measure that can be taken to prevent juvenile winter-run Chinook salmon from traveling through Georgiana Slough into the central Delta

The increase in entrainment risk stressor is expected to be **lethal**. Entrainment can result in indirect mortality by routing fish into areas of poor survival (increased predation, reduced habitat quality) or direct mortality during salvage in the Delta fish collection facilities.

Although the Proposed Action may increase the entrainment risk stressor, entrainment of yearling spring-run Chinook salmon exists in the **environmental baseline** (without the Proposed Action). Proximity to irrigation diversion operations drives the entrainment stressor (Windell et al. 2017). These diversions exist throughout the Delta and along rivers and streams in the Central Valley. Tides and flood releases can influence hydrodynamic transport and move fish into higher risk entrainment areas surrounding diversions or poor habitats which could lead to increased predation. Tidal conditions can facilitate downstream transport or entrainment depending on the flood and ebb of tides during the fortnightly spring-neap cycle (Arthur et al. 1996).

The entrainment risk stressor is influenced by thousands of non-CVP and non-SWP diversions in the rivers and Delta. Senior and junior water users would continue to operate privately-owned facilities to divert water from the Sacramento River and pose a risk of entrainment to juvenile spring-run Chinook salmon, although that risk is reduced where fish screens have been installed. As of 1997, 98.5 percent of the 3,356 diversions included in a Central Valley database were either unscreened or screened insufficiently to prevent fish entrainment (Herren and Kawasaki 2001). Most of the 370 water diversions operating in Suisun Marsh are unscreened (Herren and Kawasaki 2001). Quantification of the effect of small unscreened diversions is limited (Moyle and Israel 2005). The CVPIA Anadromous Fish Screen Program provides grants to screen facilities used to divert water. Diversions greater than 100 cfs are screened on the Sacramento River. Upstream from the Delta, CVP facilities diverting water under water service contracts and SWP diversions are screened (e.g., Red Bluff Pumping Plant, Freeport Regional Water Project, Barker Slough Pumping Plant, Contra Costa Water District).

In the Delta, Reclamation's past operation of the DCC Gates and Reclamation and DWR's past operation of export facilities influenced the flow of water in the Delta. Reclamation and DWR have operated the CVP and SWP to reduce the risk of entrainment under Biological Opinions issued by the USFWS and NMFS in 2004/2005, 2008/2009, and 2019. Under those Biological Opinions, Reclamation and DWR have: (1) closed the DCC Gates; (2) controlled the net negative flows toward the export pumps in Old and Middle rivers to reduce the likelihood that fish would be diverted from the San Joaquin or Sacramento River into the southern or central Delta; and (3) improved fish screening and salvage operations to reduce mortality from entrainment and salvage. Historic data on spring-run Chinook salmon entrainment, salvage, and loss are discussed in detail below. An existing consultation proposes to install operatable gates to increase fish routing into the Yolo Bypass. An existing consultation for the Georgiana Slough Salmonid Migratory Barrier proposed to decrease the existing routing stressor by deterring emigrating juvenile salmonid from entering Georgiana Slough and the central and south Delta, wherein survival is lower relative to remaining in the mainstem Sacramento River, improving survival to Chipps Island.

The **proportion** of the population affected by the Proposed Action varies annually and depends upon flow routing, hydrology, export rates, and migration timing and is **small**. Entrainment impacts spring-run Chinook salmon from all CVP and non-CVP tributaries and records of observations at the fish collection facilities are inclusive of portions of the population that originate outside of CVP-tributaries (e.g., the Feather River, Butte Creek). However, there is not currently a metric to define what proportion of the population fish observed in salvage represent (similar to JPE or Juvenile Production Index (JPI) for winter-run Chinook salmon). In 0 out of 11 years (0%, 2012 - 2022), a spring-run surrogate loss threshold of 2% was exceeded, Table 6-20). Spring-run Chinook salmon loss in years after 2010 are more representative of current OMR management and the Proposed Action compared with years prior to 2010 (1993 – 2009).

Descriptions of literature, datasets, model results, and weight of evidence as they pertain to outmigrating yearling spring-run Chinook salmon can be found above in the "Entrainment Risk" stressor section in Juvenile Rearing and Outmigration.

Conservation measures in the Proposed Action that minimize or compensate for effects of the operation of the CVP and SWP on this stressor include:

- DCC Gate Closure
- First Flush and Start of OMR Management
- January 1 and Start of OMR Management
- Spring-run Chinook salmon and Surrogate Thresholds
- Winter and Spring Delta Outflows
- Salvage Facilities

Conservation measures in the Proposed Action for other species, life stages and/or stressors that may exacerbate this stressor include:

- SHOT Reduction in Sacramento River Fall and Winter Flows
- Drought Actions

6.2.6.5 Stranding Risk

The proposed storage and release of water may increase or decrease the stranding risk stressor. During the yearling outmigration period, the Proposed Action will store water decreasing flows on the Sacramento River and Delta outflow. Reducing releases and the storage of water reduces flows. Yearlings can become stranded in habitat disconnected from the main channel. Appendix O presents analysis of this stressor. Appendix H presents analysis of this stressor through the "**Minimum Instream Flows**" and "**Ramping Rates**" conservation measures.

In the Delta, operations are not expected to increase the stranding risk stressor for outmigrating yearling spring-run Chinook salmon. Yearling stranding is not commonly observed in the Delta and there are no stranding monitoring programs focused on the Delta. Densities of wild Chinook salmon 1998 – 2000 were highly variable during floodplain drainage events, with no statistically significant difference between densities in isolated earthen ponds and contiguous water sources (Sommer et al. 2005).

The increase in stranding risk stressors from the Proposed Action is expected to be **lethal**. Variation in the hydrograph, particularly for yearlings migrating through the upper Sacramento River, that leads to a reduction of water velocity plays a key role in risk to yearlings becoming stranded. Where habitats are desiccated, fish cannot survive, or they may be in isolated pools or shallow areas off the mainstem increasing their exposure to higher levels of predation.

Although the Proposed Action may, at times, increase the stranding risk, stranding of juvenile winter-run Chinook salmon exists in the **environmental baseline** (without the Proposed Action). The physical attributes of the habitat and magnitude of the change in flows drive the stranding stressor (Windell et al. 2017). Historically, fish in California rivers and streams, even before construction of CVP and SWP facilities, have been subject to stranding and dewatering. Flow fluctuations due to hydrology and other factors contributed to the risk of dewatering and stranding. Flow fluctuations from past and current Clear Creek operations have contributed to Chinook salmon stranding in Clear Creek. Generally, natural flows in the Sacramento River increase in the summer months and decrease in the late-fall and winter months. As part of routine Chinook salmon monitoring in the Sacramento River, the California Department of Fish and Wildlife identifies juveniles stranded in isolated pools and relocates them back to the main channel. Reclamation has implemented the Fall and Winter Refill and Redd Maintenance action which coordinates with members of the Upper Sacramento Scheduling Team. While the multi-agency group coordinates fall flow reductions mainly to reduce stranding of winter-run Chinook salmon redds, members also consider whether proposed flows may strand juveniles. Reclamation, in coordination with the Clear Creek Technical Team has also implemented flow management actions to reduce dewatering of spring-run Chinook salmon redds and stranding of juveniles.

The **proportion** of the population affected by the Proposed Action depends on presence of juveniles and hydrology and is **low** for Sacramento River. In the Proposed Action, reduced releases occur for water temperature management, storage rebuilding, rice decomposition smoothing, and redd dewatering avoidance actions.

Literature on stranding shows that on the mainstem Sacramento River, peak movement of yearling spring-run Chinook salmon occurs between October and December (Goertler et al. 2020). For those fish that over summer in natal habitats, outmigration begins with the first rainstorms in the fall or winter following their birth. Peak movement of yearling spring-run Chinook salmon in the Sacramento River at Knights Landing occurs in December (NMFS 2009). After November, when flow reduction starts in the Proposed Action, a portion of the outmigrating yearling spring-run Chinook salmon is potentially at risk of stranding in the Sacramento River.

Datasets use historical conditions and observation to inform how spring-run Chinook salmon may respond to the Proposed Action. Historical monitoring may support or refute hypotheses and inform the reasonableness of information generated by models. Although spring-run Chinook salmon stranding has not been recorded in annual stranding reports, the fall-run Chinook salmon may serve as a possible surrogate species. An average of 4,492 fall-run Chinook salmon were observed stranded between 2012 and 2021 (17 to 8,165, table in "Juvenile Rearing and Outmigration" "Stranding Risk" stressor above). In the 2016-2017 stranding report a total of 19,892 juvenile Chinook strandings were reported, but this count lumped all spring/fall/late-fall run Chinook salmon juveniles together.

Models do not uniquely inform the proportion of the population affected.

The **frequency** of occurrence is **high** since it is likely to occur annually in the Proposed Action. Use of Minimum Flows defines a floor, or flow threshold below which habitat can become disconnected allowing an area to remain viable for spring-run Chinook salmon yearlings. Additionally, ramping rates provide cues through changes in flows, generating time needed by some juvenile salmon to exit areas that may become disconnected. The frequency within a year depends upon hydrologic conditions which may result in multiple increases and decreases in releases from Shasta Reservoir during the outmigration and rearing period.

To evaluate the **weight of evidence** for stranding stressor, there is a historical record of spring-run Chinook juvenile stranding monitoring and releases specific to the Sacramento River. There are records of river flow. However, it is inconsistent and sometimes not run-specific. In these analyses, fall-run Chinook salmon were used as a surrogate to assess effects on spring-run Chinook salmon.

- Historic stranding observations, Sac River + Clear Creek: quantitative, species-specific (sometimes, inconsistent and sometimes fall-run Chinook salmon), location-specific but no formal monitoring, available through sources and QA/QCed, and not expected to have statistical power
- Historic proportion of population in stranding area, Sac River + Clear Creek: quantitative, species-specific (sometimes, inconsistent and sometimes fall-run Chinook salmon), location-specific but no formal monitoring, available through sources and QA/QCed, and not expected to have statistical power
- Historic flows and disconnected sites: quantitative, not species-specific (but not expected to be, environmental variable), location-specific, available through multiple sources and QA/QCed, long time-series and not expected to have statistical power
- USRDOM daily flow modeling LOE: quantitative, not species-specific (but not expected to be), environmental variable, location-specific, model developed to evaluate flows using multiple inputs, widely accepted as daily flow modeling system for use in the Central Valley upper watershed

Conservation measures in the Proposed Action that minimize or compensate for effects of the operation of the CVP and SWP on this stressor include:

- Sacramento River
    - Minimum Instream Flows
    - Ramping Rates

- Clear Creek
    - Minimum Instream Flows
    - Ramping Rates

6.3 Designated Critical Habitat Analysis

Critical habitat for the Spring-Run Chinook Salmon was designated on September 2, 2005 (70 FR 52488). The geographical range of designated critical habitat includes stream reaches of the Feather, Yuba, and American rivers; Big Chico, Butte, Deer, Mill, Battle, Antelope, and Clear creeks; and the Sacramento River downstream to the Delta, as well as portions of the northern Delta (70 FR 52488 2005).

The critical habitat designation for spring-run Chinook salmon identifies essential physical and biological features which are those sites and habitat components that support one or more life stages and are described in the subsections below.

6.3.1 Freshwater Spawning Sites

This essential physical and biological feature includes freshwater spawning sites with water quantity and quality conditions and substrate supporting spawning, incubation and larval development. Analysis of freshwater spawning sites draws information from multiple sections. For spawning, incubation, fry development, and fry emergence flows, Section 6.2.2.1, *Spawning Habitat*, analyzes the habitat suitability curves of spawning habitat quantity and quality. Section 6.2.3.1, *Redd Stranding and Dewatering*, analyzes the maintenance of flows and potential for dewatering. Section 6.2.3.2*, Redd Quality*, addresses redd quality. Section 6.2.2.2, *Water Temperature*, and Section 6.2.3.3, *Water Temperature*, addresses water temperature management.

On the Sacramento River, spawning is affected by the presence of Shasta and Keswick dams. Spring-run Chinook salmon have been excluded from historical spawning habitat since the construction of Shasta and Keswick dams (NMFS 2011). On Clear Creek, water users constructed, and historically diverted water at, the McKormick-Saeltzer Dam. In 1963, Reclamation completed construction of Whiskeytown Dam above the McKormick-Saeltzer Dam. In 2000, Reclamation removed the McKormick-Saeltzer Dam, which opened approximately 12 miles of lower Clear Creek to salmon and steelhead spawning. Additionally, each year USFWS installs and operates a temporary weir each year to physically separate the two runs during spawning to minimize hybridization and redd superimposition. Hydrology, which then influences the available erodible sediment supply, the bathymetry of the river, and downstream flows drives spawning habitat quantity and quality.

At times, increased water temperatures may result in unsuitable water temperatures for freshwater spawning sites. During the adult holding and spawning period, proposed imports from Trinity Reservoir, proposed operation of a TCD on Shasta Reservoir, and use of the temperature curtains in Whiskeytown reservoir are expected to maintain cooler water temperatures. During egg incubation and fry emergence, the proposed releases will blend water from different elevations in Shasta and Whiskeytown reservoirs and import water from Trinity Reservoir to manage water temperatures below Keswick Dam. Overall, temperature management is anticipated to result in beneficial effects, however, certain temperature management activities may result in negative impacts.

During the egg incubation and fry emergence period, the Proposed Action will release water from Shasta Reservoir into the Sacramento River and release water from Whiskeytown into Clear Creek increasing flows in the Sacramento River and Clear Creek, respectively. Increased surface flows are likely to increase hyporheic flows that improve DO and additionally may reduce sedimentation improving egg and alevin essential functions and development (Bennett et al. 2003).

6.3.2 Freshwater Rearing Sites

This essential physical and biological feature includes freshwater rearing sites with water quantity and floodplain connectivity to form and maintain physical habitat conditions and support juvenile growth and mobility; water quality and forage supporting juvenile development; and natural cover such as shade, submerged and overhanging large wood, log jams and beaver dams, aquatic vegetation, large rocks and boulders, side channels, and undercut banks. Analysis of freshwater rearing sites draws information from multiple sections. For juvenile rearing and outmigration, Section 6.2.4.2, *Refuge Habitat*, Section 6.2.4.3, *Food Availability and Quality,* and Section 6.2.4.5, *Stranding Risk*, and for yearling rearing, Section 6.2.5.1, *Refuge Habitat*, and Section 6.2.5.2, *Food Availability and Quality,* Section 6.2.5.3, *Stranding Risk,* and Section 6.2.5.4, *Water Temperature and Dissolved Oxygen*, address this physical and biological feature.

A decrease in sufficient refuge habitat can result in juveniles lacking cover to avoid predation or habitat to stop and hold during outmigration. A decrease of flows may reduce suitable margin and off-channel habitats available as refuge habitat for juveniles and yearlings. A decrease in sufficient refuge habitat can result in juveniles and yearlings lacking cover to avoid predation. Generally, dams impair the recruitment of large woody material to the river channel and floodplain below the dam and contribute to channelization, which contributes to a loss of riparian habitat and instream cover, which aquatic and terrestrial invertebrates depend upon. Stable year-round flows have resulted in diminished natural channel formation, altered foodweb processes, and slowed regeneration of riparian vegetation. Juvenile and yearling life stages of salmonids are dependent on the function of this habitat for successful survival and recruitment. Some complex, productive habitats with floodplains remain in the system (*e.g.*, Clear Creek, Sacramento River reaches with setback levees and some flood bypasses). Outside of this consultation, Reclamation has completed many side-channel restoration projects in the upper Sacramento River that provide refuge habitat for juveniles and yearlings. Additionally, since 2009, Reclamation has operated Whiskeytown Dam to provide channel maintenance flows.

The Proposed Action storage of water in Shasta Reservoir in the winter and spring will decrease flows in the Sacramento River that reduce suitable margin and off-channel habitats available as refuge habitat for juveniles. Storage of water in Whiskeytown will reduce downstream flows on Clear Creek in the winter, increasing the stressor. Increasing releases decrease potential refuge habitat in both the Sacramento River and Clear Creek due to high velocities, until the channel overflows the channel and accesses off-channel habitats. During the yearling rearing and outmigration period, the Proposed Action will store water decreasing flows in the spring and release water increasing flows in the summer on Clear Creek below Whiskeytown Dam which may cause the refuge habitat stressor to increase in the spring resulting in negative effects and decrease in the summer months resulting in beneficial effects.

A decrease in quality and quantity of food for foraging juvenile spring-run Chinook salmon will impact growth rates. Additionally, food limitation can weaken juvenile spring-run Chinook salmon, leading to extremes such as starvation, and alter behavior resulting in predation risk. Generally, natural flows in the Sacramento River increase in the summer months and decrease in the late-fall and winter months. Over the past 20 years, Reclamation has implemented the Lower Clear Creek Floodway Restoration Project to fill in remnant gravel mining pits in lower Clear Creek which addressed juvenile stranding in isolated pools. Reclamation, in coordination with the Clear Creek Technical Team has also implemented flow management actions to reduce dewatering of spring-run Chinook salmon redds and stranding of juveniles.

The Proposed Action will store water decreasing flows in the spring and release water increasing flows in the summer on Clear Creek below Whiskeytown Dam. Reducing releases and the storage of water reduces flows where yearlings can become stranded in habitat disconnected from the main channel. When habitats are desiccated, fish cannot survive, or they may be in isolated pools or shallow areas off the mainstem increasing their exposure to higher levels of predation. While proposed operations will both decrease and increase flows during the times of year yearlings are present in Clear Creek, flows are expected to be stable, resulting in yearlings not becoming stranded resulting in beneficial effects.

6.3.3 Freshwater Migration Corridors

This essential physical and biological feature includes freshwater migration corridors free of obstruction and excessive predation with water quantity and quality conditions and natural cover such as submerged and overhanging large wood, aquatic vegetation, large rocks and boulders, side channels, and undercut banks supporting juvenile and adult mobility and survival. Analysis of freshwater migration corridors draws information from multiple sections. For juvenile rearing and outmigration, Section 6.2.4.1, *Outmigration Cues,* Section 6.2.4.2, *Refuge Habitat*, Section 6.2.4.3, *Food Availability and Quality,* and Section 6.2.4.4, *Entrainment Risk*; for yearling rearing, Section 6.2.5.1, *Refuge Habitat*, and Section 6.2.5.2, *Food Availability and Quality;* and for yearling outmigration, Section 6.2.6.1, *Outmigration Cues*, Section 6.2.6.2, *Refuge Habitat,* Section 6.2.6.3, *Food Availability and Quality,* and Section 6.2.6.4 *Entrainment Risk* address this physical and biological feature. Additionally, as identified in Section 6.2.1. *Adult Migration*, there are no water quality, water quantity, water temperature, or water velocity related stressors that are anticipated to adversely affect freshwater migration corridors for spring-run Chinook salmon.

Outmigration cues are generally defined as fish outmigration behavior being impacted by reduced variation and volume of flows. Generally, natural flows in Clear Creek decrease through the summer and increase into the fall and winter and in the Sacramento River decrease through the summer and into fall until late-fall and winter rains. Those flows influence fish outmigration behavior and affect fish travel times in the upper watershed. In addition, other facilities owned by senior water users affect flows in the Sacramento River.

Proposed storage of water in Shasta Reservoir and Whiskeytown Reservoir will reduce downstream flows on the Sacramento River and Clear Creek, particularly in the winter and spring from December through April. If fish stay in the upper Sacramento River longer because they are not cued to outmigrate, the risk of exposure to sources of mortality increases (e.g., higher exposure to predation). Masking the outmigration cues may affect spring-run Chinook salmon outmigration behavior and travel times increasing their exposure to predators and poor environmental conditions.

The Proposed Action may result in entrainment risks for the juvenile and yearling life stage as the proposed diversion of water alters hydrodynamic conditions in the Sacramento River and Delta which may influence fish travel time and migration routing in the Sacramento River mainstem and the central and south Delta. Once in the central and south Delta, entrainment into the Jones and Banks pumping plants may occur. This entrainment can result in indirect mortality by routing fish into areas of poor survival (increased predation, reduced habitat quality) or direct mortality during salvage in the Delta fish collection facilities.

The Proposed Action storage of water in Shasta Reservoir in the winter and spring will decrease flows in the Sacramento River that reduce suitable margin and off-channel habitats available as refuge habitat for juveniles. Storage of water in Whiskeytown will reduce downstream flows on Clear Creek in the winter. Increasing releases decrease potential refuge habitat in both the Sacramento River and Clear Creek due to high velocities, until the channel overflows the channel and accesses off-channel habitats. During the yearling rearing and yearling outmigration periods, the Proposed Action will store water decreasing flows in the spring and release water increasing flows in the summer on Clear Creek below Whiskeytown Dam which may cause the refuge habitat stressor to increase in the spring resulting in negative effects and decrease in the summer months resulting in beneficial effects.

A decrease in quality and quantity of food for foraging juvenile spring-run Chinook salmon will impact growth rates. Additionally, food limitation can weaken juvenile spring-run Chinook salmon, leading to extremes such as starvation, and alter behavior resulting in predation risk. The level of production and retention drives food availability and quality (Windell et al. 2017). The Proposed Action will store water decreasing flows on the Sacramento River and Delta outflow. and will both release and then store water first increasing then decreasing flows on Clear Creek in the fall and winter. The Proposed Action will store water decreasing flows in the spring and release water increasing flows in the summer on Clear Creek below Whiskeytown Dam which may cause the food availability and quality stressor to increase in the spring resulting in negative effects and decrease in the summer months resulting in beneficial effects.

6.3.4 Estuarine Areas

This essential physical and biological feature includes estuarine areas free of obstruction and excessive predation with water quality, water quantity, and salinity conditions supporting juvenile and adult physiological transitions between fresh- and saltwater; natural cover such as submerged and overhanging large wood, aquatic vegetation, large rocks and boulders, and side channels; and juvenile and adult forage, including aquatic invertebrates and fishes, supporting growth and maturation. Analysis of freshwater migration corridors draws information from multiple sections. For juvenile rearing and outmigration, Section 6.2.4.1, *Outmigration Cues,* Section 6.2.4.2, *Refuge Habitat*, and Section 6.2.4.3, *Food Availability and Quality,* for yearling rearing, Section 6.2.5.1, *Refuge Habitat*, and Section 6.2.5.2, *Food Availability and Quality;* and for yearling outmigration, Section 6.2.6.1, *Outmigration Cues*, Section 6.2.6.2, *Refuge Habitat,* and Section 6.2.6.3, *Food Availability and Quality,* address this physical and biological feature.

During the juvenile rearing and outmigration period, storage of water in Shasta Reservoir will reduce downstream flows on the Sacramento River, particularly in the winter and spring from December through April. Storage of water in Whiskeytown will reduce downstream flows on Clear Creek, particularly in the winter. During the yearling outmigration period, the Proposed Action will store water decreasing flows on the Sacramento River and Delta outflow. If fish stay in the upper Sacramento River longer because they are not cued to outmigrate, the risk of exposure to sources of mortality increases (e.g., higher exposure to predation). Masking the outmigration cues may affect spring-run Chinook salmon outmigration behavior and travel times increasing their exposure to predators and poor environmental conditions.

The Proposed Action storage of water in Shasta Reservoir in the winter and spring will decrease flows in the Sacramento River that reduce suitable margin and off-channel habitats available as refuge habitat for juveniles. Storage of water in Whiskeytown will reduce downstream flows on Clear Creek in the winter, increasing the stressor. Increasing releases decrease potential refuge habitat in both the Sacramento River and Clear Creek due to high velocities, until the channel overflows the channel and accesses off-channel habitats.

A decrease in quality and quantity of food for foraging juvenile spring-run Chinook salmon will impact growth rates. Additionally, food limitation can weaken juvenile spring-run Chinook salmon, leading to extremes such as starvation, and alter behavior resulting in predation risk. The level of production and retention drives food availability and quality (Windell et al. 2017). The Proposed Action will store water decreasing flows on the Sacramento River and Delta outflow and will both release and then store water first increasing then decreasing flows on Clear Creek in the fall and winter. The Proposed Action will store water decreasing flows in the spring and release water increasing flows in the summer on Clear Creek below Whiskeytown Dam which may cause the food availability and quality stressor to increase in the spring resulting in negative effects and decrease in the summer months resulting in beneficial effects.

6.3.5 Nearshore Marine Areas

This essential physical and biological feature includes nearshore marine areas free of obstruction with water quality and quantity conditions and forage, including aquatic invertebrates and fishes, supporting growth and maturation; and natural cover such as submerged and overhanging large wood, aquatic vegetation, large rocks and boulders, and side channels.

The Proposed Action will not affect nearshore marine areas.

6.3.6 Offshore Marine Areas

This essential physical and biological feature includes offshore marine areas with water quality conditions and forage, including aquatic invertebrates and fishes, supporting growth and maturation. These features are essential for conservation because without them juveniles cannot forage and grow to adulthood.

The Proposed Action will not affect offshore marine areas.

6.4 Lifecycle Analysis

6.4.1 Life Stage Transitions in the Literature

Measurements of fecundity, juvenile production, outmigration survival through the Sacramento River and Bay-Delta, and marine survival are very limited for spring-run Chinook salmon. Data for winter-run Chinook salmon represent the best surrogate information. Data from these species can be assembled to represent these life stage transitions during various historical hydrologic periods representing the long-term operations of the CVP and SWP and environmental conditions affecting spring-run Chinook salmon. There is no Clear Creek specific information about survival to better estimate fry and yearling survival to Red Bluff Diversion Dam, at which location, survival is likely to be equal. Thus, Clear Creek spring-run Chinook salmon are assumed to experience the same fry and yearling survival as Sacramento River spring-run Chinook salmon. These data are summarized here by hydrologic periods characterized by drought and non-drought operations and conditions (Table 6-22, Table 6-23). Drought periods include transitions during critical and dry water years. Non-drought periods include transitions for during wet, above normal, and below normal water years. Ocean survival transitions are likely to represent survival during all years.

Using these transitions values, a replacement rate for spring-run Chinook salmon during historical drought and non-drought periods can be estimated. The Proposed Action includes Coldwater Pool Management and Spring Outflow actions during drought years that are likely to result in greater egg to fry survival and outmigration survival through the Sacramento River and Bay-Delta, so historical estimates likely represent minimum replacement values during drought years. During non-drought years, historical estimates likely are similar to what may be observed in the Proposed Action.

Table 6-27. Observed average transition rates for spring-run Chinook salmon and estimated recruitment during non-drought water years.

Location	Life Stage	Observed average Survival	Estimated Replacement	Data source
Sacramento	Adult migration and holding	1.00	1	
Sacramento	Adult spawning	5021.00	5,021	WCS LSNFH average
Sacramento	Egg incubation and emergence	0.33	1,657	Use WRCS estimates as surrogate, Average of ETF AppC Table 14- W,BN
Sacramento	River juvenile rearing	0.49	812	No estimates, WRCS oversummer estimate used as surrogate
Sacramento	River yearling proportion	0.02	16	hypothesized small proportion oversummer
Sacramento	River juvenile outmigration	0.98	796	hypothesized large proportion outmigrate
Sacramento	Yearling oversummer rearing	0.49	8	No estimates, WRCS oversummer estimate used as surrogate
Sacramento	Juvenile rearing and outmigration (release to Sacramento)	0.25	199	Coleman Fall run AT releases between April 5 and May 21 (2012-2021)
Sacramento	Yearling Outmigration (release to Sacramento)	0.33	3	Coleman LFCS AT releases between Nov 29 - January 5 (Water years 2018-2021)
Bay Delta	Juvenile rearing and outmigration (Sacramento to Benicia)	0.58	115	Coleman Fall run AT releases between April 5 and May 21 (2012-2021)
Bay Delta	Yearling Outmigration (Sacramento to Benicia)	0.26	1	Coleman LFCS AT releases between Nov 29 - January 5 (Water years 2018-2021)
Bay Delta	Juvenile rearing and outmigration (Benicia to Golden Gate)	0.78	90	Coleman Fall run AT releases between April 5 and May 21 (2012-2021).
Bay Delta	Yearling Outmigration (Benicia to Golden Gate)	1	1	Coleman LFCS AT releases between Nov 29 - January 5 (Water years 2018-2021)
	Ocean rearing	0.05	4	Juveniles
	Ocean rearing	0.05	0	Yearling
Total			**5**	

Table 6-28. Observed average transition rates for spring-run Chinook salmon and estimated recruitment during drought water years.

Location	Life Stage	Observed average Survival	Estimated Replacement	Data source
Sacramento	Adult migration and holding	0.99	0.99	
Sacramento	Adult spawning	5021.00	4,970.79	Appendix C
Sacramento	Egg incubation and emergence	0.16	795.33	Use WRCS estimates as surrogate, Average of ETF AppC Table14- W,BN
Sacramento	River juvenile rearing	0.49	389.71	No estimates, WRCS fry to smolt estimate used as surrogate
Sacramento	River yearling proportion	0.02	7.79	hypothesized small proportion oversummer
Sacramento	River juvenile outmigration	0.98	381.92	hypothesized large proportion outmigrate
Sacramento	Yearling oversummer rearing	0.49	3.82	No estimates, WRCS oversummer estimate used as surrogate
Sacramento	Juvenile rearing and outmigration (release to Sacramento)	0.09	34.37	Coleman Fall run AT releases between April 5 and May 21 (2012-2021)
Sacramento	Yearling Outmigration (release to Sacramento)	0.38	1.45	Coleman LFCS AT releases between Nov 29 - January 5 (Water years 2018-2021)
Bay Delta	Juvenile rearing and outmigration (Sacramento to Benicia)	0.02	0.69	Coleman Fall run AT releases between April 5 and May 21 (2012-2021)
Bay Delta	Yearling Outmigration (Sacramento to Benecia)	0.3	0.44	Coleman LFCS AT releases between Nov 29 - January 5 (Water years 2018-2021)
JoBay Delta	Juvenile rearing and outmigration (Benicia to Golden Gate)	0.78	0.54	Coleman Fall run AT releases between April 5 and May 21 (2012-2021), No estimate for Drought years, use non-drought years as a surrogate
Bay Delta	Yearling Outmigration (Benicia to Golden Gate)	0.7	0.30	Coleman LFCS AT releases between Nov 29 - January 5 (Water years 2018-2021)
Ocean	Ocean rearing	0.05	0.03	Juveniles
Ocean	Ocean rearing	0.05	0.02	Yearling
Total			**0.04**	

6.4.2 CVPIA Decision Support Models

The CVPIA spring-run Chinook salmon life cycle model (Appendix F, *Alternatives Modeling*, Attachment F.4, *CVPIA Spring-Run Life Cycle Model*) provides estimates of adult abundance, rearing survival in natal tributaries and migratory corridors, juvenile production, outmigration survival through the Sacramento River and Bay-Delta, and other transition values. These performance measures are estimated at monthly and annual time steps between 1980 and 2000.

Predicted total and natural-origin-only spawner abundances in the Central Valley for the deterministic model runs generally fluctuated between 1980 and 1999. The population as a whole and in the Upper Sacramento River reached a low in the early 1980s and peaked in 1988, decreased steadily until 1990 and then generally trended upward (Table 6-29, Table 6-30; Figures 33 and 34). The Clear Creek natural spawner abundances peaked in 1980 and reached a low in 1990 (Figure 33). The range of natural-origin-only spawner abundances across alternatives at the end of the time series was narrow, ranging from 12,613 to 12,614. Over the entire time series, predicted natural-origin-spawner abundances ranged from 7,712 to 14,379 (Table 6-30). Predicted natural-origin-only spawner abundances in the Central Valley varied more widely across stochastic model runs, from a low of approximately 0 to a high of approximately 88,000 spawners (Figure 35).

For deterministic model runs, population change over time, defined by mean (i.e., geometric) lambda values (N_t/N_{t+1}), over the entire 1980-1999 time series was consistently at 1.01 across phases of the Proposed Action (Table 6-31), and terminal lambda values ($N_{t=19}/N_{t=1}$) were consistently 1.205 (Table 6-32). These values indicated that predicted spawner abundances increased over the course of the time series. Annual lambda values from deterministic model runs ranged from approximately 0.75 to 1.37 (Figure 36). Mean lambda values across stochastic model iterations ranged from approximately 0.96 to 1.11 (Figure 37). Terminal lambda values from stochastic models ranged from approximately 0.5 to 7.5 (Figure 38), suggesting some model runs resulted in expected population growth over the time series. Under deterministic models, Critical water years had the highest mean annual lambdas (>1.07) and Above Normal and Wet water years also had a mean annual lambda greater than 1, indicating that the population grew in both wetter and drier conditions, just not under Dry WYT (Table 6-32). Mean lambdas were less than 1 in Dry water years, indicating that populations declined. Likewise, across stochastic model runs, Dry water years had a lower mean lambda value than other WYT (Figure 39). Spawner abundances in any given year (or WYT) reflect a multitude of influences over time (e.g., previous spawner abundances and rearing conditions), and not just flow and temperature conditions during the spawning year.

Population trends may be explained by differences in life stage-specific demographic parameters. The egg-to-fry survival life stage transition in the DSM is not sensitive to alternative-dependent flow or temperature values, and thus will be constant across alternatives. Across deterministic runs, monthly rearing survival for small juveniles (i.e., <42 mm) in the Upper Sacramento River varied from a low of approximately 0.016 to a high of approximately 0.024, excluding baseline alternatives (Figure 40); rearing survival in the Upper Sacramento River also varied across months, peaking in December and January, and showing greater variation across water years in April and May. In Clear Creek, monthly rearing survival for small juveniles (i.e., <42 mm) varied across deterministic runs from approximately 0.12 to 0.18; rearing survival in Clear Creek also varied across months, with greater survival in February-May and lower survival in November-January. Additionally, model-estimated migratory survival for very large fish also varied across months and WYT along their migratory routes in the Sacramento River and the Delta (e.g., from 0.97 to 0.94 in the North Delta, Figure 41). Migratory survival often increases moving from a Critical to Dry to Above Normal to Wet WYT and peaks in February and March.

Table 6-29. Predicted annual total spring-run spawner abundance in the Central Valley, including both natural- and hatchery-origin fish, from deterministic model runs.

Year	EXP1	EXP3	NAA	Alt2woTUCPwoVA	Alt2woTUCPDeltaVA	Alt2woTUCPAllVA
1980	14889	14887	14886	14886	14886	14886
1981	13041	13045	13045	13045	13045	13045
1982	13242	13139	13094	13098	13109	13134
1983	16213	15968	15808	15819	15837	15881
1984	16135	15952	15749	15759	15764	15777
1985	14933	14816	14600	14604	14601	14595
1986	13255	13111	12862	12859	12854	12863
1987	14743	14676	14297	14320	14314	14356
1988	20008	19998	19576	19637	19640	19713
1989	18408	18325	18234	18277	18283	18354
1990	13716	13517	13536	13553	13575	13602
1991	14492	14127	13976	14027	14068	14081
1992	15958	15444	15275	15476	15465	15528
1993	16758	16202	16086	16412	16299	16374
1994	18607	18142	18044	18218	18099	18143
1995	17255	16976	16891	16860	16828	16862
1996	15057	14826	14757	14728	14731	14760
1997	18618	18270	18116	18122	18116	18128
1998	19919	19592	19404	19401	19399	19397
1999	18239	18032	17936	17938	17938	17937

Table 6-30. Predicted annual natural-origin spring-run spawner abundance in the Central Valley from deterministic model runs.

Year	EXP1	EXP3	NAA	Alt2woTUCPwoVA	Alt2woTUCPDeltaVA	Alt2woTUCPAllVA
1980	9565	9563	9561	9562	9562	9562
1981	7709	7711	7712	7712	7712	7712
1982	7919	7816	7771	7775	7786	7811
1983	10890	10645	10485	10496	10514	10558
1984	10811	10628	10424	10434	10439	10452
1985	9600	9483	9267	9270	9268	9261
1986	7932	7788	7539	7536	7531	7540
1987	9411	9342	8964	8987	8981	9023
1988	14674	14664	14243	14303	14306	14379
1989	13075	12991	12901	12944	12950	13020
1990	8387	8187	8206	8223	8245	8272
1991	9159	8794	8643	8694	8735	8748
1992	10625	10111	9942	10143	10131	10195
1993	11433	10878	10762	11088	10975	11049
1994	13274	12807	12710	12885	12766	12810
1995	11932	11653	11568	11537	11505	11539
1996	9734	9501	9434	9405	9408	9437
1997	13289	12945	12791	12797	12792	12804
1998	14596	14269	14081	14078	14076	14074
1999	12915	12707	12611	12613	12614	12613

Table 6-31. Predicted mean lambda (N_t/N_{t+1}) for total spring-run spawner abundance in the Central Valley, including both natural- and hatchery-origin fish, from deterministic model runs.

WYT	EXP1	EXP3	NAA	Alt2woTUCPwoVA	Alt2woTUCPDeltaVA	Alt2woTUCPAllVA
C	1.074	1.072	1.072	1.072	1.072	1.072
D	0.958	0.960	0.962	0.962	0.962	0.962
AN	1.050	1.049	1.053	1.060	1.054	1.054
W	1.016	1.016	1.013	1.013	1.013	1.013
All	1.011	1.010	1.010	1.010	1.010	1.010

Table 6-32. Predicted terminal lambda ($N_{t=19}/N_{t=1}$) for total spring-run spawner abundance in the Central Valley, including both natural- and hatchery-origin fish, from deterministic model runs.

EXP1	EXP3	NAA	Alt2woTUCPwoVA	Alt2woTUCPDeltaVA	Alt2woTUCPAllVA
1.225	1.211	1.205	1.205	1.205	1.205

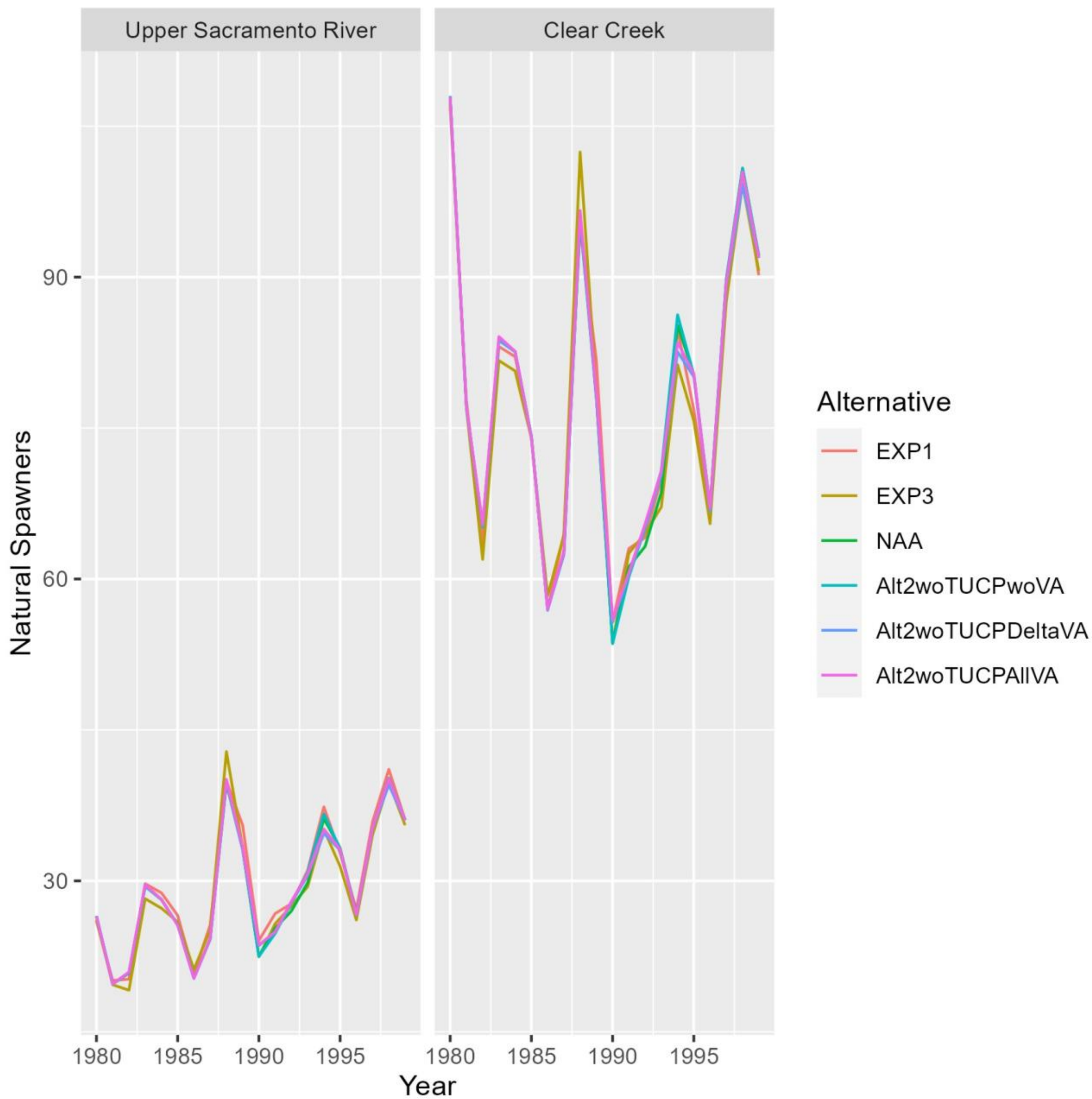


Figure 6-38. Expected annual abundances of natural-origin spring-run Chinook salmon spawners in the Upper Sacramento River and Clear Creek from deterministic model runs.

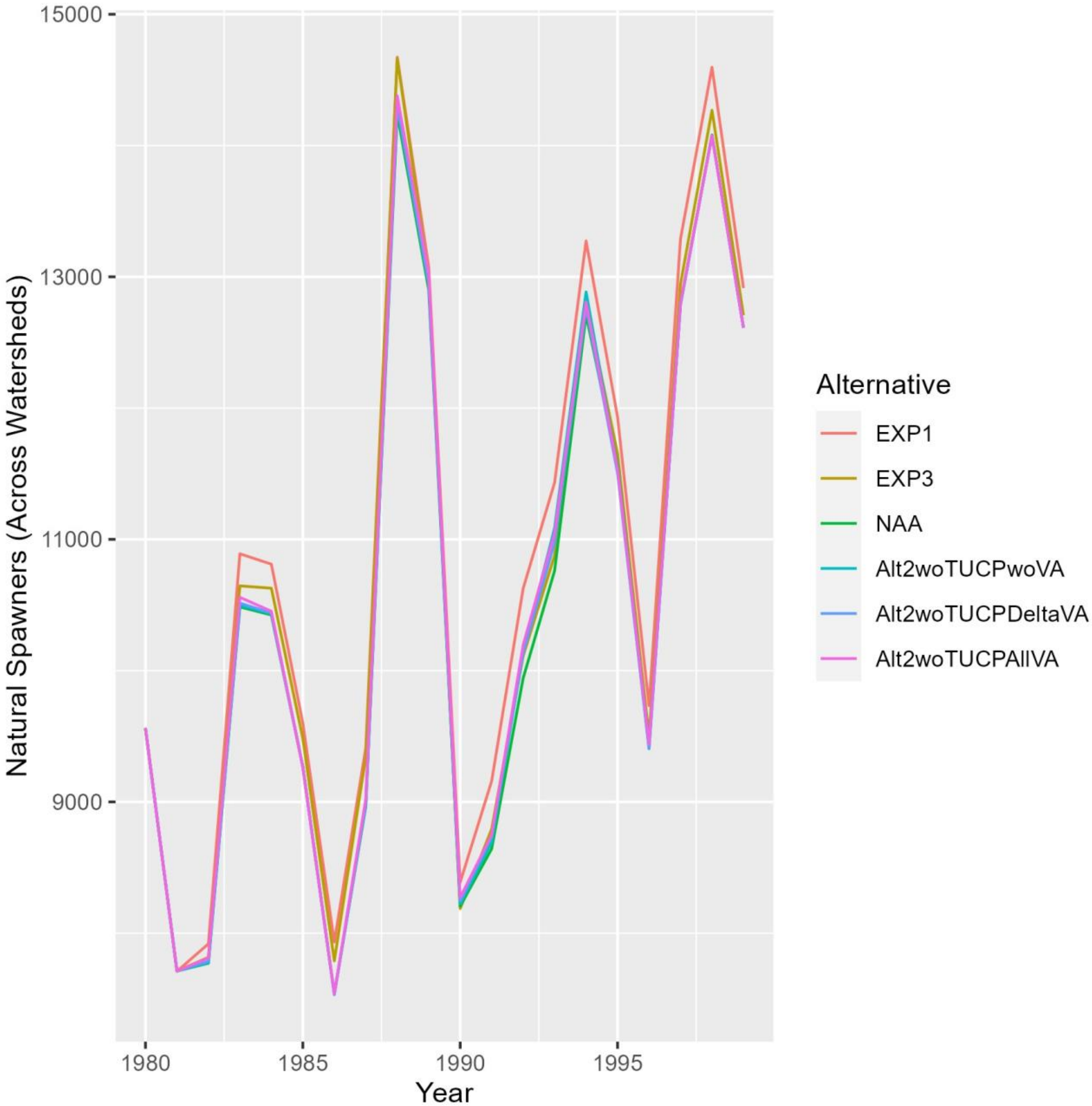


Figure 6-39. Expected annual abundances of natural-origin spring-run Chinook salmon spawners in the Central Valley from deterministic model runs.

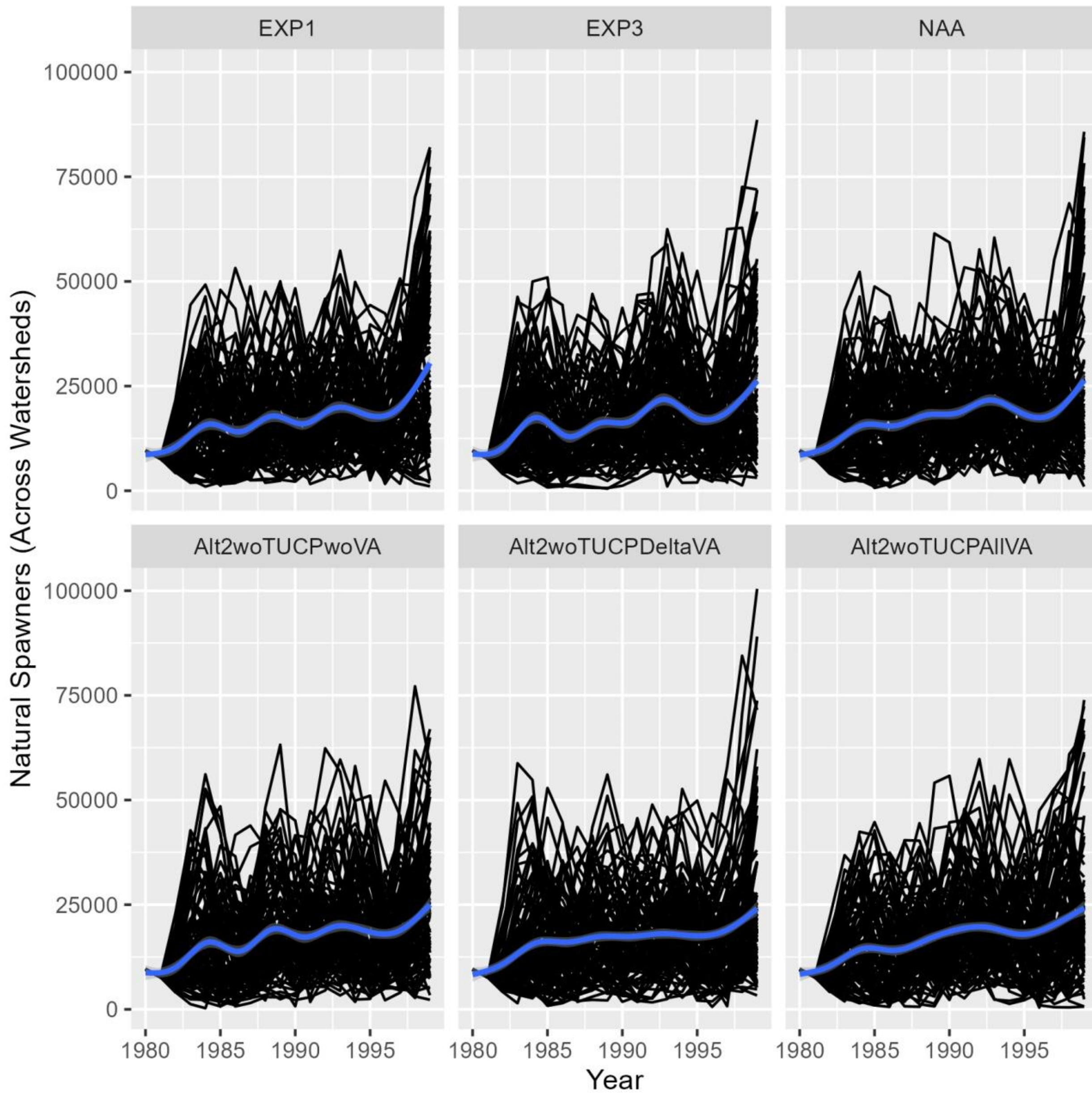


Figure 6-40. Expected annual abundances of natural-origin spring-run Chinook salmon spawners in the Central Valley from stochastic model runs. Black lines represent iteration-specific abundances over time and the blue line represents an expected trend obtained by ‘gam’ smoothing in ggplot2.

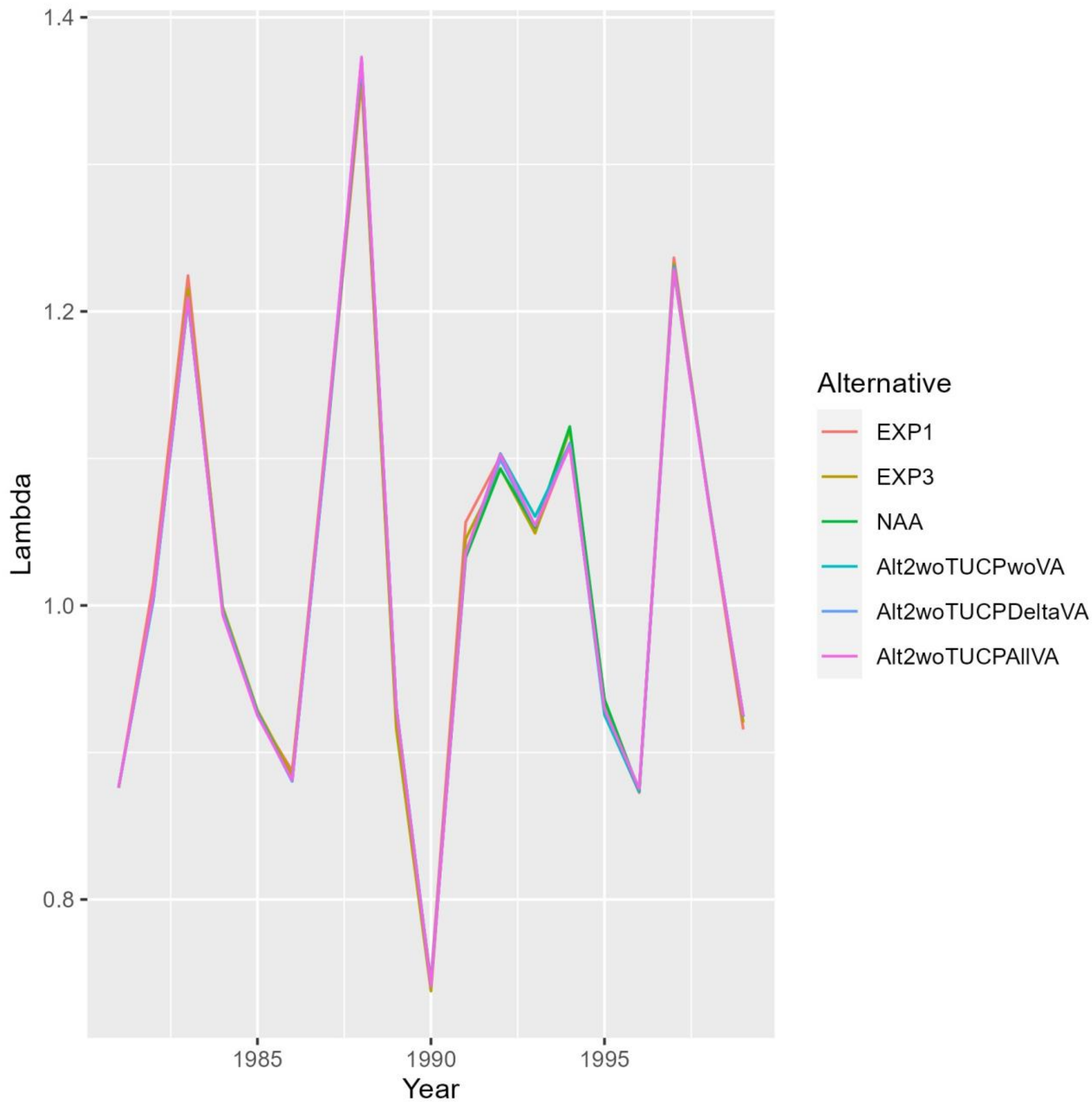


Figure 6-41. Predicted annual lambda values (N_t/N_{t+1}) for total spring-run spawner abundance in the Central Valley, including both natural- and hatchery-origin fish, from deterministic model runs.

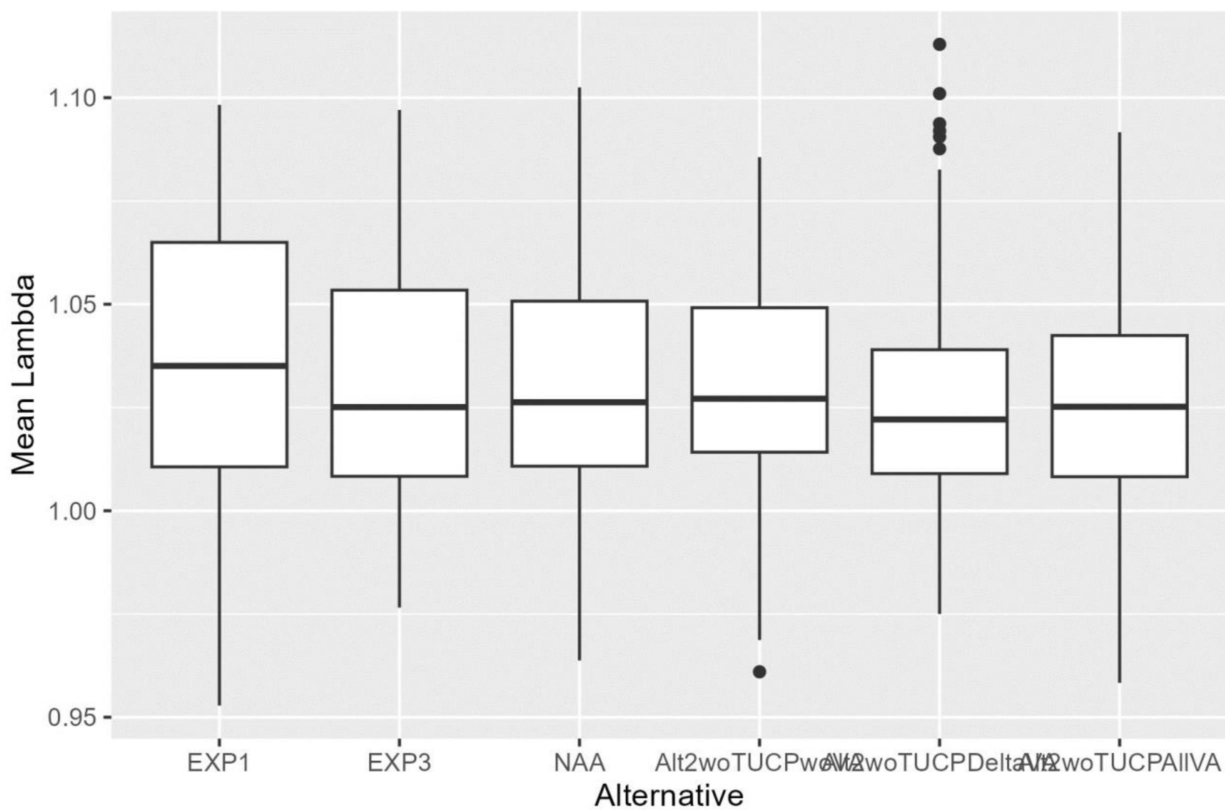


Figure 6-42. Predicted mean lambda values (Nt/N_{t+1}) for total spring-run spawner abundance in the Central Valley, including both natural- and hatchery-origin fish, across stochastic model iterations.

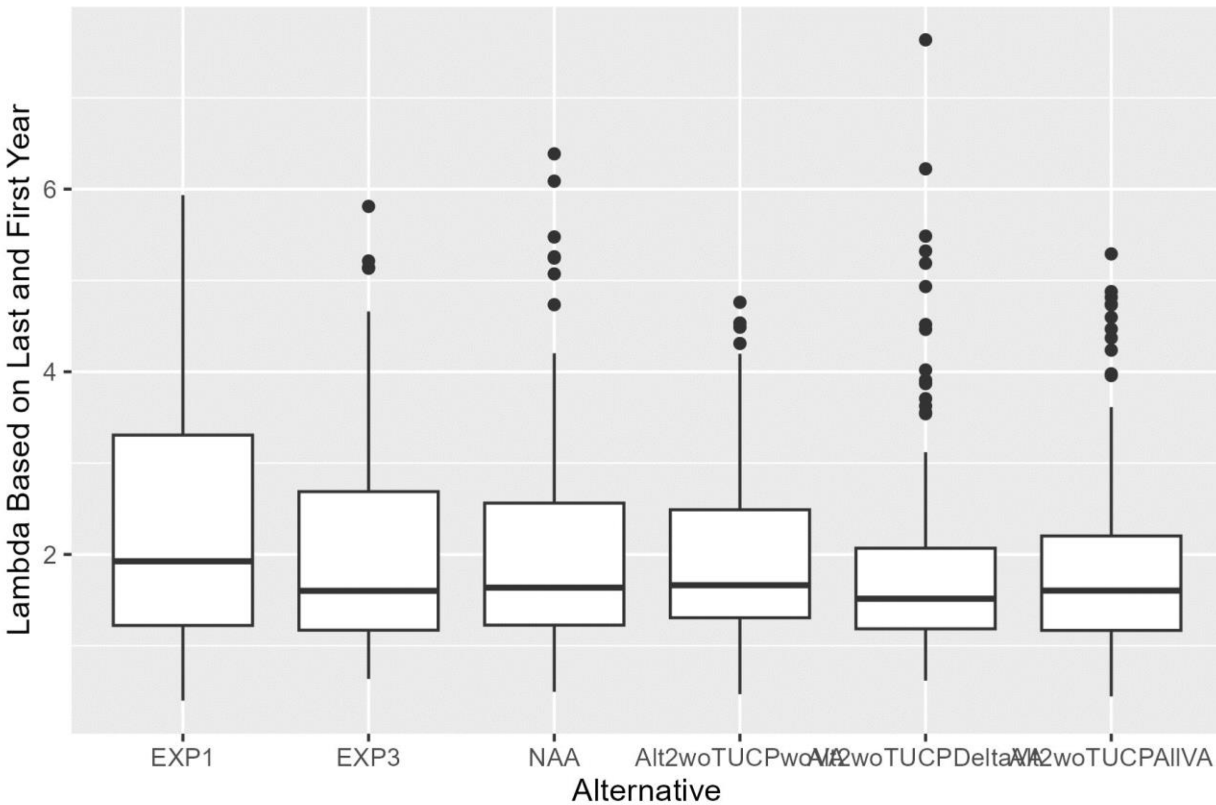


Figure 6-43. Predicted end lambda values ($N_{t=19}/N_{t=1}$) for total winter-run spawner abundance in the Upper Sacramento River, including both natural- and hatchery-origin fish, across stochastic model iterations.

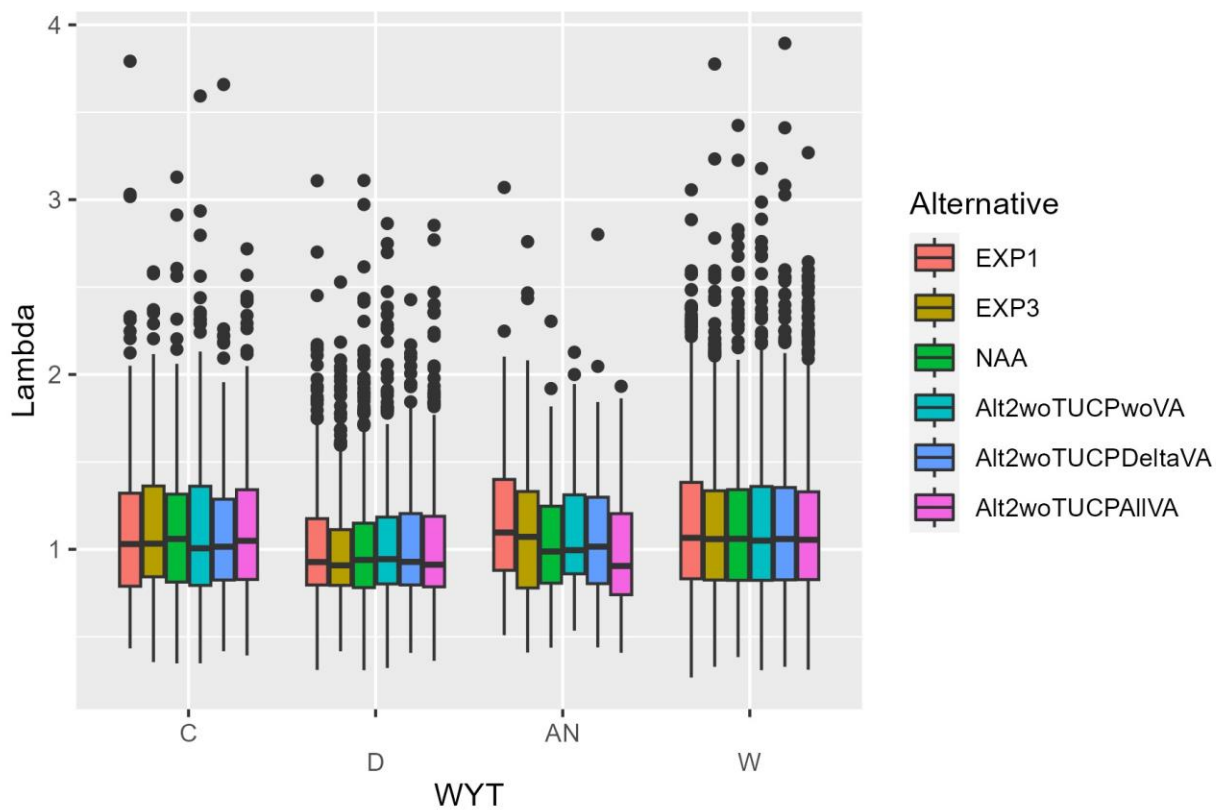


Figure 6-44. Predicted lambda values across water year types (N_{t+1}/N_t) for total spring-run spawner abundance in the Upper Sacramento River, including both natural- and hatchery-origin fish, across 100 stochastic model iterations.

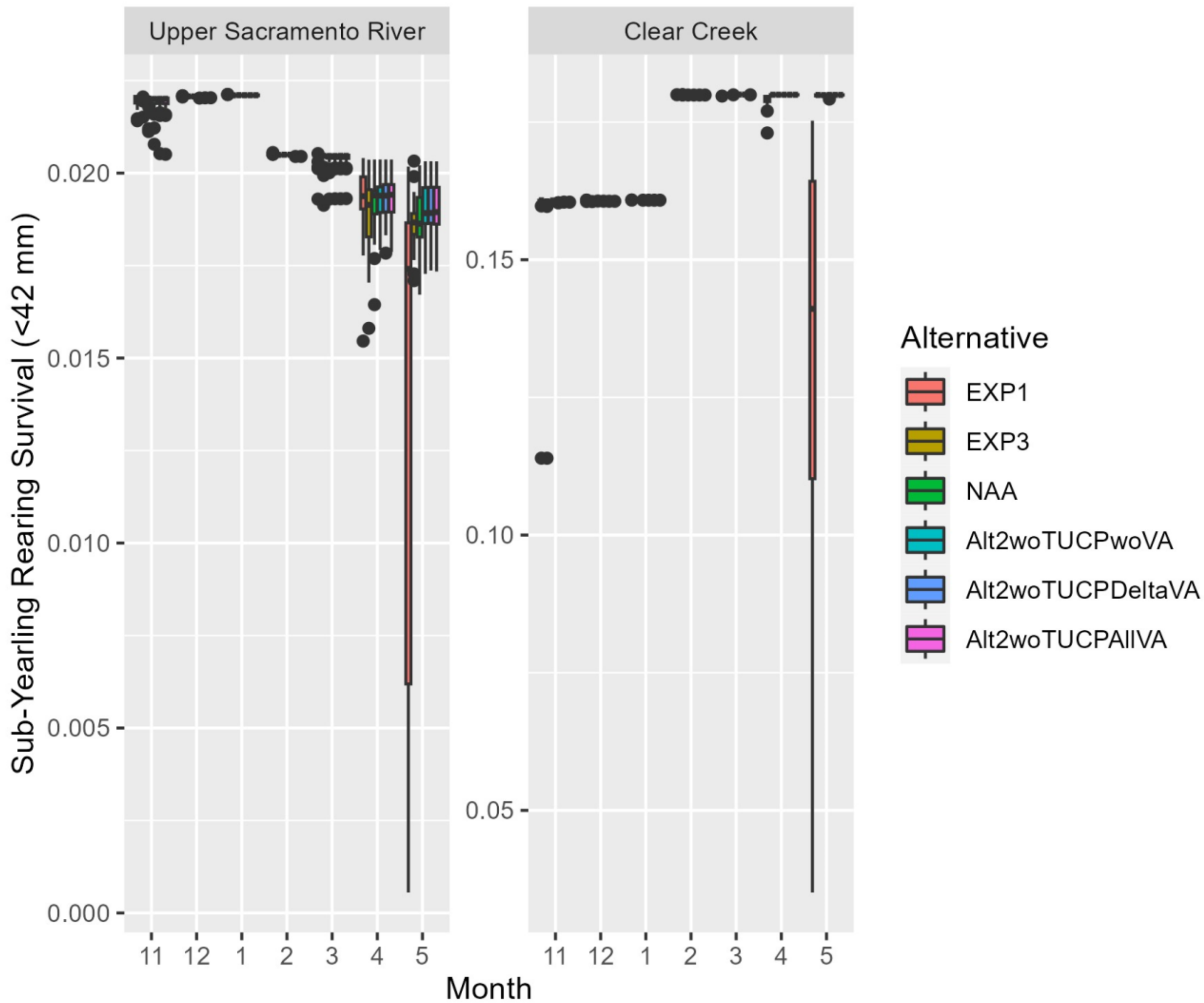


Figure 6-45. Predicted small, young-of-year, juvenile rearing survival for winter-run Chinook salmon in the Upper Sacramento River and Clear Creek from deterministic model runs.

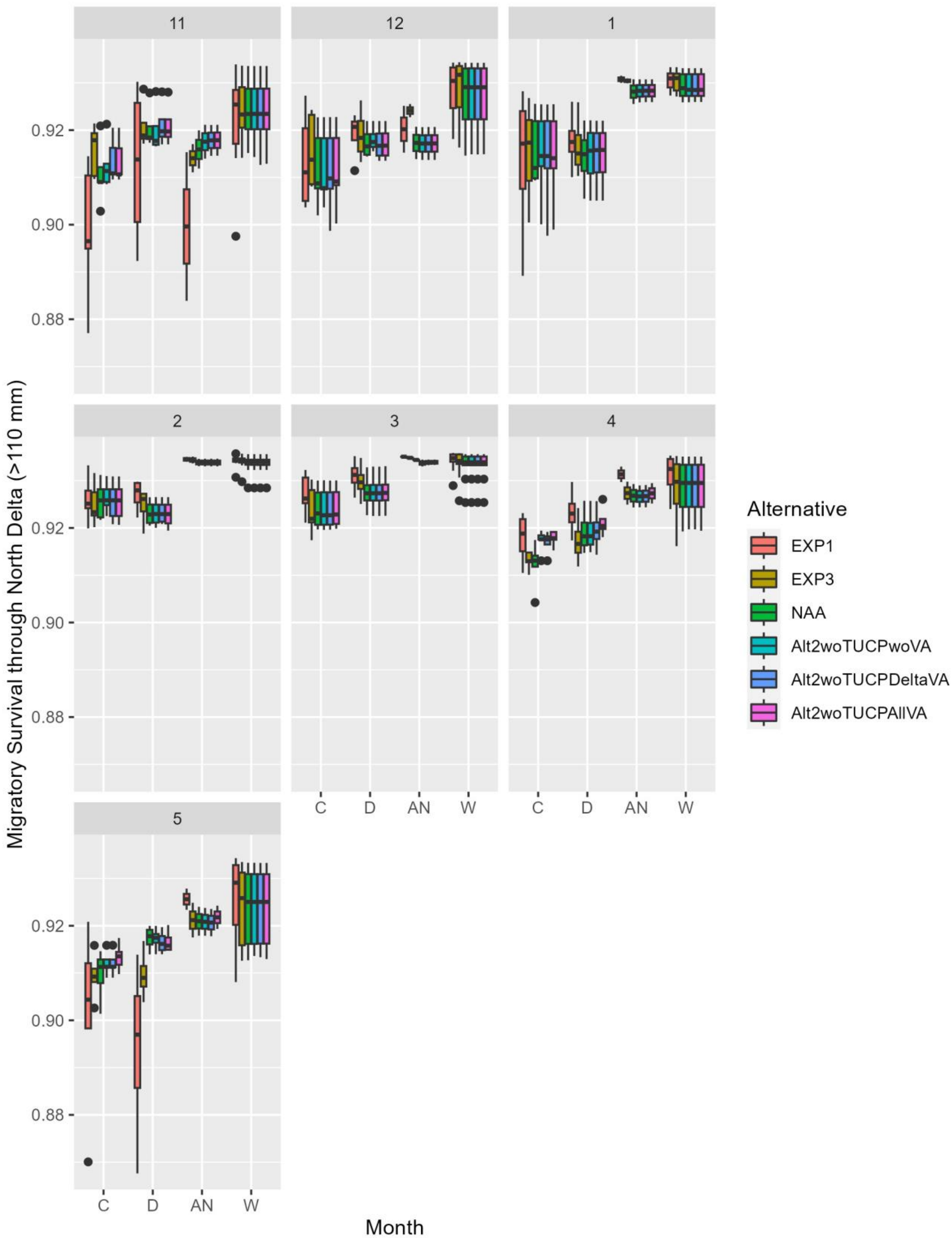


Figure 6-46. Predicted smolt migratory survival for spring-run Chinook salmon in the North Delta from deterministic model runs, faceted by month.

6.5 References

6.5.1 References

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6.5.2 Personal Communication

Derek Rupert, Fish Biologist, Environmental and Natural Resources Division, Northern California Area Office, Reclamation, Personal Communication, June 2023.